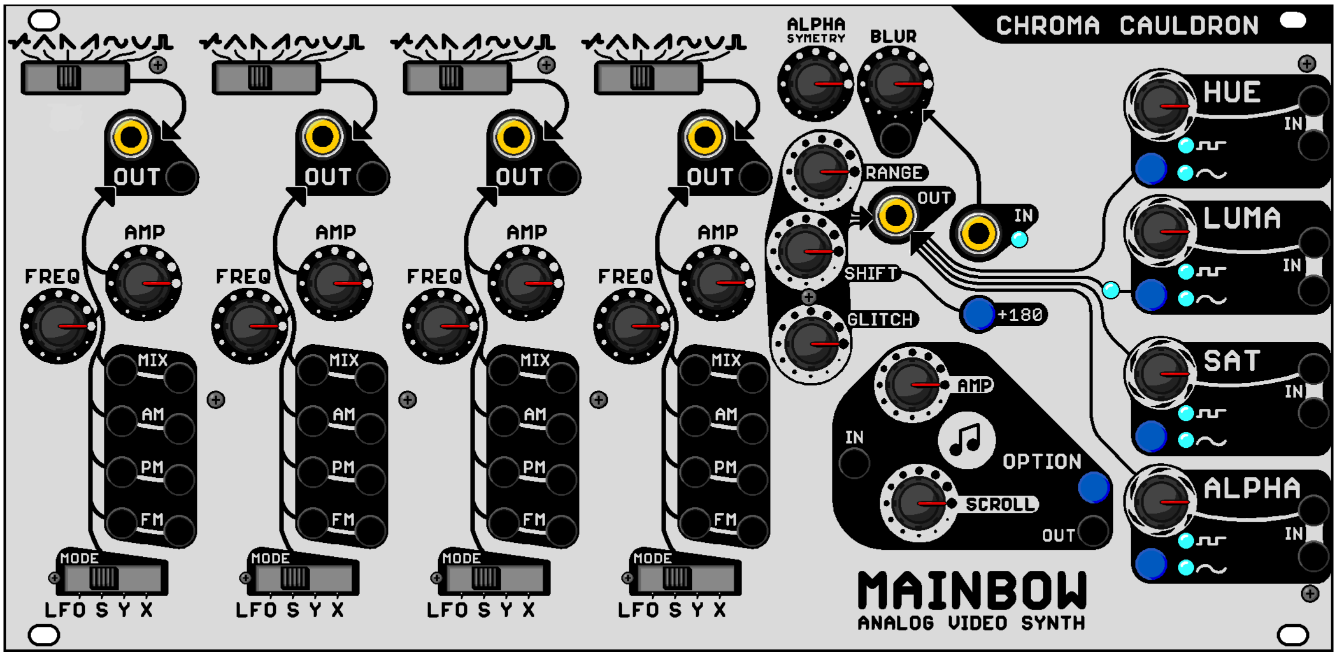
CHROMA CAULDRON

MAINBOW 2.0

ANALOG VIDEO SYNTH



Requires Eurorack case and power supply.
Cables not included.

Features:

- LZX compatible 0-1V signalling.
- Music visualization system.
- Built in splitters at all inputs.
- **Eurorack module.** 3U x 52HP (128.5 x 260 x 18 mm)
- DIY kit uses only easy to solder thru-hole components.

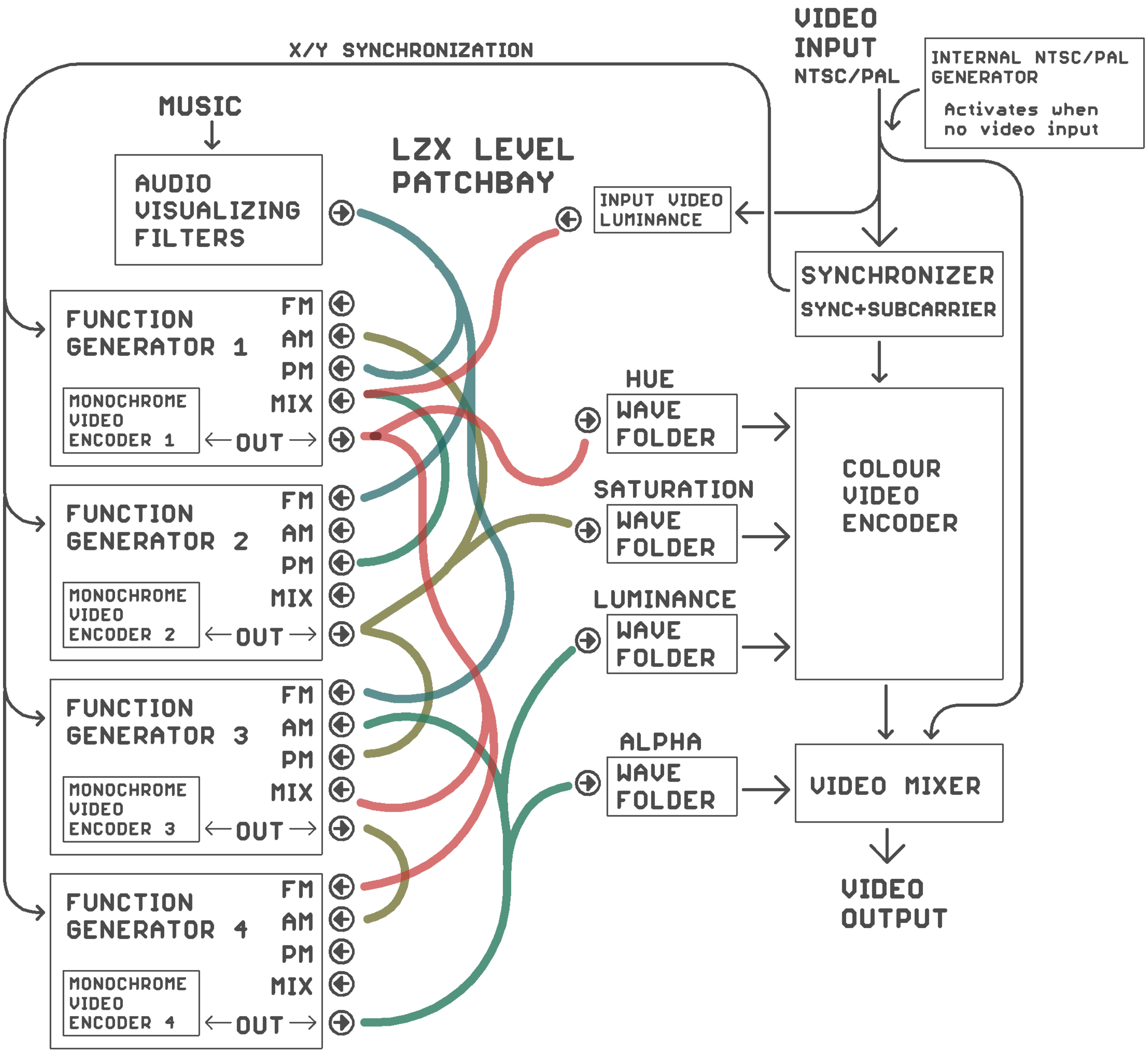
Colour Video Encoder and Synchronizer

- Can synchronize to an external video signal or operate independently.
- Hue, Saturation, Luminance, Alpha(transparency) input channels.
- Wavefolding and hard/soft control on all inputs.
- Fine control over hue and glitch effects.

Four Video Function Generators

- Monochrome NTSC/PAL output in addition to 0-1v output.
- Four modulation inputs (Phase, Frequency, Amplitude, Mix).
- Four oscillation modes (Horizontal, Vertical, Scrolling, LFO).
- Seven Waveforms (Heartbeat, Triangle, +Ramp, -Ramp, Sin, Log, Pulse)

Functionality Block Diagram

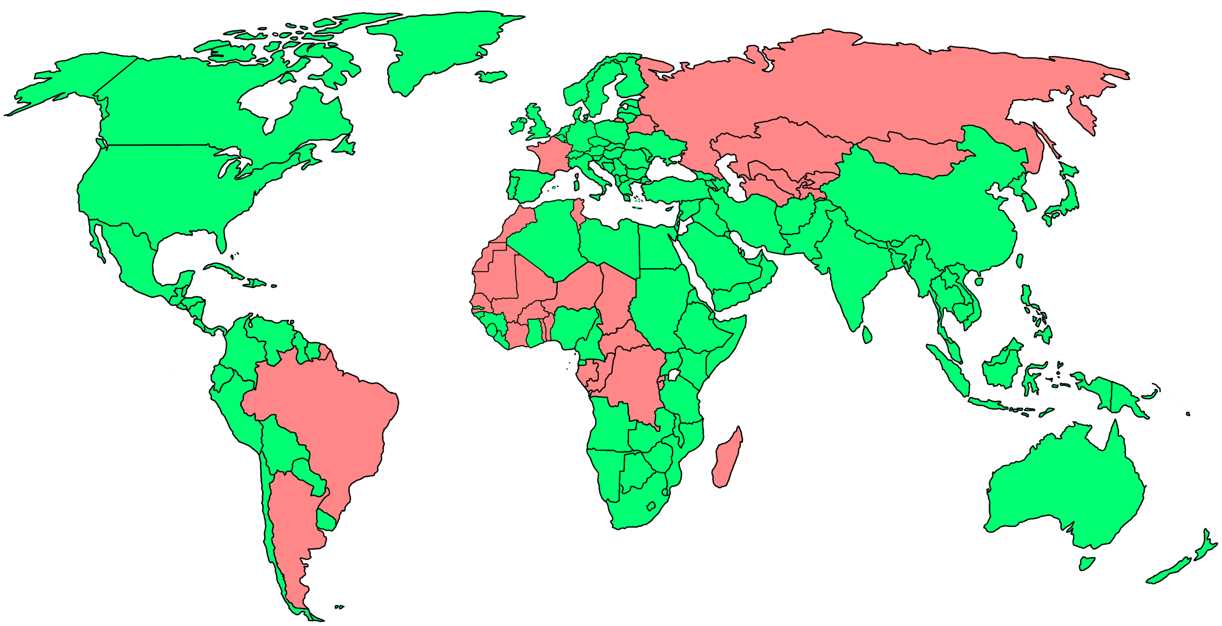


Supported Video Formats

- All versions NTSC are supported. (NTSC-J / NTSC-M).
- Most versions of PAL are supported. The only unsupported versions are PAL-NC (Argentina) and PAL-M (Brazil).
- No versions of SECAM are supported. SECAM countries include France, Russia, and Georgia. This is not an exhaustive list.

Used NTSC or a supported PAL Format

Used SECAM or an unsupported PAL Format



This map only provides a general reference. Green countries historically used video formats compatible with Mainbow. If you plan to use Mainbow with a specific piece of gear please check which formats it supports before ordering.

Modern TVs with analog inputs generally accept international formats, but older equipment tends to only work with the format of the region in which it was sold.

Improvements since v1.0 (May 2021)

- Fully automatic wide range genlock. No more tuning capacitor.
- Alpha symmetry control is much easier to use. No more trying to get a trimmer resistor into the perfect position.
- Internally generated line/frame timing is much more stable. It's now generated from crystal osc instead of an RC osc.
- Aluminum Faceplate.
- All units support both PAL and NTSC and can be switched on the fly.
- Size increased from 48HP to 52HP for better component and control spacing.
- Resistors and diodes are arranged in rows to make soldering faster.
- Wider pads on all components to make soldering faster and easier.
- Indicator LEDs show wave folder hard/soft button state.
- An options menu allows deeper functionality control. For example, making function generators produce interlaced patterns, or disabling colour-burst to produce a chroma dot output.
- All components sourced from official suppliers to avoid defects and knockoffs.
- Capable of inserting a colour burst into a monochrome video input.
- Higher quality potentiometer knobs.
- <u>This manual now contains detailed instructions for identifying and solving assembly problems.</u>

Table of contents

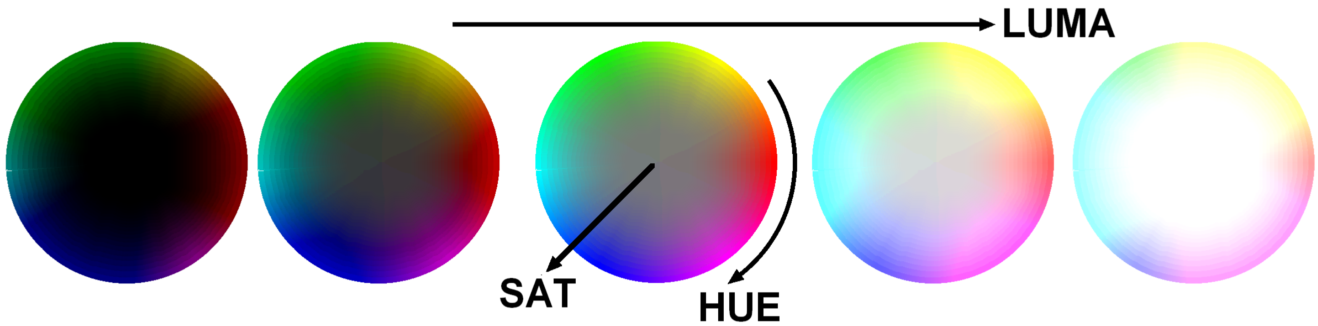
Feature Descriptions

Assembling the kit

Deep Technical Information

Understanding HSL Colour Space

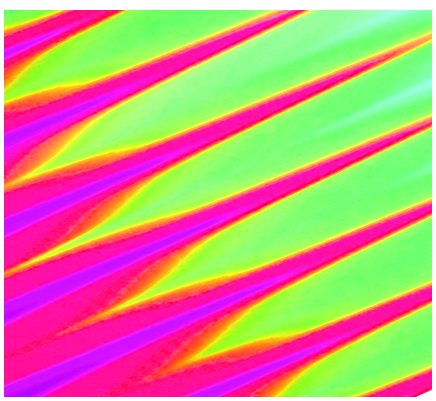
Hue: Rotation around a continuous colour wheel.
Saturation: Shifts from grey to intense colour.
Luminance: Darkens and lightens.



HSL simplifies producing vibrant colourful patterns. Every colour in the rainbow can be produced by controlling the hue channel. In RGB this would require different signals to all three channels.

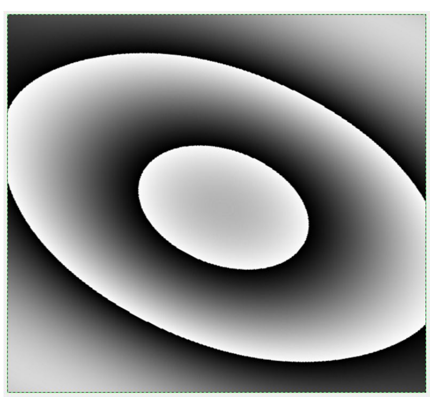
Alpha Channel

The alpha channel allows keying and blending with a video input. It produces a fade to black if no video input is present.



Synthesized Video

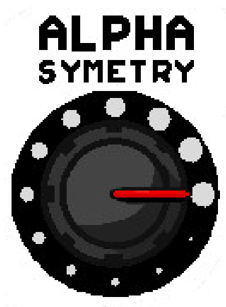
Video Input



Alpha Channel

Video Output

Alpha Symmetry



The Alpha Symmetry knob controls the opaque/transparent balance of the alpha channel.

The Alpha symmetry knob remains active when no external video input is supplied. In this state it shifts the synthesized video to black. It will result in a completely black screen if fully clockwise.

Symmetry knob fully clockwise. Synthesized video is always fully transparent. Alpha channel has no effect.

Symmetry knob slightly counter-clockwise. Synthesized video begins to appear. The balance is still mostly transparent.

Symmetry knob further counter-clockwise. The alpha channel is going between opaque and transparent evenly.

Symmetry knob almost fully counter-clockwise. Alpha-channel is unable to bring synthesized video fully transparent.

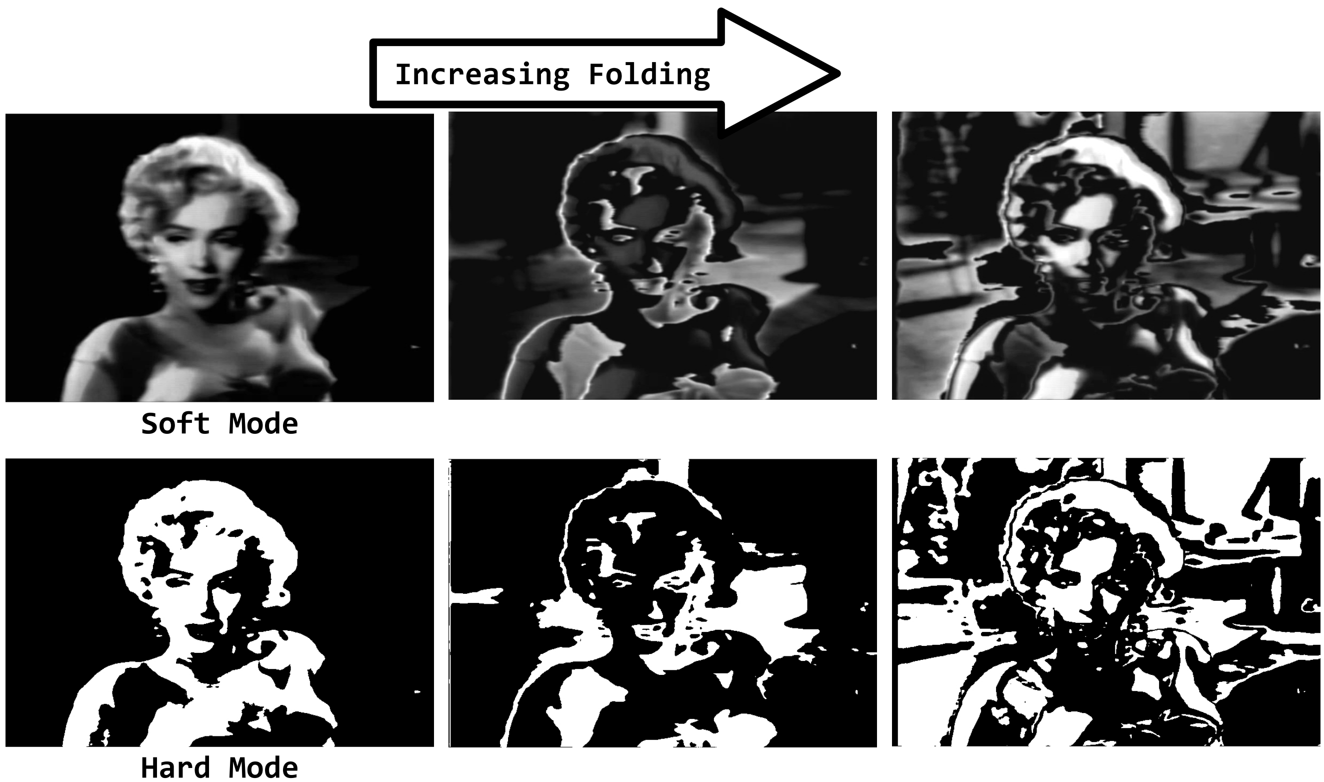
Turning the symmetry knob fully counter-clockwise may allow synthesized video to interfere with sync pulses and colour burst. This produces a glitchy output.

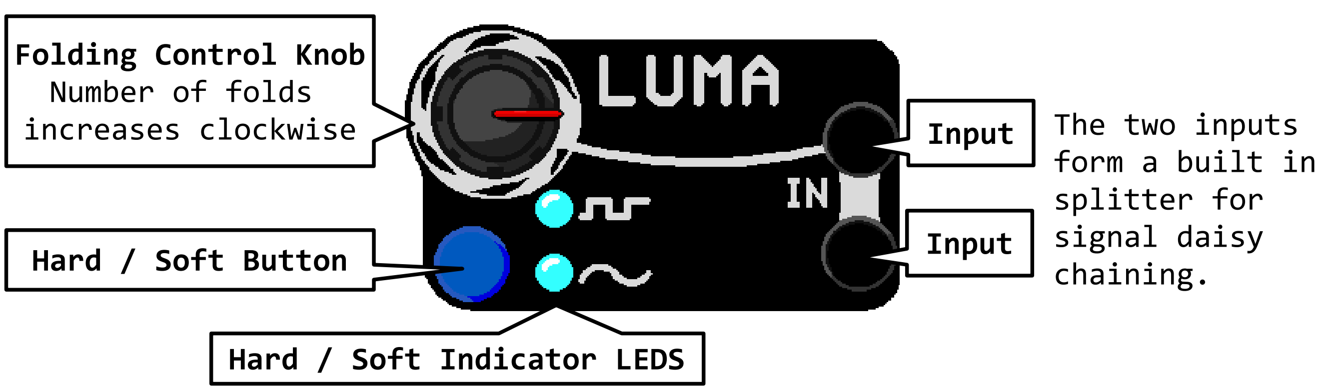
Wave Folding

All four HSV-A inputs have a wevefolder and hard/soft button. Wavefolding can bring the channel from 0% to 100% up to eight times as the control signal goes from 0v to 1v. This adds significant depth and complexity to synthesized patterns. The number of folds is controlled by the fold knob. This knob also sets the constant value of a channel if no input signal is applied.

The hard/soft button changes the channel from a continuous gradient to two discrete values.

Example: Turning up luminance folding in hard and soft modes. Luminance input is external video. Saturation is set to 0 for a monochrome output.

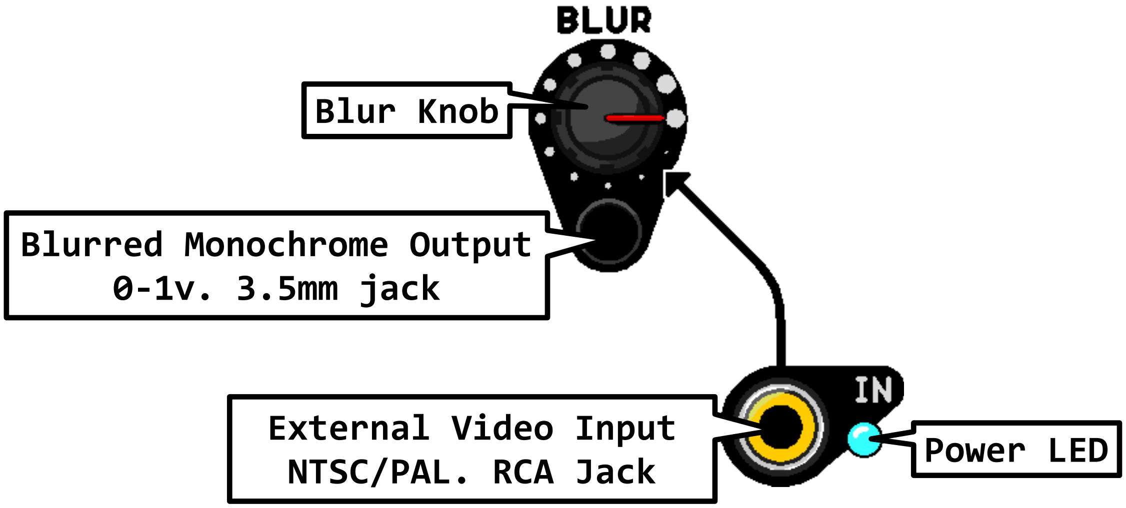




The same controls are present on hue, saturation, and alpha channels.

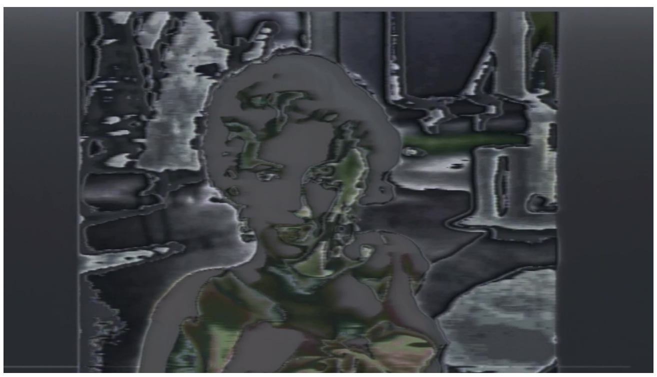
External Video Input

Video input provides the background layer used by the alpha channel. A monochrome version of this signal is converted to 0-1v signalling levels. This can be patched to the HSV-A video encoder or function generator modulation inputs. Variable blurring is provided for removing noise and pixelation. It produces a liquid metal effect when used with wavefolding.

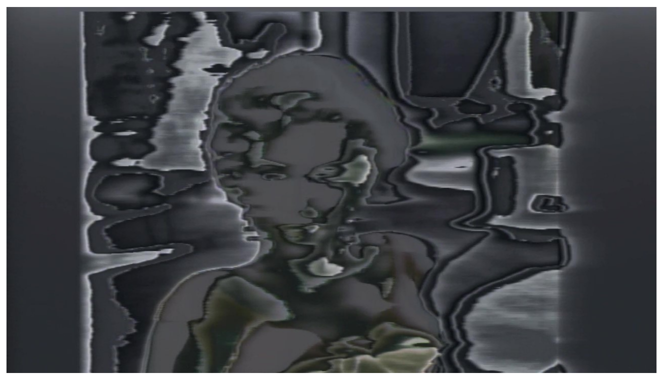


Power LED should always be dimly lit.

Increasing Blur while sending output to Luma Wavefolding.



1



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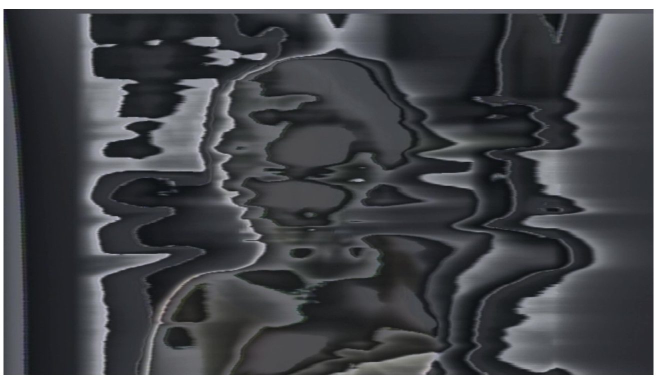

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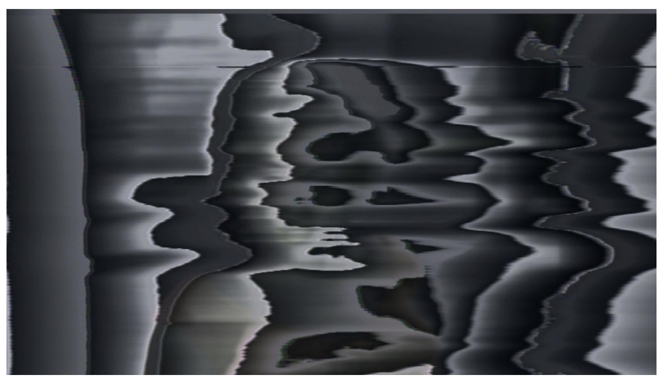
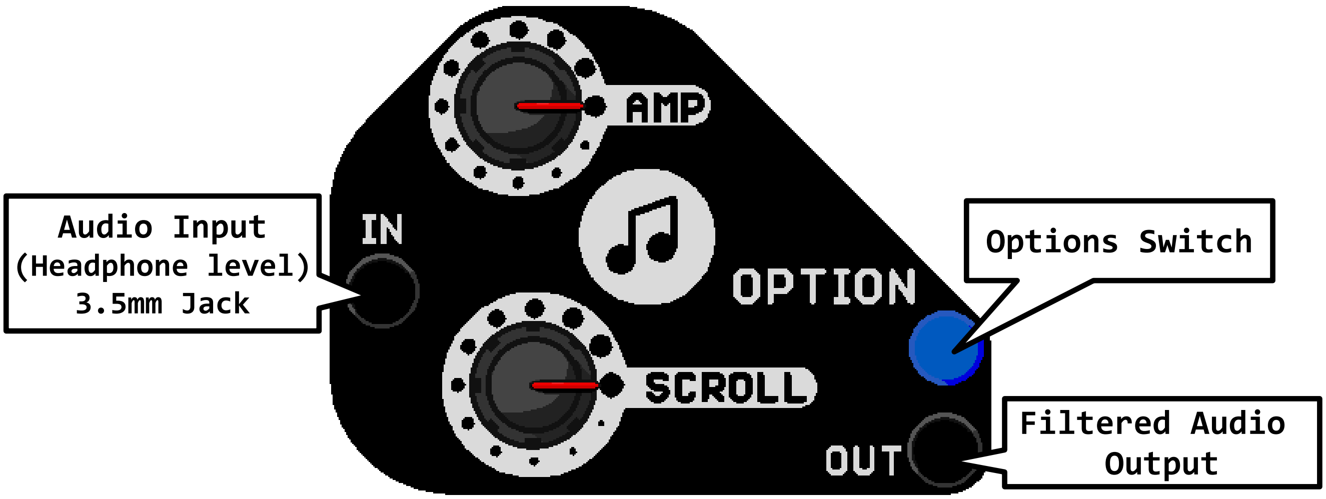


4

Audio Processor

Running unfiltered music directly into a video synthesiser produces a flickery mess regardless of how mellow the music is. Mainbow's audio system converts music into calmer sound responsive waveforms. These work best when modulating a function generator in X mode. The audio input accepts a headphone level signal directly from a device such as a Walkman. It is not meant to accept the 0-1v signalling used elsewhere in this module.



- **Amp Knob.** The audio input can be amplified to varying levels before filtering. This allows a wide range of input volume levels.
- **Scroll Knob.** Sets how fast output waves scroll up or down the screen.
- **Options Switch.** Brings up the options menu. Audio Filter Modes can be set through the **AM** option:

  0) Centred scrolling amplitude graph.

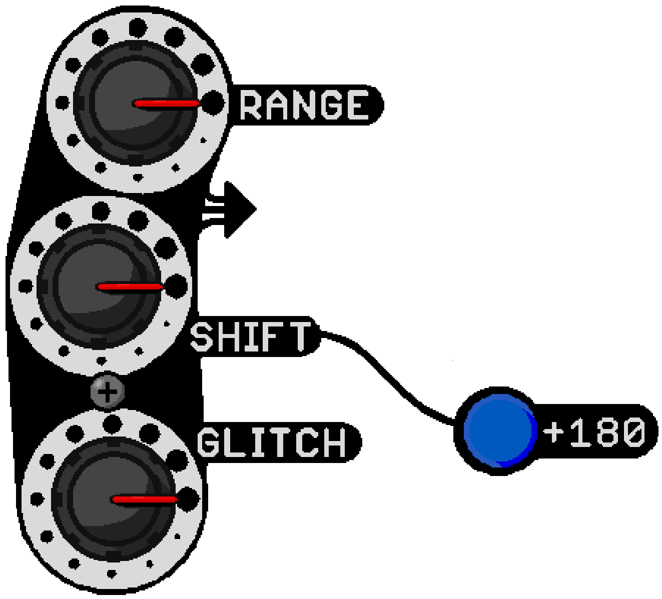
  1) Scrolling amplitude graph.

  2) Simple Peak detector. Scroll knob sets decay rate.

  3) Vertical ramp phase modulated by peak detector. Scroll knob sets decay rate.

Extra Hue Controls

These additional controls allow modification of the hue channel.

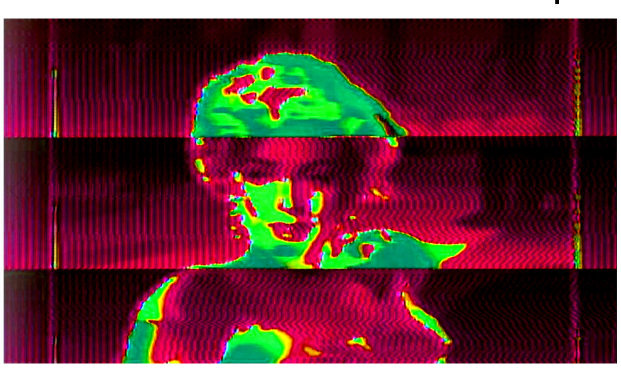


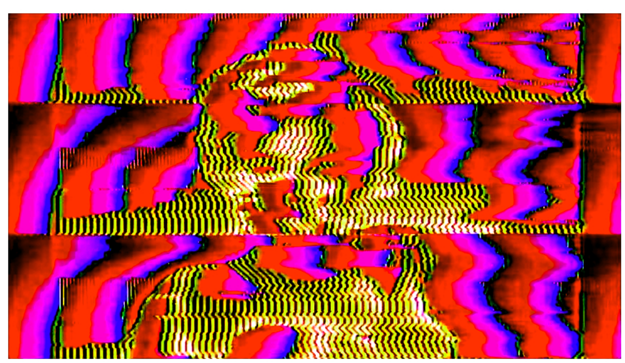
Hue Range Knob
Turning counter-clockwise collapses the range of hues that can be encoded. For example, you may wish to generate patterns ranging from pink to blue instead of the entire rainbow. This can be achieved by limiting the hue range and setting the starting point with the shift knob.

Hue Shift Knob
Defines the starting angle of rotations around the colour wheel. Adjusting it will shift the hue of all synthesized patterns. <u>In PAL mode some positions reduce colour intensity and produce interlacing effects.</u> The +180 **button** flips the starting angle to the opposite side of the colour wheel.

Glitch
Replaces some hues with glitchy lines and rainbows. Turn the knob fully counter-clockwise to disable the glitching effects.

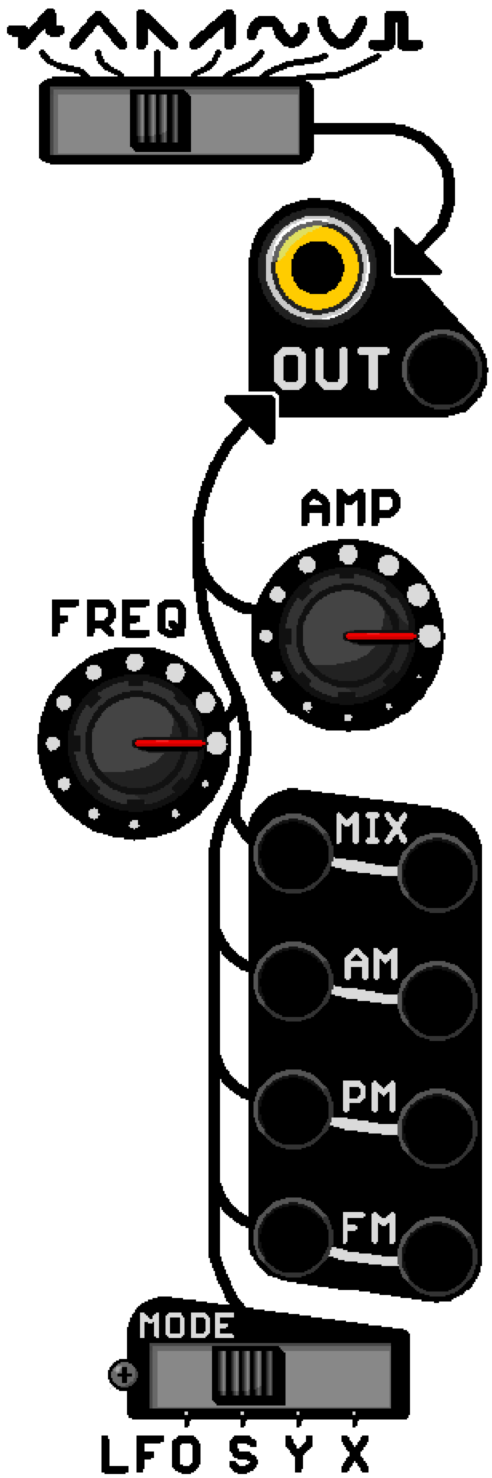
Example Glitch Effects





Function Generators

Mainbow contains four function generators. Elaborate patterns emerge when they modulate each other. All modulation inputs have a built in splitter for easy daisy chaining. Try modulating a function generator by itself! Function generators output both monochrome NTSC/PAL and 0-1v signalling.



Waveform Switch
Selects one of seven waveforms.

Monochrome Video Out (RCA Jack)
Run to a TV to see what the function generator is doing. It's fun and useful to see the intermediate steps of video synthesis.

0-1v LZX output (3.5mm Jack)
Patch to modulation inputs of other function generators and the colour video encoder.

Amplitude Knob
Sets the amplitude of the output signal.

Frequency Knob
Sets the Frequency of the output signal.

Mix input (Dual 3.5mm jacks)
Mixes another signal with this function generator in a 50% ratio.

Amplitude Modulation input (Dual 3.5mm jacks)
Multiplies output amplitude by another signal.

Phase Modulation input (Dual 3.5mm jacks)
Shifts waveform phase by another signal. Only active in X,Y modes.

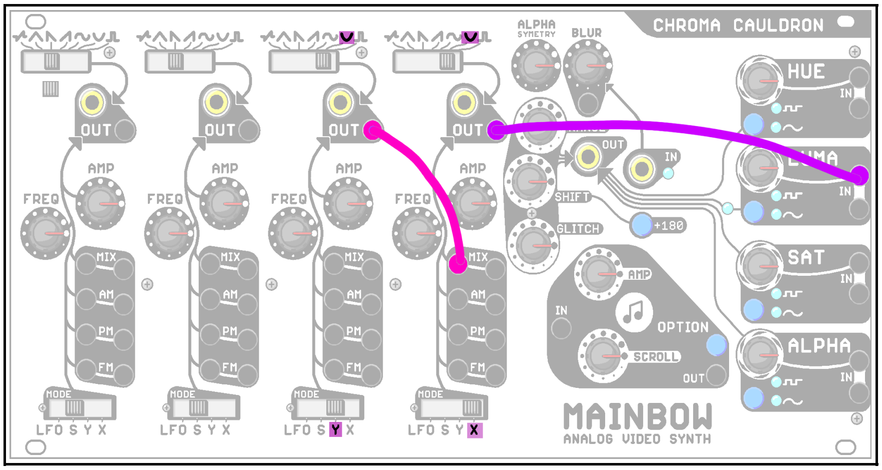
Frequency Modulation input (Dual 3.5mm jacks)
Multiplies output frequency by another signal.

Oscillation Mode Switch

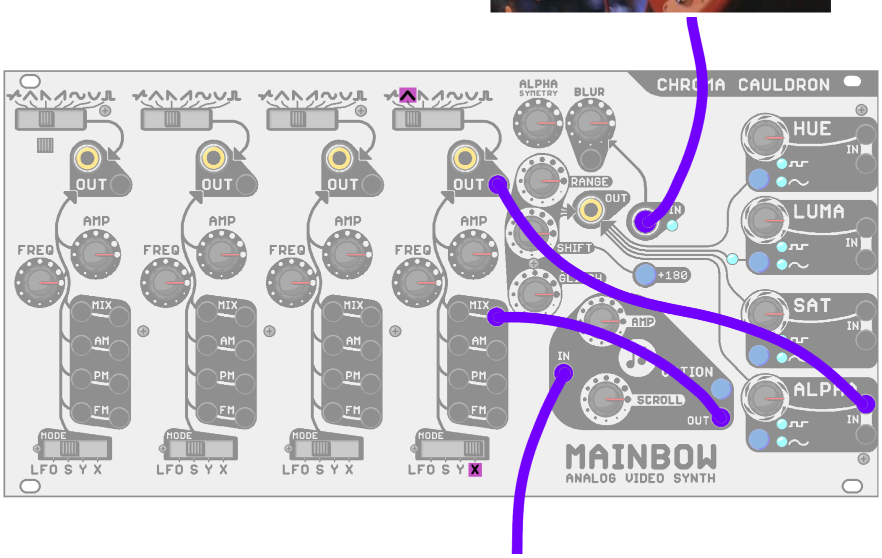
X:	Horizontal patterns.
Y:	Vertical patterns.
S (Scroll):	Scrolling vertical patterns.
LFO:	Low frequency oscillations.

Example Patches

Circle

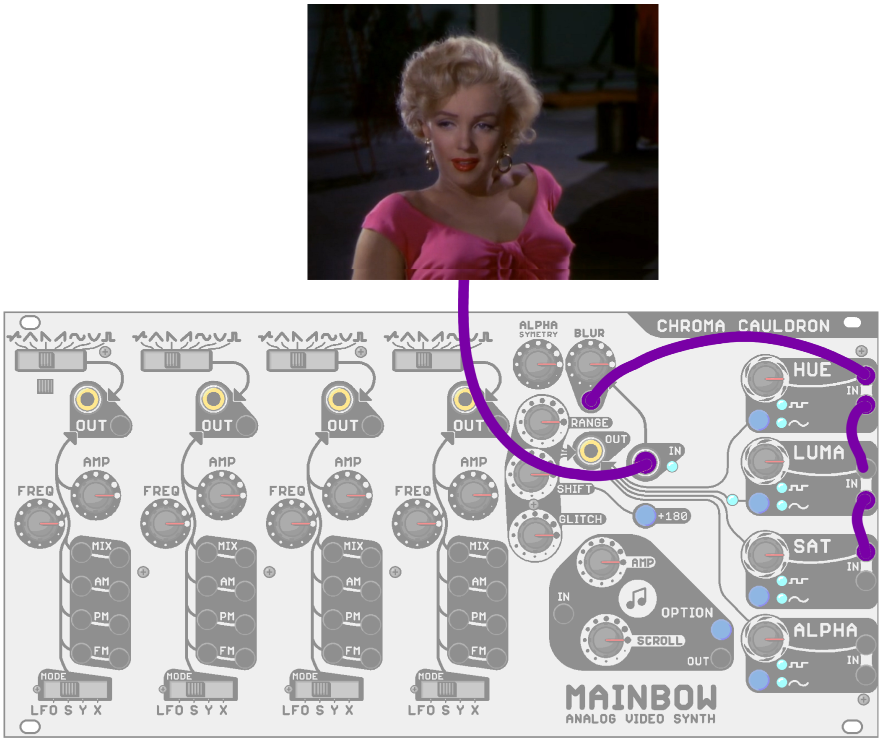


Music amplitude graph overlay

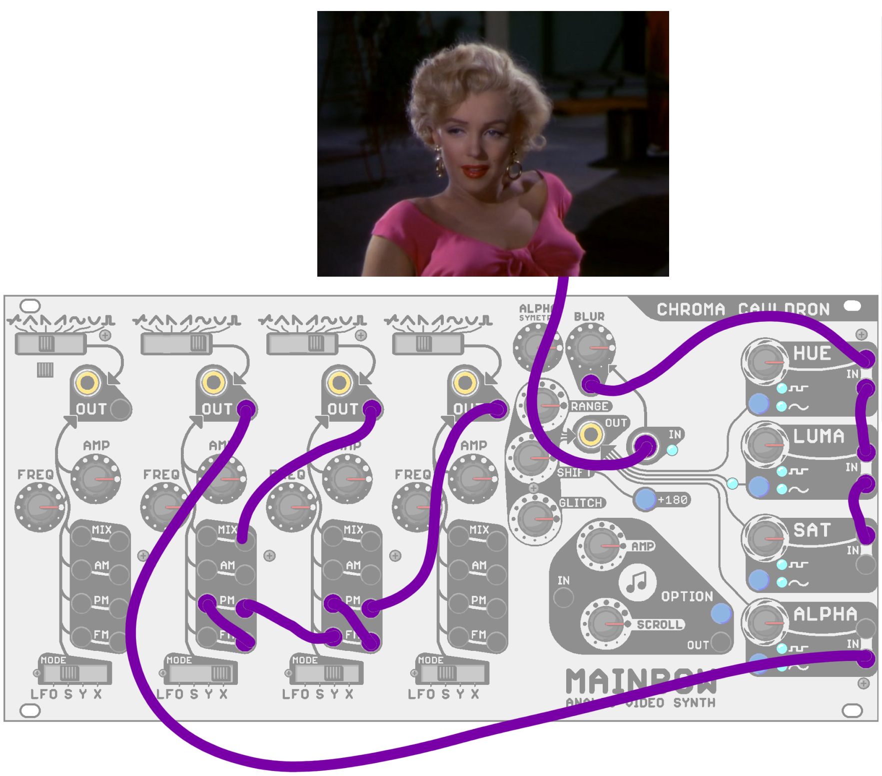


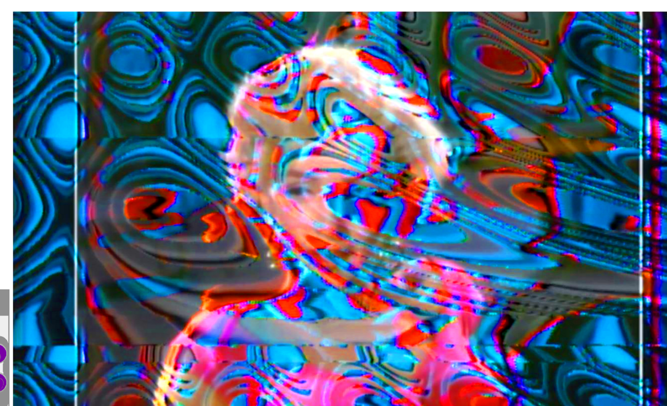
Headphone Level Audio

Recolourizer



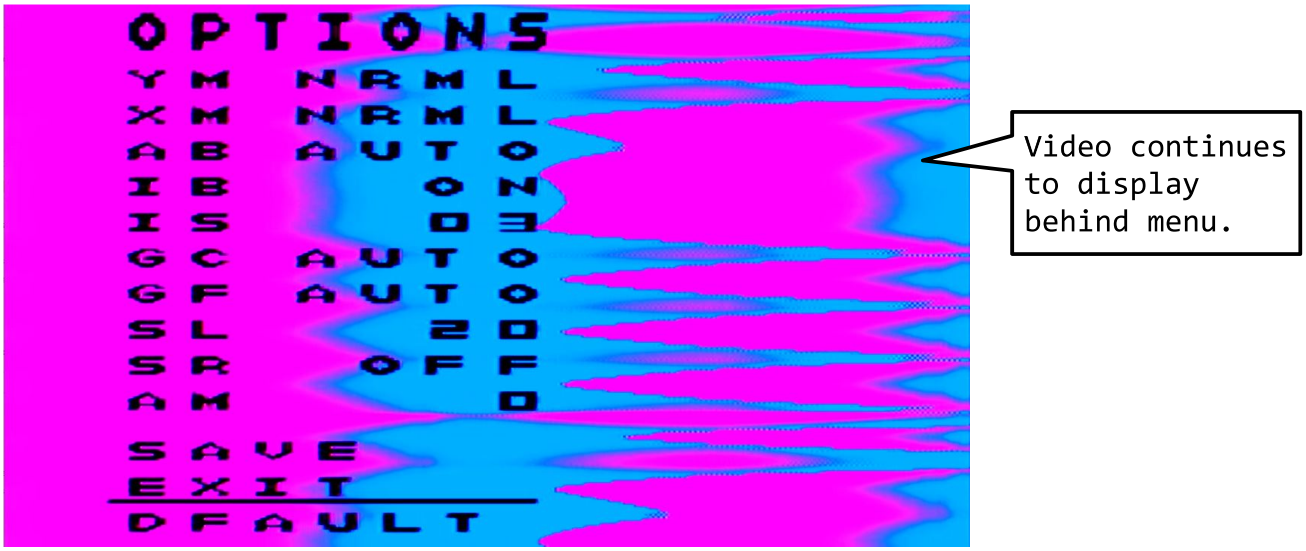
Abstract pattern recolourizer overlay





Options Menu

The options menu allows more advanced control of Mainbow's functionality. Options can be saved to permanent memory. Some options intentionally break and corrupt the video signal. If your Mainbow isn't working properly ensure that options are set to default. Powering up with no crystal will result in a reset to defaults.



Enter the options menu by pressing the option button. Use the audio scroll knob to select an option and press the option button to change it. Scroll to EXIT and press the option button to leave.

The option menu is drawn onscreen through the alpha channel. The regular voltage control of alpha and HSV inputs remains active. You may need to adjust these to see the text clearly.

Certain settings can corrupts the video signal so much that the options menu can no longer render. This causes Mainbow to reset to the last save after two seconds. Press the option button quickly to skip over a state causing the issue. You can also change an option in a state where it has no effect, such as adjusting sync level without a video input present.

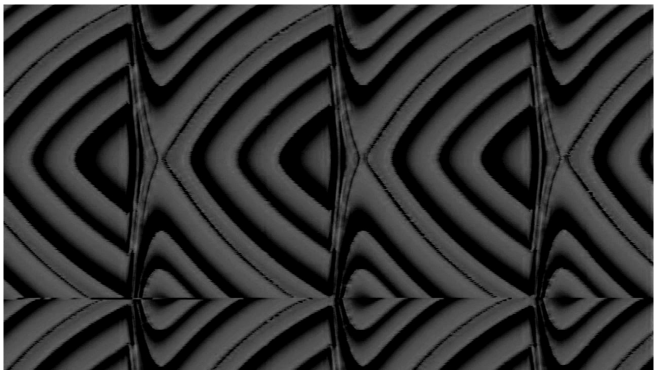
Audio filter output is disabled while the options menu is open.

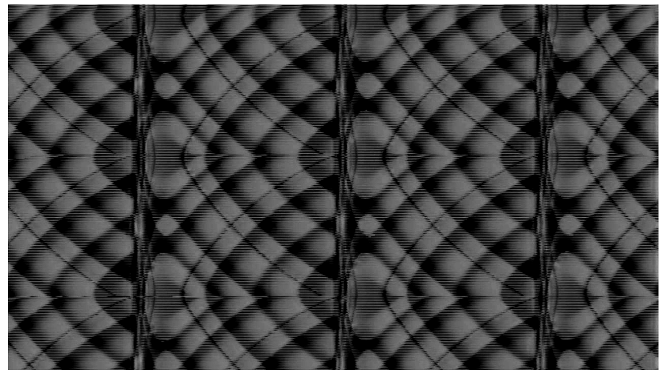
YM Y-Mode

This option changes the behaviour of function generators while in Y mode. All function generators are effected simultaneously.

NRML: Normal vertical patterns.

INTI: Interlaced vertical patterns.


Normal


Interlaced

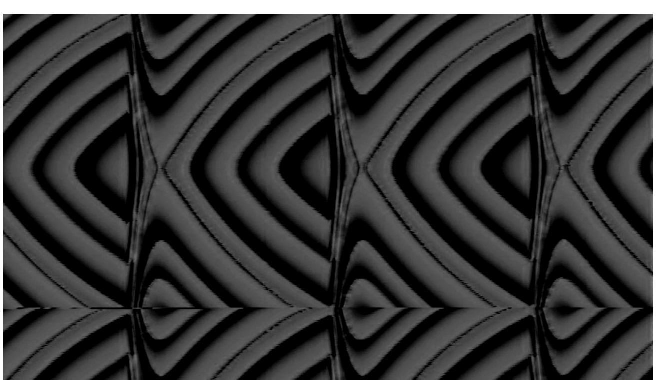
XM X-Mode

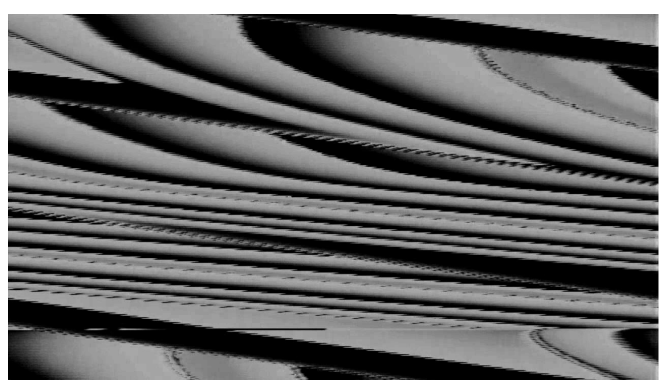
This option changes the behaviour of function generators while in X mode. All function generators are effected simultaneously.

NRML: Normal horizontal patterns.

DIAG: Diagonal patterns. Frequency knob and FM input control the slope. These patterns tend to be shaky and unstable. <u>Function Generator monochrome video output does not work properly in this mode.</u>

FREE: Moving diagonal patterns. Highly unstable. <u>PM does not work in this mode. Function Generator monochrome video output does not work properly in this mode.</u>


Normal


Diagonal

AB Add Burst

This option only has an effect when video input is present.

Colour bursts tell TVs that a video signal contains colour information. Monochrome video inputs might be missing the colour burst. By default Mainbow detects the missing colour burst and inserts a new one at the video output. This allows Mainbow to add colour to monochrome video signals. The AB option changes the behaviour of this feature.

AUTO: Only insert a new colour burst if it is missing from the input. Automatic detection may not work properly for very noisy or weak signals.

ON: Always insert a colour burst. Use this option if AUTO is failing to detect a missing burst. Inserting a burst into a video input that already contains one will cause a hue shift in NTSC.

OFF: Never insert a new colour burst. Use this option if automatic mode is erroneously deciding to insert a colour burst. If the input video does not contain a colour-burst it will become impossible to colourize it.

Colour video input with AB set to AUTO or OFF.

Colour video input with AB set to ON. NTSC Input becomes hue shifted.

Burstless monochrome video input with AB set to AUTO or ON.

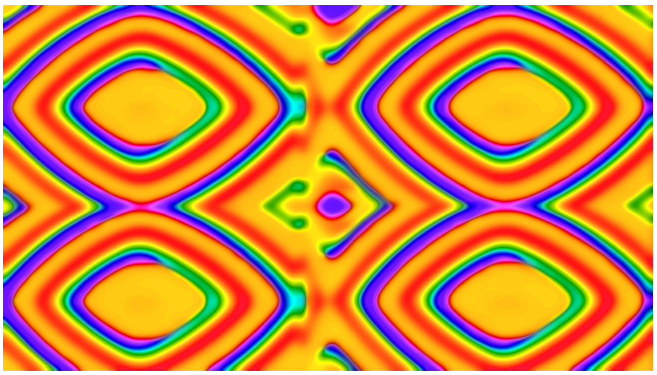
Burstless monochrome video input with AB set to OFF. Synthesized colour appears as chroma-dots.

IB Internal Burst

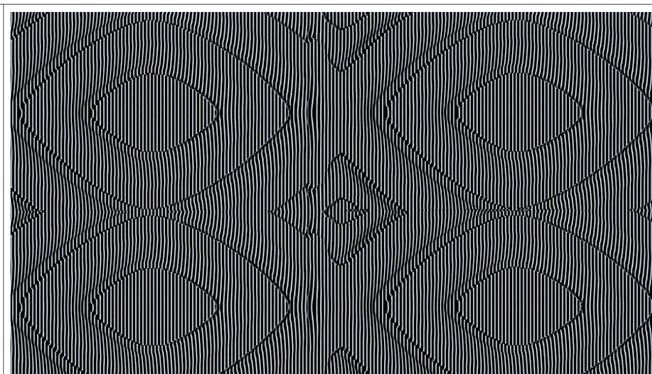
This option only has an effect when no video input is present.

ON: Video output will contain a colour burst. TVs will interpret it as a colour video signal.

OFF: Video output will not contain a colour burst. TVs will interpret it as a monochrome signal. Colour information shows up as a monochrome texture.



IB **ON.**



IB **OFF.**

IS Internal Subcarrier Frequency Adjust

This option only has an effect when no video input is present. It makes small adjustments to the colour subcarrier frequency. You should try adjusting this value if Mainbow's colour video output goes to a device that is struggling to achieve genlock (not synchronizing colours properly).

GC Genlock-Coarse
GF Genlock-Fine

This option only has an effect when a video input is present.

Mainbow has an automatic Genlock system but it may fail for very noisy or very weak video inputs. You may also want to intentionally take Mainbow out of genlock and manually adjust the subcarrier frequency. This produces a scrolling rainbow effect.

- **If Mainbow isn't achieving genlock:**
  Leave Genlock-Fine as AUTO. Cycle Genlock-Coarse through the numeric (non-automatic) states.

- **If you want to take Mainbow out of genlock:**
  Take both Genlock-Fine and Genlock-Coarse out of AUTO. The number of rainbow lines and how fast they scroll can now be manually controlled by adjusting their numeric values.

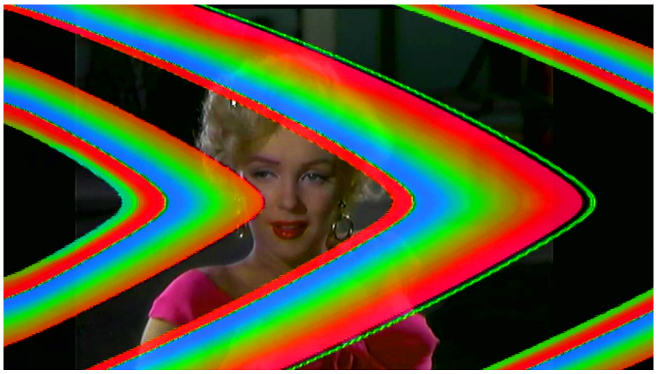
Genlock achieved.

Genlock disabled.

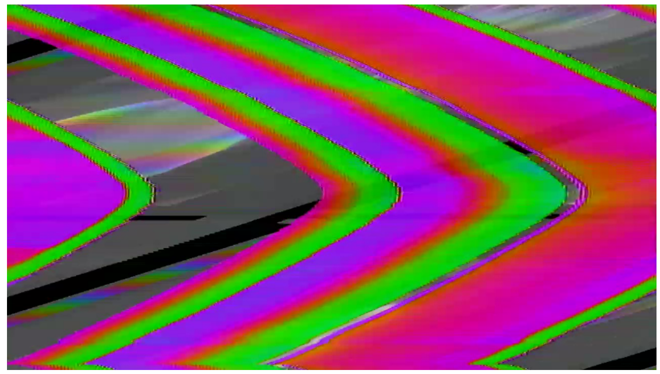
SL Sync-Level

This option only has an effect when a video input is present.

Mainbow synchronizes itself to video inputs by detecting sync pulses. This uses a comparator with a digitally controlled reference voltage. The Sync-Level option is provided just in case the default reference voltage isn't working. You may also want to intentionally break synchronization to produce a glitchy cyberpunk effect.



Normal.



Bad Sync Level. Video input is now distorted and scrolling.

SR Sync-Restore

This option only has an effect when a video input is present.

OFF: The sync pulses in Mainbow's video output are copied directly from the video input. Any noise and distortions are copied.

ON: Output sync pulses are cleaned up and slightly amplified. This is necessary to stop distortions from accumulating when several pieces of video gear are connected in series. A slight change in video brightness occurs when toggling this option.

AM Audio-Mode

Refer to the Audio Processor section.

SAVE

Save the present options to permanent memory. Mainbow will be in the saved state the next time it powers up.

EXIT

Close the options menu.

DFAULT

Restore all options to defaults. Save to make it permanent.

Component list

Resistors

Value	Colour Code				Quantity
75Ω	violet	green	black	gold	6
330Ω	orange	orange	brown	gold	14
470Ω	yellow	violet	brown	gold	11
1kΩ	brown	black	red	gold	34
2kΩ	red	black	red	gold	11
3kΩ	orange	black	red	gold	10
5.1kΩ	green	brown	red	gold	7
10kΩ	brown	black	orange	gold	25
20kΩ	red	black	orange	gold	2
62kΩ	blue	red	orange	gold	22
1MΩ	brown	black	green	gold	1
1kΩ 3x array					10

Capacitors

Value	Code	Quantity
15pF	150	10
47pF	470	5
1nF	102	6
1.5nF	152	4
22nF	223	1
100nF	104	29
330nF	334	5
10µF	10µF	4
100µF	100µF	14

Discrete semiconductors

Name	Quantity
1N914 diode	16
3v 20ma 5mm LED	10
J113 transistors	5
2N3904 transistor	9
2N3906 transistor	8
“Red” transistor	4
17.734 MHz Crystal	1
14.318 MHz Crystal	1

Controls

2P4T switch	4
2P2T pushbutton	6
1P7T switch	4
10kΩ potentiometer	19

Jacks

RCA	6
3.5mm	47
16pin power header	1
8p board connector m/f	1

IC Sockets

8 pin	4
14 pin	11
16 pin	4
28 pin	1

Integrated Circuits

NE555P	4
TL974IN	11
CD74HC4050	2
CD74HC123	2
LM1117	1
LM7905	1
PIC16F15354	1

Some kits may contain a PIC16F15355 due to component shortages. This is the same chip but with more memory.

Misc

M3 Screw Posts	8
Tiny screws	4
M3 screws	18
M3 nuts	2
Knobs	19

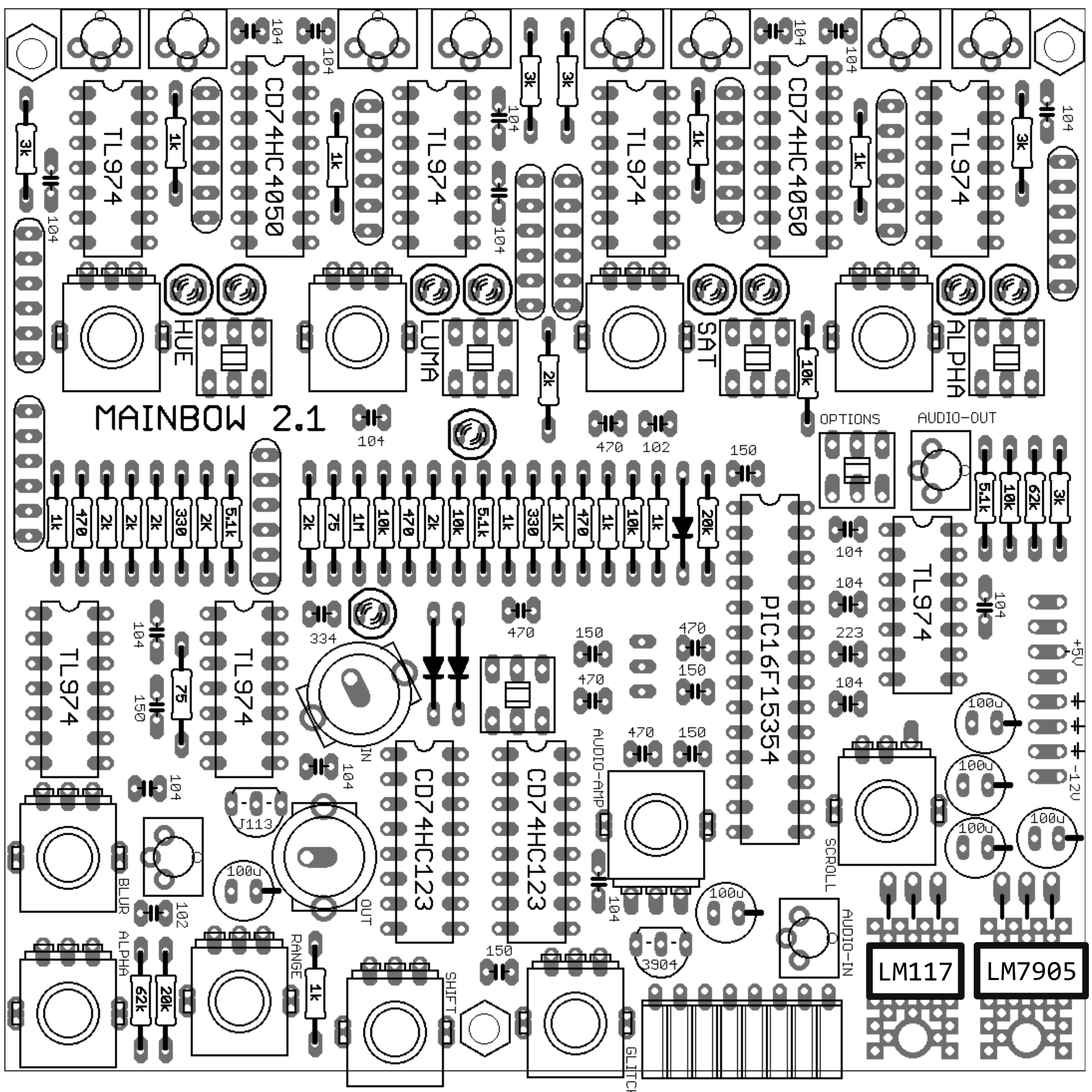
PCB (Soldering)

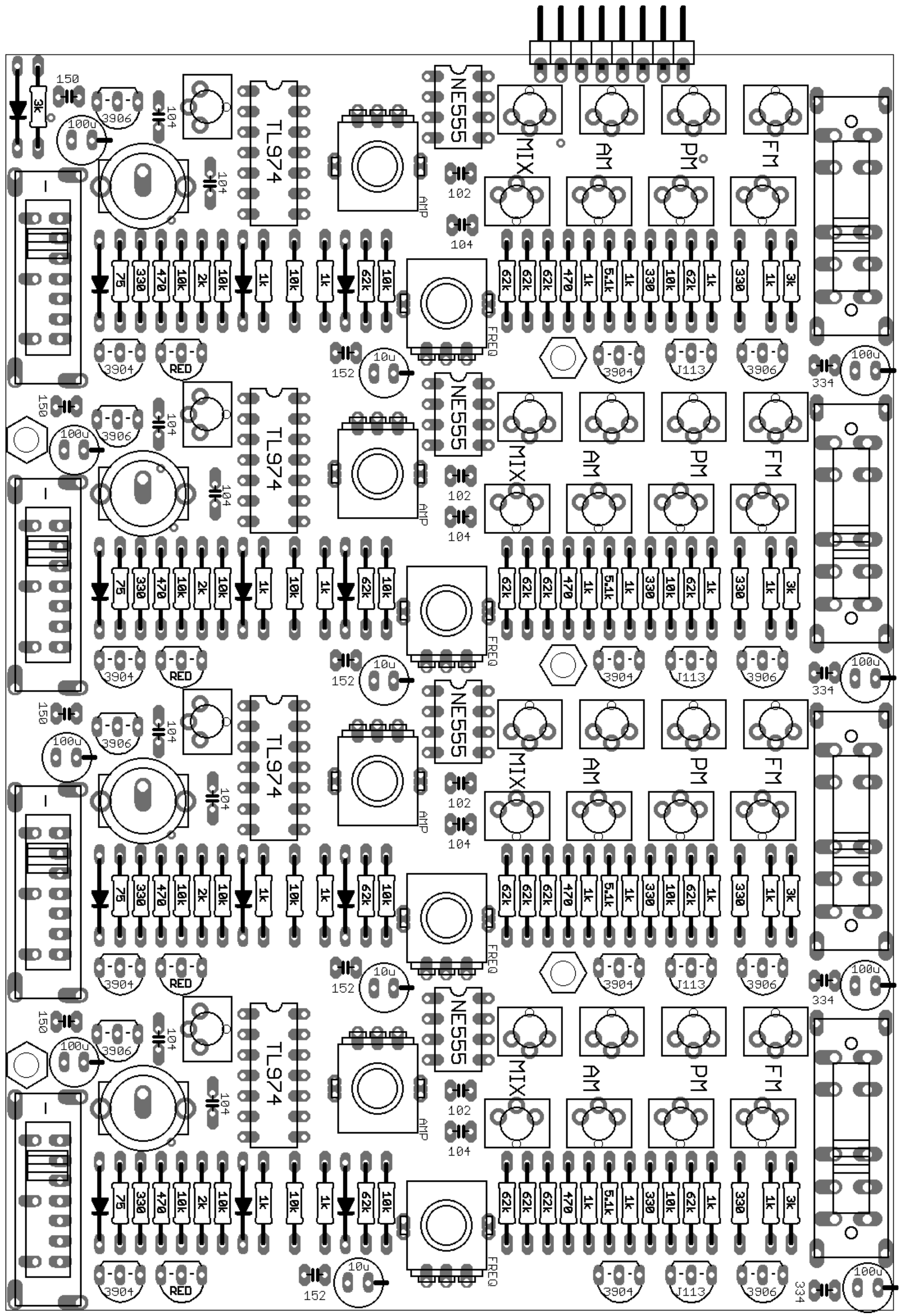
Ceramic capacitors are labelled with their numeric codes. 104 = 100nF, etc. Some manufacturers omit trailing zeros so capacitors labelled “150” and “470” on the PCB may have “15” and “47” printed on them.

Electrolytic capacitors must be pushed in all the way or the case will not fit properly.

Jacks, potentiometers, and buttons will not align with panel holes if they are soldered crooked.

The board breaks in half just in case there is an unfixable problem. The working half can be saved and the broken half replaced.



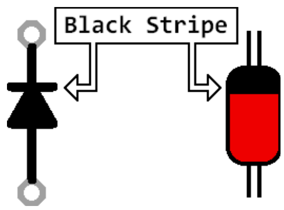


150
3k
3906
104
100u
TL974
NE555
MIX
AM
PM
FM
102
AMP
75
330
470
10k
2k
1k
62k
5.1k
FREQ
3904
RED
152
10u
J113
334

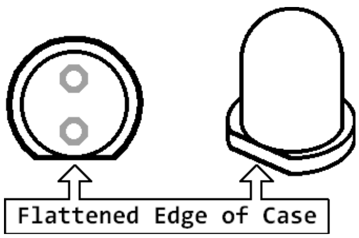
Component Polarization

Don't put these in backwards!

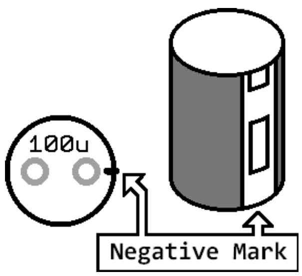
Diode



LEDs

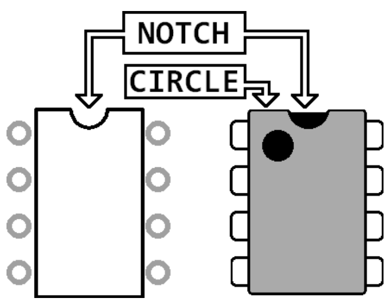


Electrolytic Capacitors



Electrolytic capacitors may explode if installed backwards.

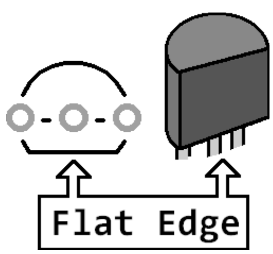
Chips



Some chips use a circle in the top left corner instead of a notch.

Chips can be permanently damaged if installed backwards. TL974s break in a way that shorts the power supply after being reinserted correctly.

Transistors



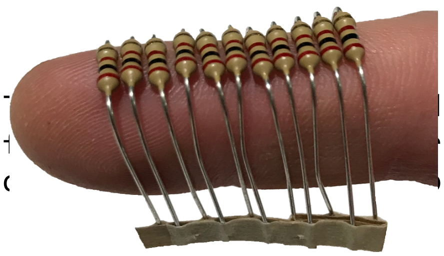
Resistors, resistor arrays, ceramic capacitors, and crystals are not polarized. Solder in any direction.

Step by Step Assembly Instructions

This section documents each step of assembling a Mainbow video synth kit. The process takes approximately five hours and 20 grams of solder.

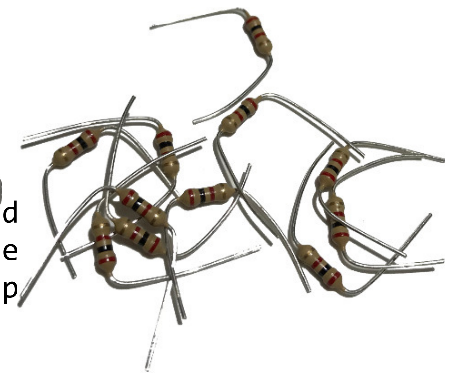
Step 1) Insert and solder all diodes and resistors. Don't get diodes backwards. Resistor/diode strips can be quickly bent and separated using the following technique:

Bend the resistor strip over your finger.

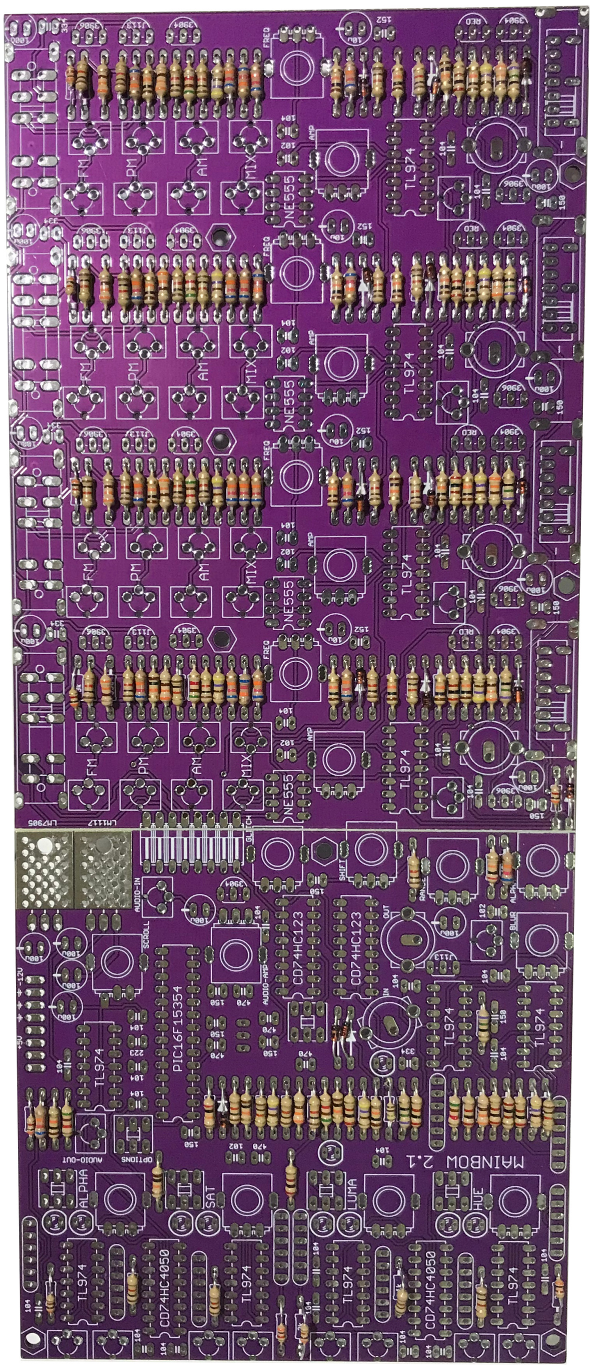


Cut the resistor strip leads with scissors.

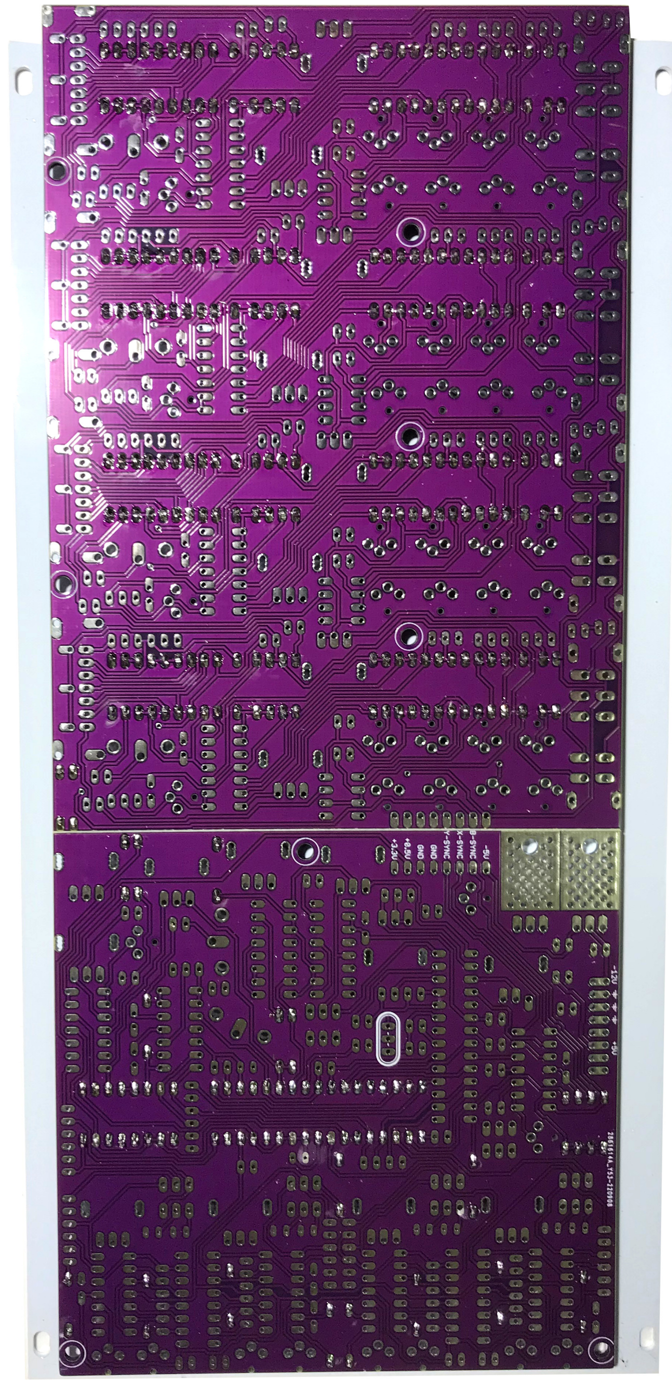
This is much faster than bending each resistor individually.



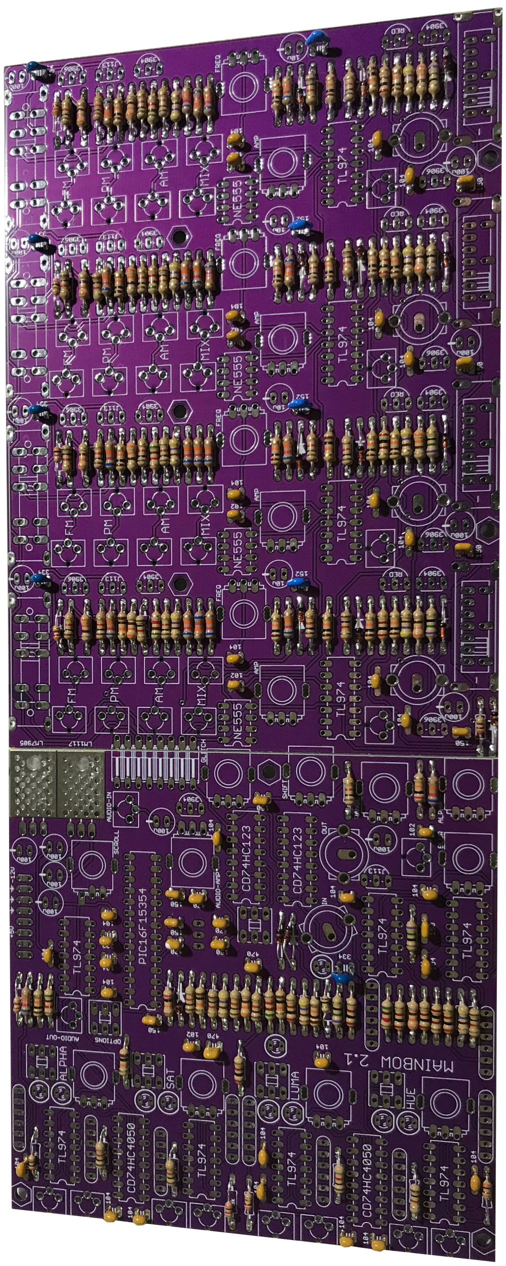
PCB with all resistors and diodes inserted.



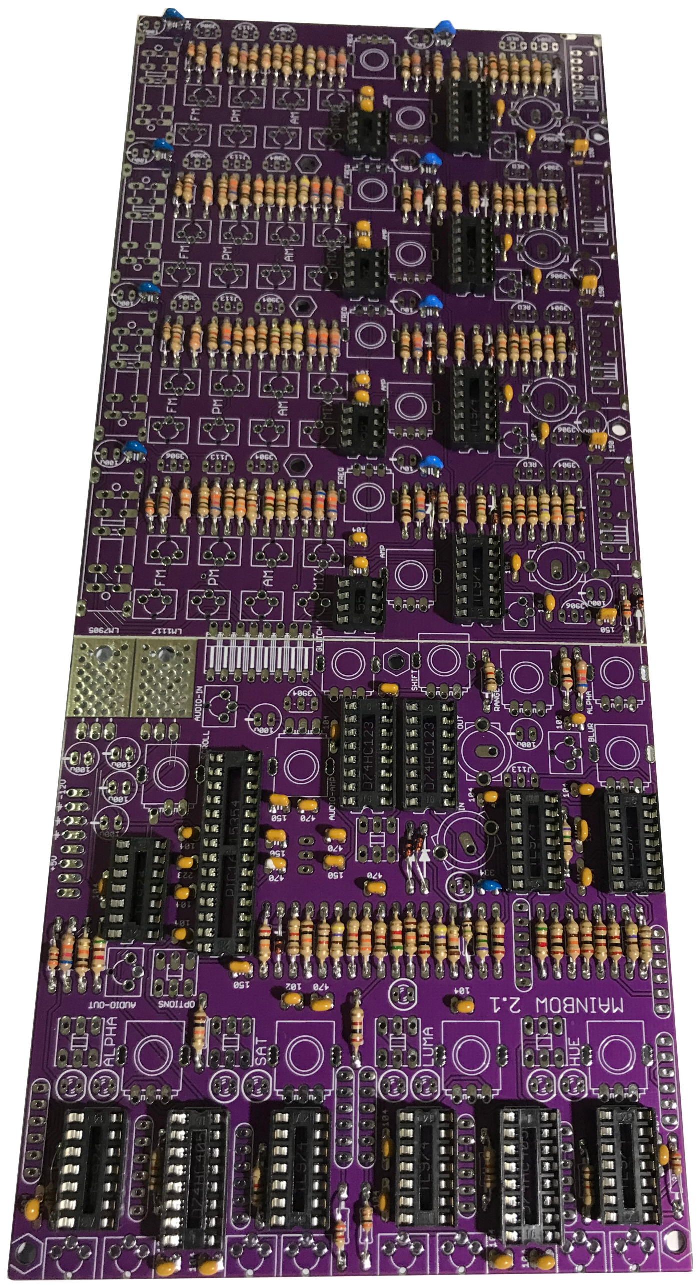
Back side of PCB with resistors/diodes soldered and leads trimmed. Faceplate used to hold resistors/diodes while flipping upside down.



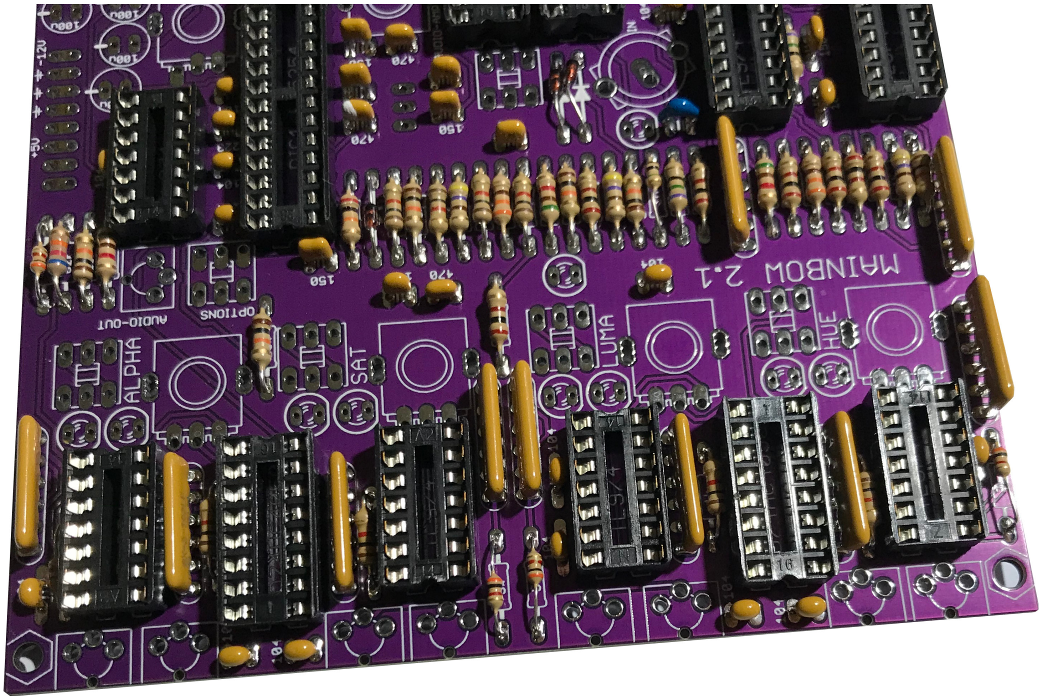
Step 2) Insert and solder all ceramic capacitors.



Step 3) Insert and solder all IC sockets. Don't insert the chips yet.

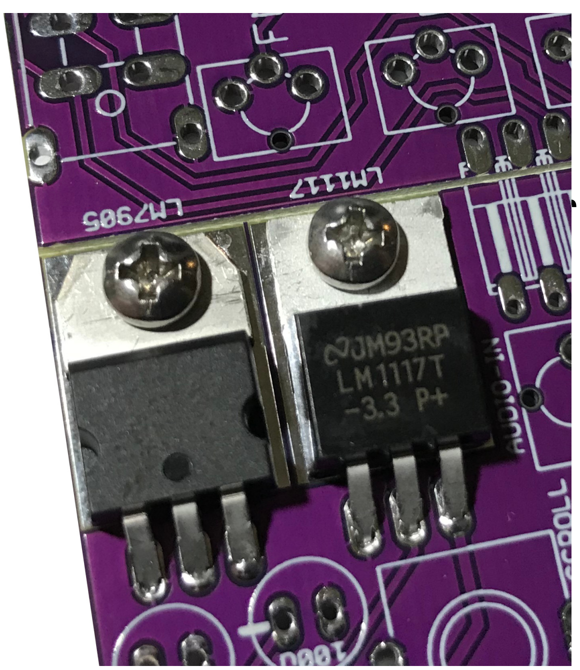


Step 4) Insert and solder the resistor arrays.

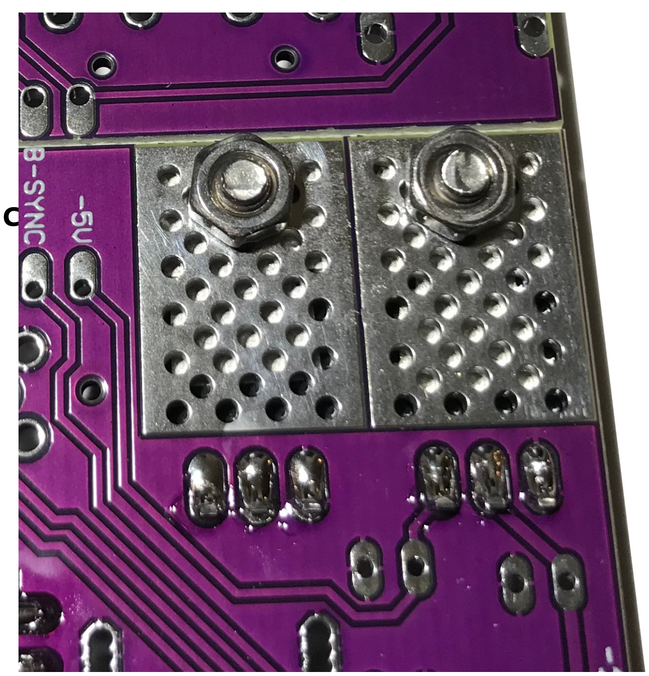


Step 5) Bend the regulator leads back so they sit flat against the PCB. Use the supplied nuts and bolts to hold them firmly in place. This ensures they make good contact with the PCB heatsink. Solder and trim the leads after tightening the screws. The regulators must not touch each other or each other's pads.

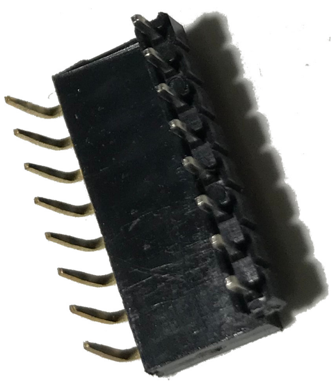
Front

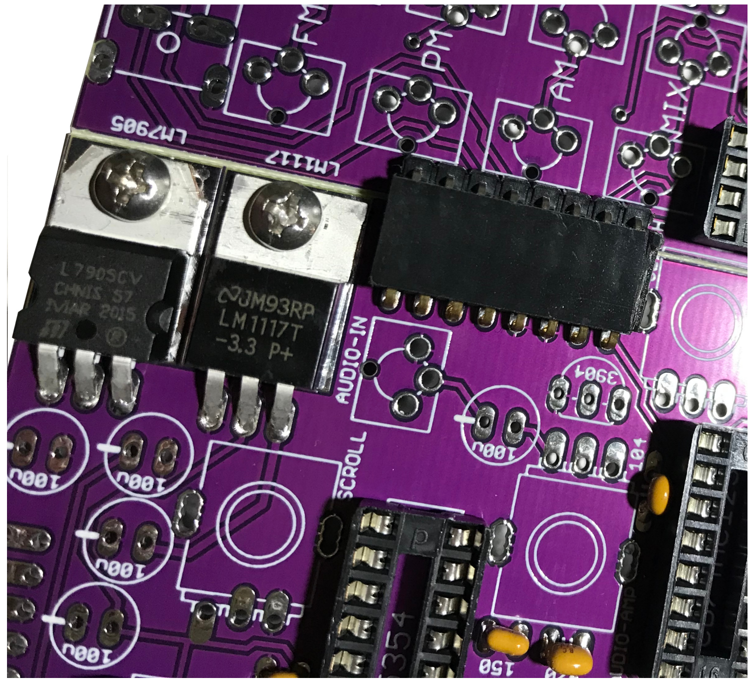


Back

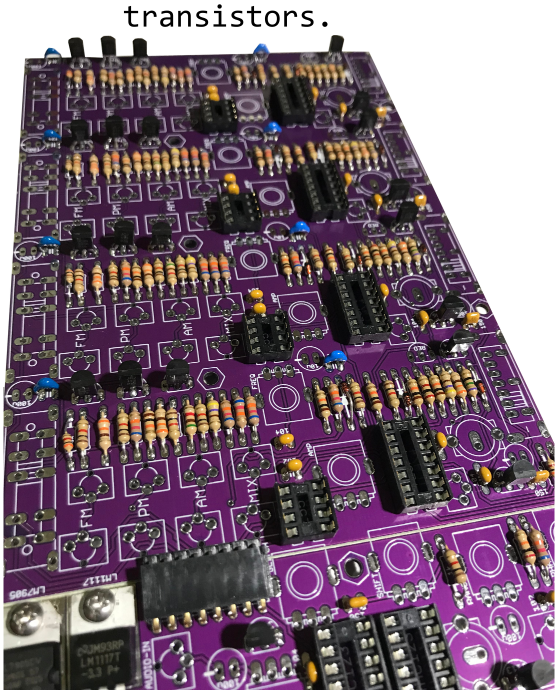


Step 6) Insert and solder the board headers. First push the male and female headers together then insert this into the PCB. The female header's PCB pins may need to be bent inwards slightly.

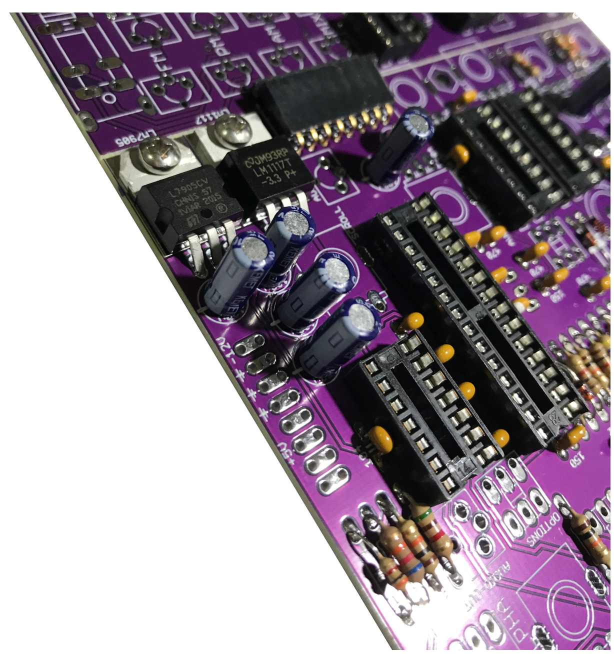




Step 7) Insert and solder all transistors.

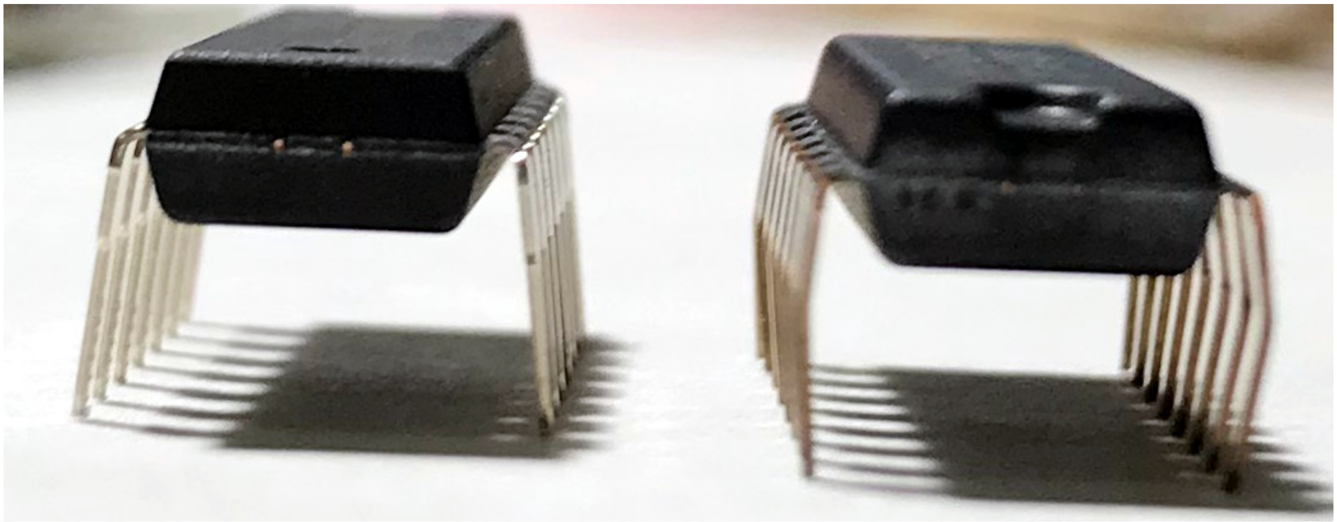


Step 8) Insert and solder all electrolytic capacitors.

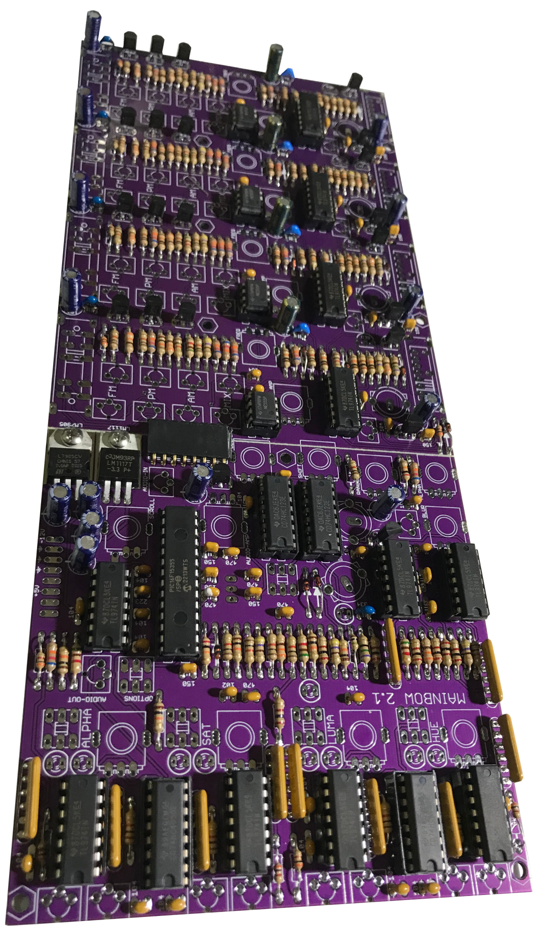


Step 9) Place chips into sockets. Chip leads need to be bent to right angles to fit into the sockets. Do this by gently pushing the chip against a flat surface.

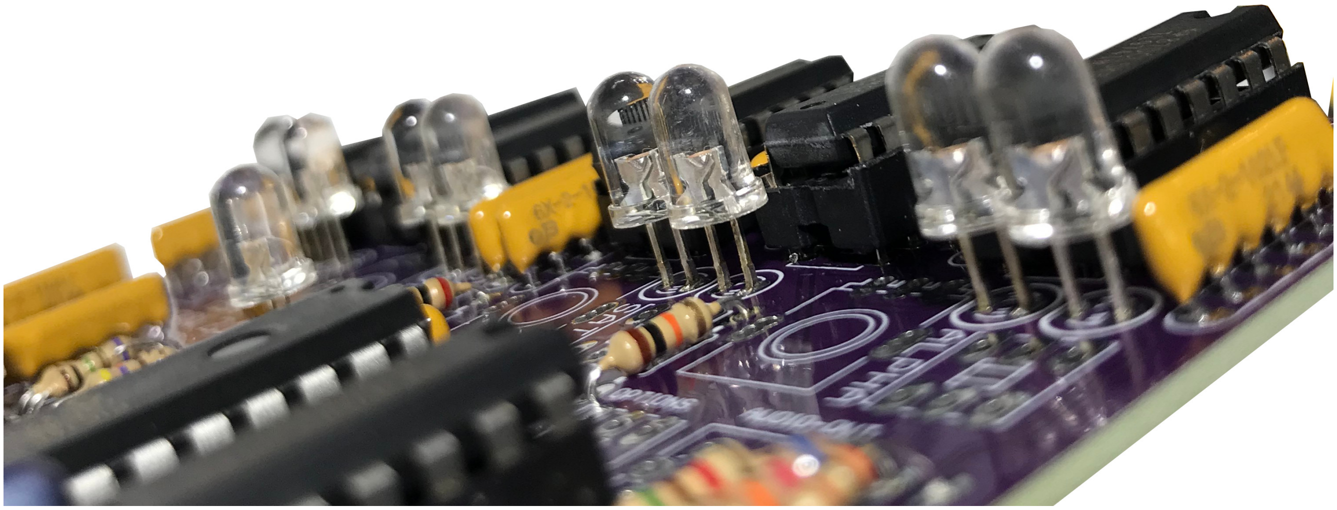
Unbent Bent



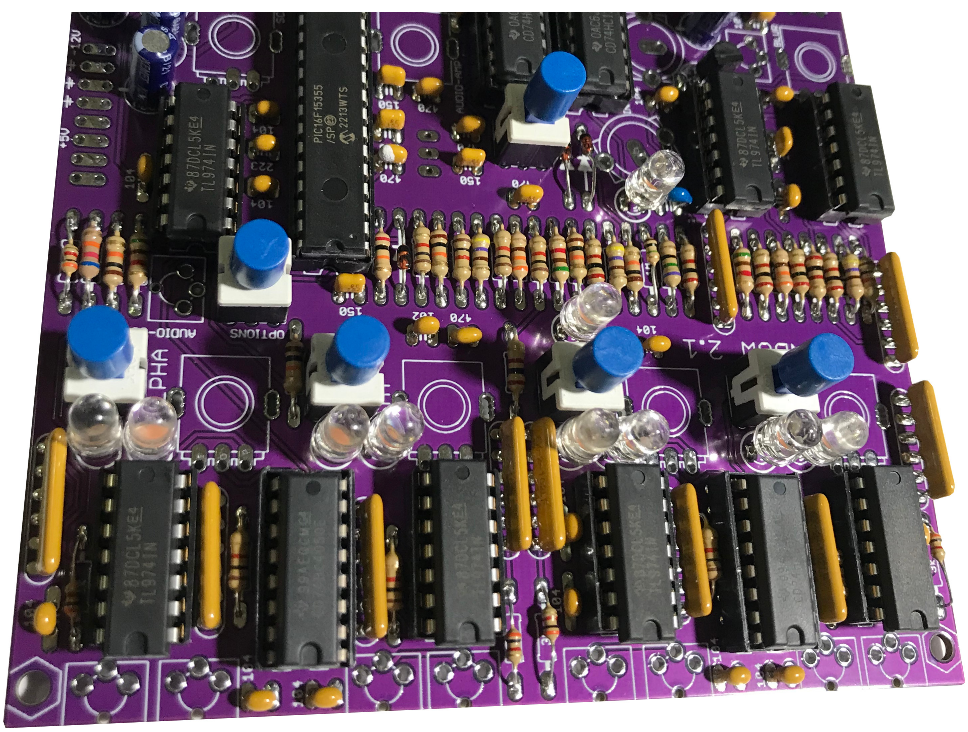
Don't put chips in backwards. Watch out for chip leads bending under the chip instead of entering the socket.



Step 10) Insert and solder the LEDs. The PCB holes are sized such that LEDs can only be pushed in to a point where their leads widens. This holds LEDs close to their faceplate holes. Don't get the LEDs backwards.

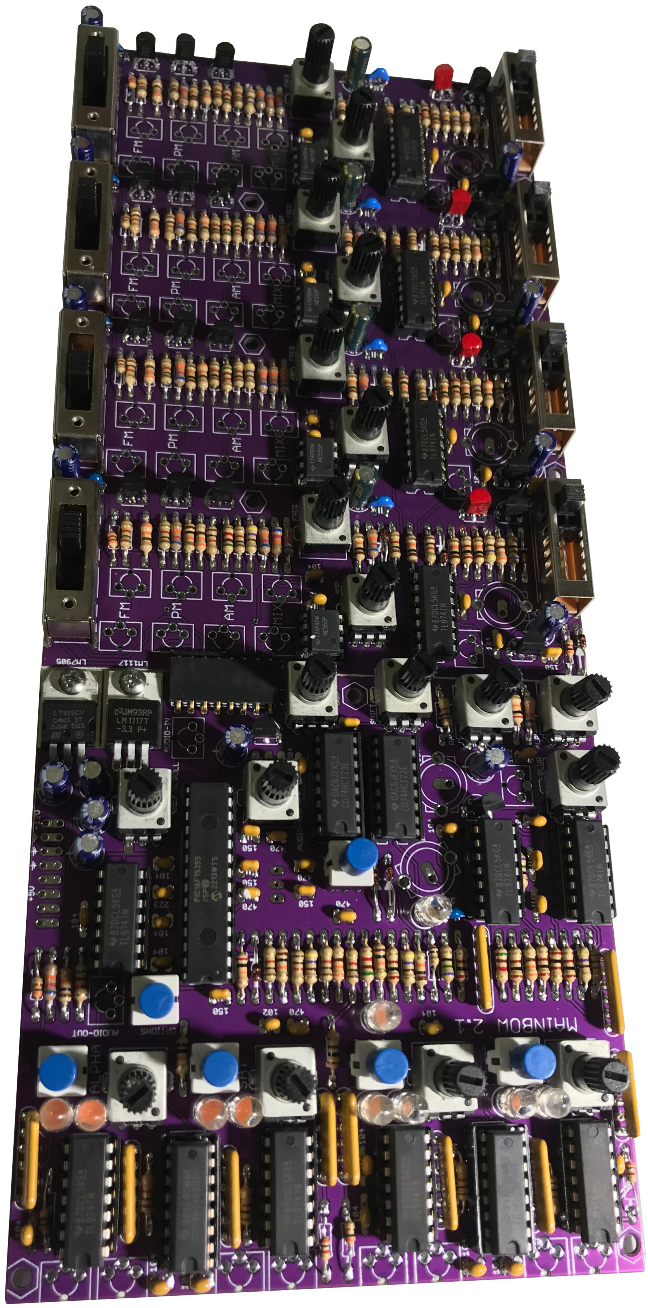


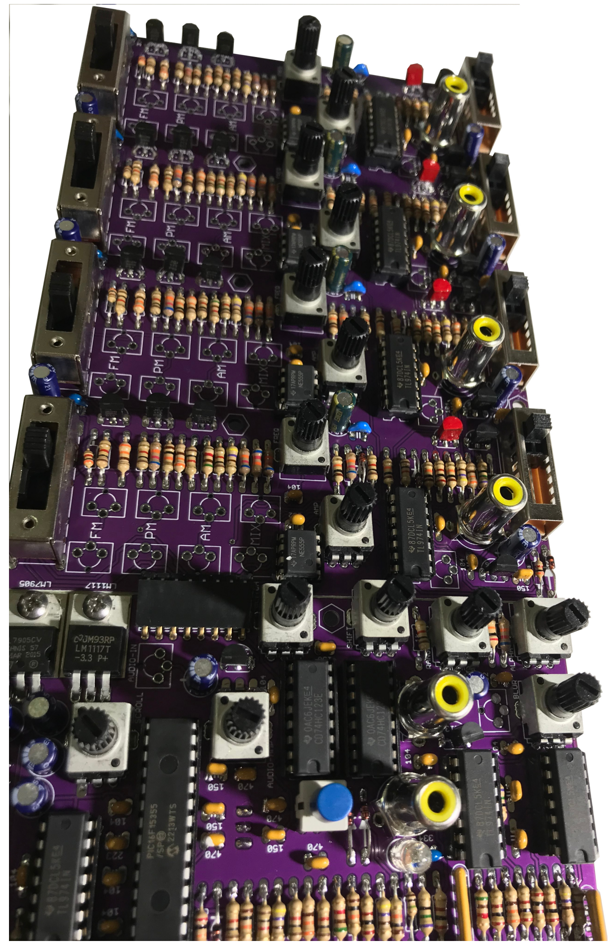
Step 11) Insert and solder the pushbuttons. Avoid soldering them in crooked by pushing them in firmly. Crooked pushbuttons will not align with faceplate holes.



Step 12) Insert and solder the slide switches and potentiometers. Slide switch leads may need to be straightened.

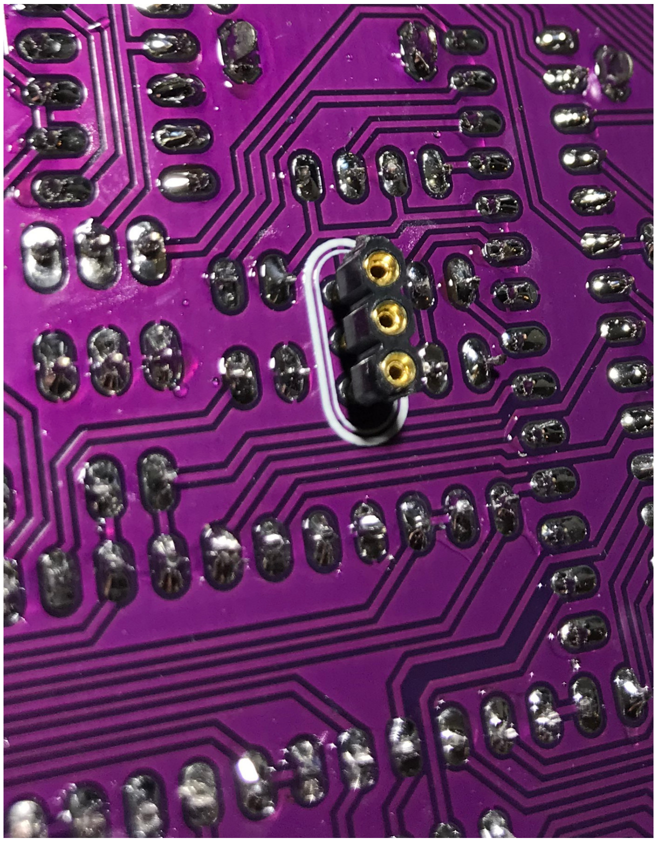
Step 13) Insert and solder RCA Jacks.

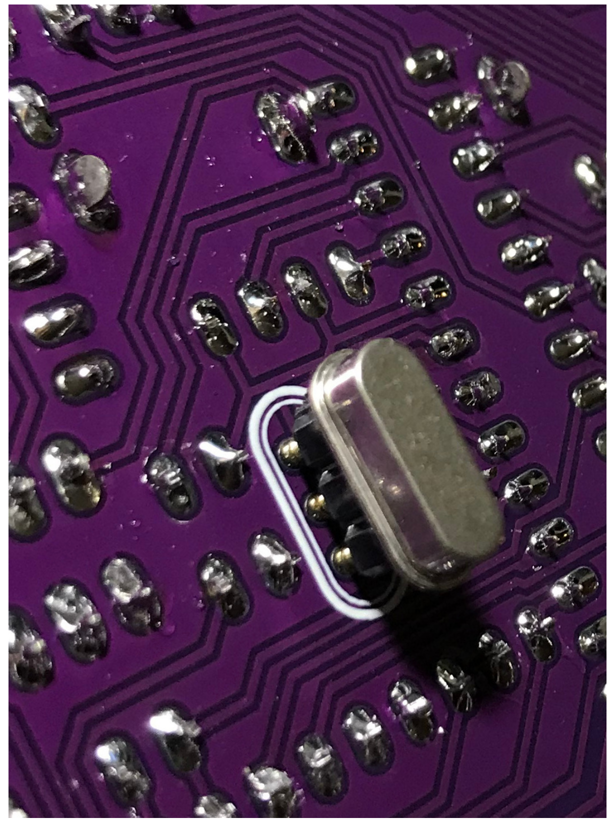




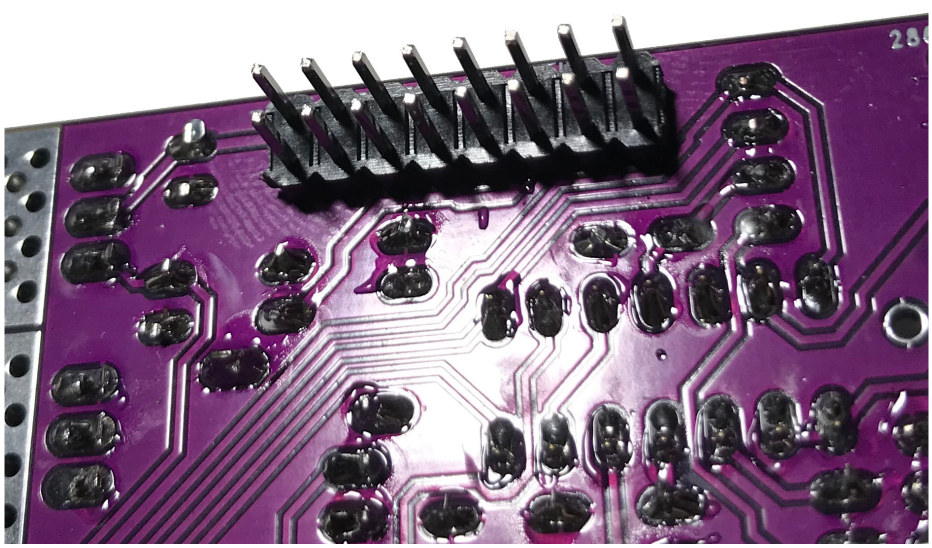
Step 14) Solder in the crystal socket. It mounts on the back of the PCB so the crystal can be changed without removing the faceplate.

Step 15) Choose the crystal corresponding to your desired video format, trim its leads, and place it in the socket.

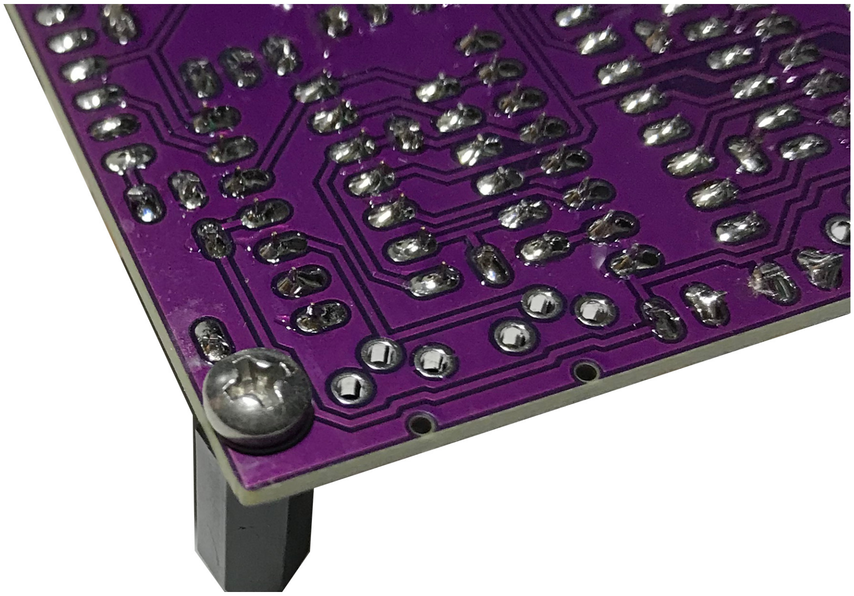




Step 16) Solder in the power header. It also mounts on the back.

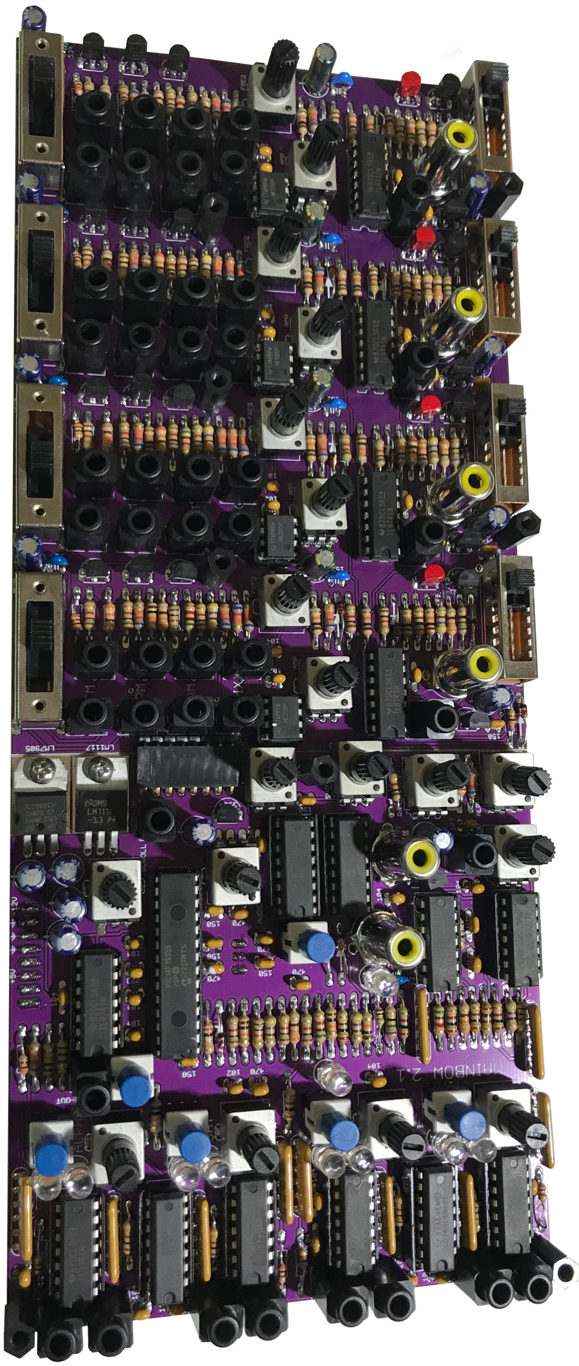


Step 15) Install the standoffs. They are held to the PCB and faceplate with the supplied bolts.



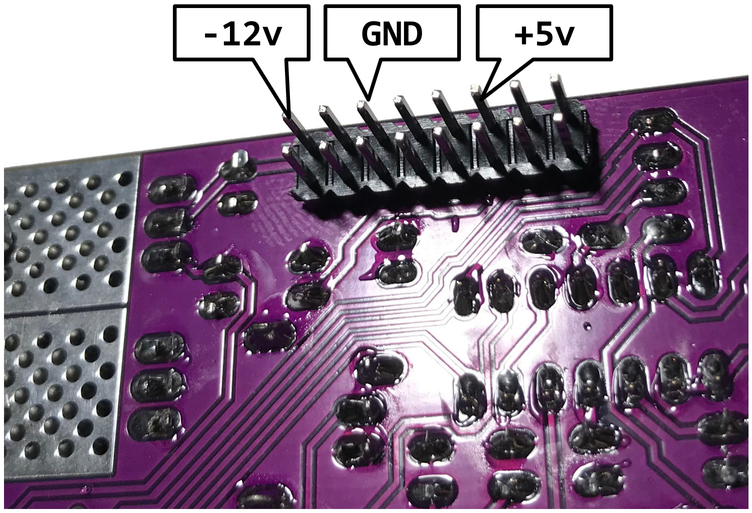
Step 16) The faceplate has low tolerance for crooked 3.5mm jacks so they have been left for last. Insert all of the jacks, but don't solder them right away. Put the faceplate on top of the unsoldered jacks, line them up with their holes, then bolt the faceplate to the standoffs. The jacks are now within their respective faceplate holes and therefore line up perfectly after soldering.

3.5mm Jacks inserted.

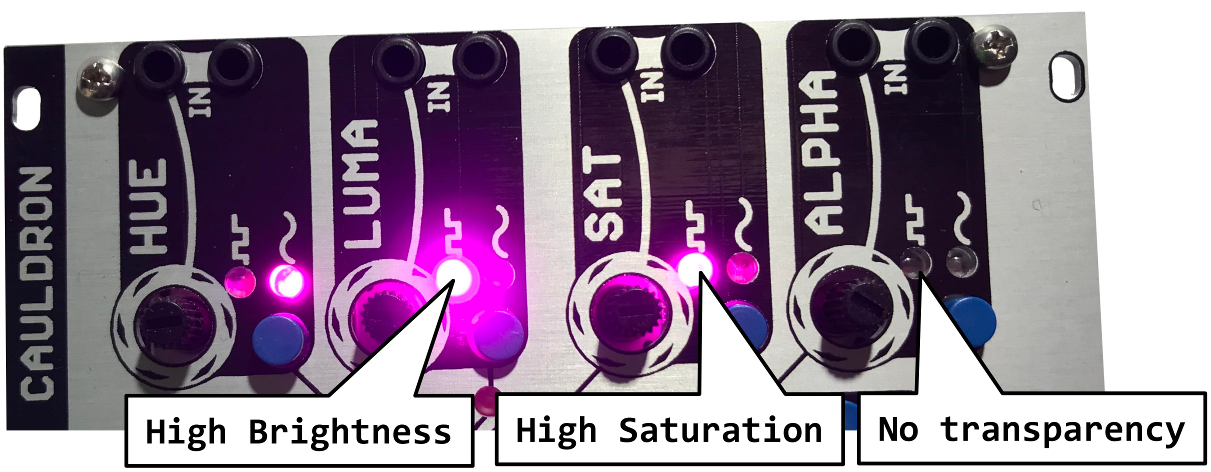


Faceplate holding jacks in place before soldering.

Step 17) Perform a quick test: Connect your Mainbow to a eurorack power supply. The cable orientation needs to be correct. The red stripe on eurorack ribbon cables is not a reliable indicator. The power supply should have labelling indicating which wire is which.



Connect a TV to the video output and power up your Mainbow. If you only get a black screen don't panic. This can be because both saturation and luma are at zero (black), alpha symmetry is in a bad position, or the alpha fold knob is set to 100% transparent (the background is black when there is no video input). Adjust the fold knobs until the LED indicators match the following pattern.



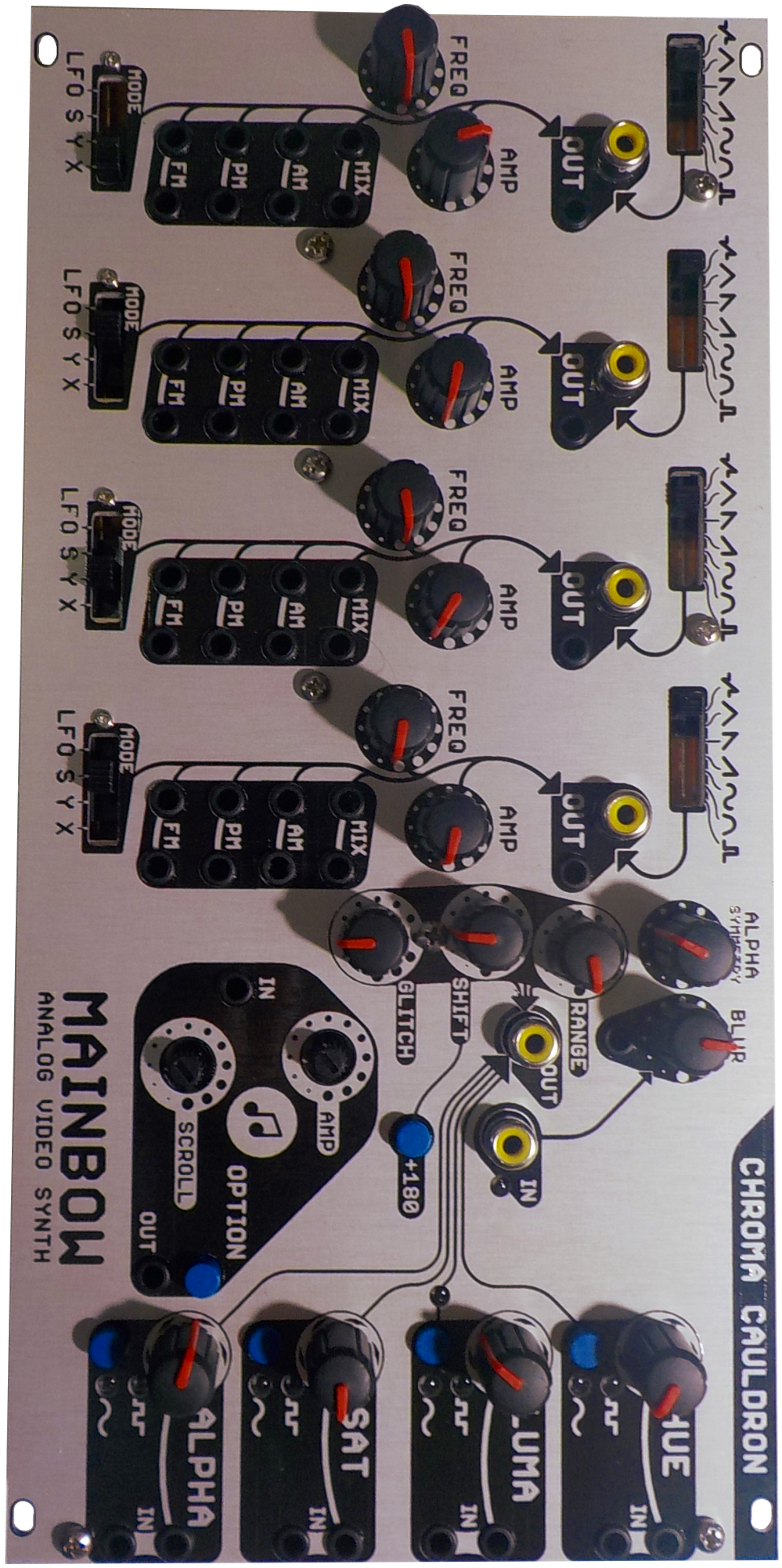
Adjust the alpha symmetry knob. If the screen is all black it is too far clockwise. If the screen is tearing or flickering it is too far counter-clockwise. The alpha symmetry knob was intended to be calibrated once then not touched. You may wish to not put a knob on it.

Upon resetting your Mainbow you should see an info screen displaying the firmware version number and video format (NTSC/PAL). This disappears after five seconds and only shows up when there is no external video present

You should now be able to produce screens of solid colour by playing with the hue, sat, and luma knobs, as well as the hue shift and limit knobs. If the colours are glitchy rainbows try turning the glitch knob counter-clockwise.

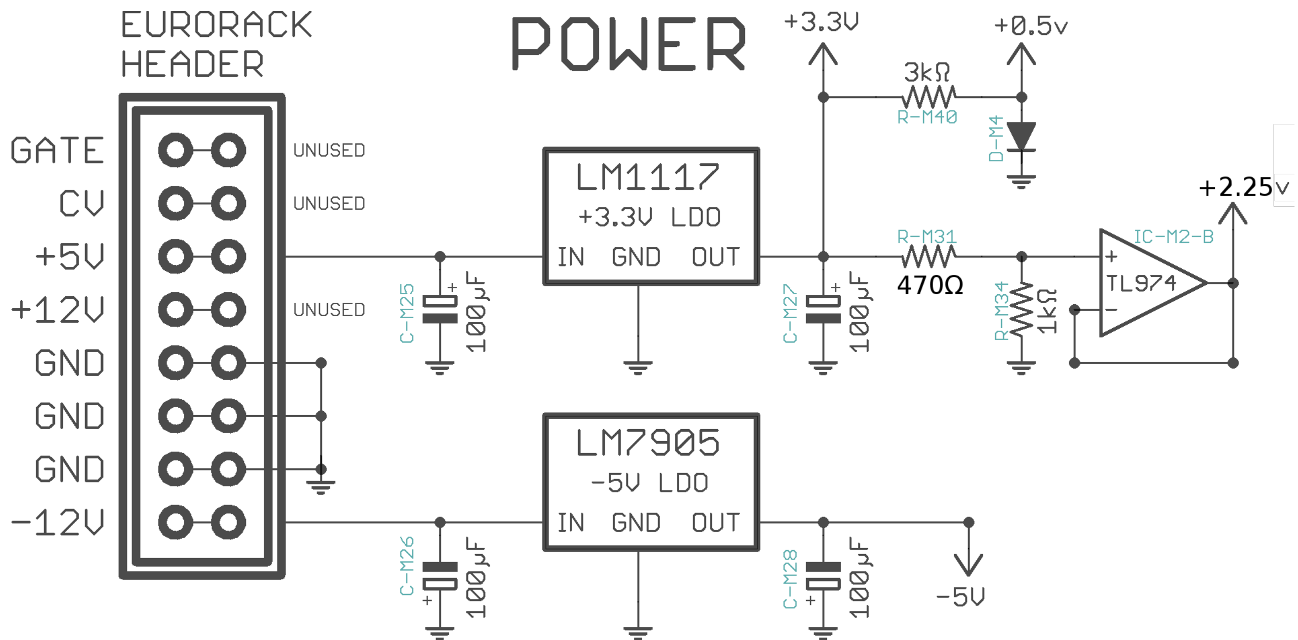
Connect an external video signal. You should still be able to produce screens of solid colour. The Alpha fold knob should be able to shift between the synthesized solid colours and the external video. Alpha symmetry needs to be adjusted if you can't go very far in one direction.

Test out each of the function generators by running them to the HSV inputs, try the different modes and waveforms. Once you are satisfied all circuits are working properly, finish things up with the small screws and potentiometer knobs. Knobs may be loose and require glue to stay on securely.



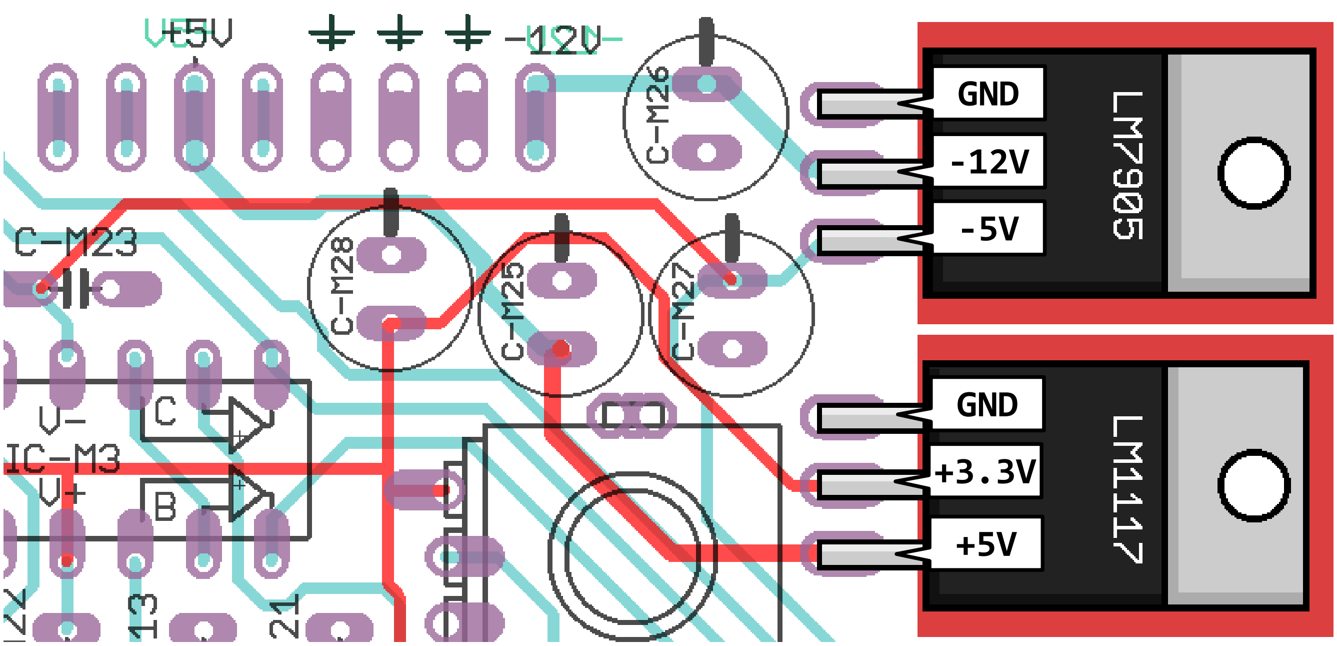
Deep technical information

The following sections explain how Mainbow's circuits work in detail. This is intended to help debug assembly problems, and for those interested in how Mainbow works.



Power Regulator PCB

This image is from the component side (top) of the PCB. Eurorack header is mirrored on the back side.



Power Regulator Notes

- Not all Eurorack power supplies have +5v output. Check this if Mainbow isn't working.

- Power regulators get hot. That's normal.

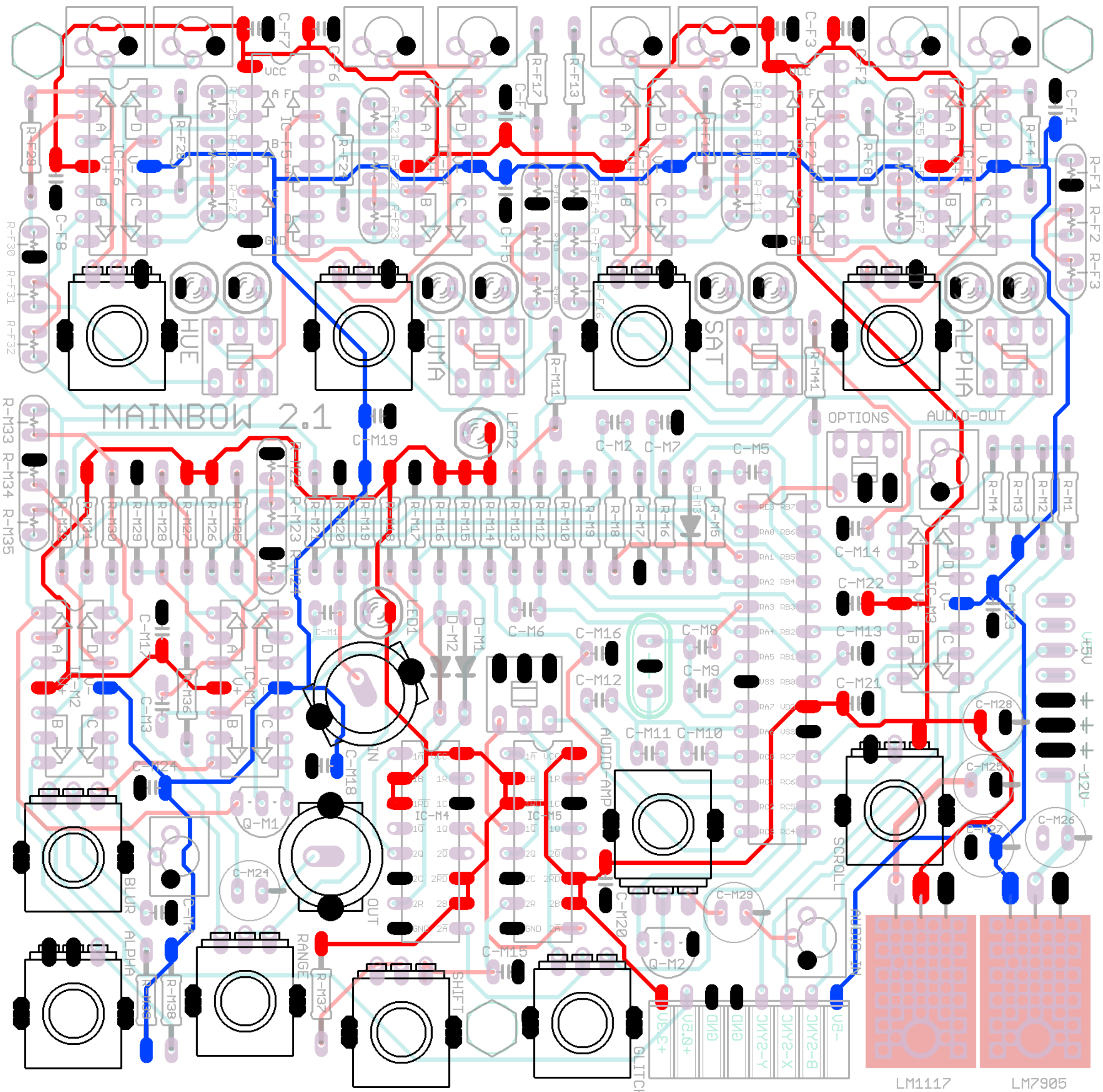
- Power regulators have overcurrent protection and will shut down if their outputs are shorted. Your Eurorack power supply may detect the short and shut down first.

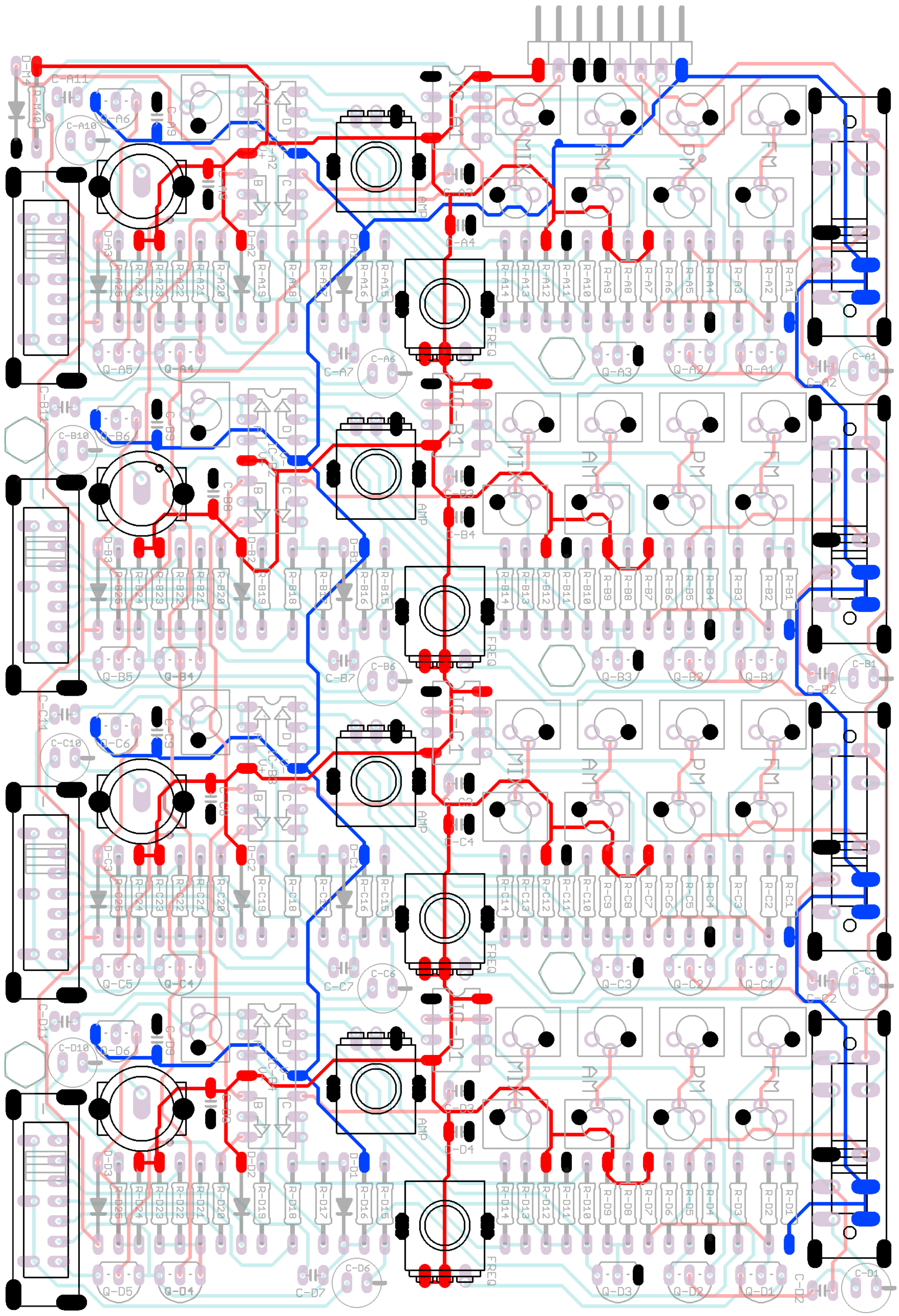
- Putting a TL974 in backwards will break it in a way that shorts the power supply after being re-inserted correctly.

PCB (Power Rails Highlighted)

This PCB image highlights the power rails. Use it to debug power issues such as a component not properly soldered to the ground plain.

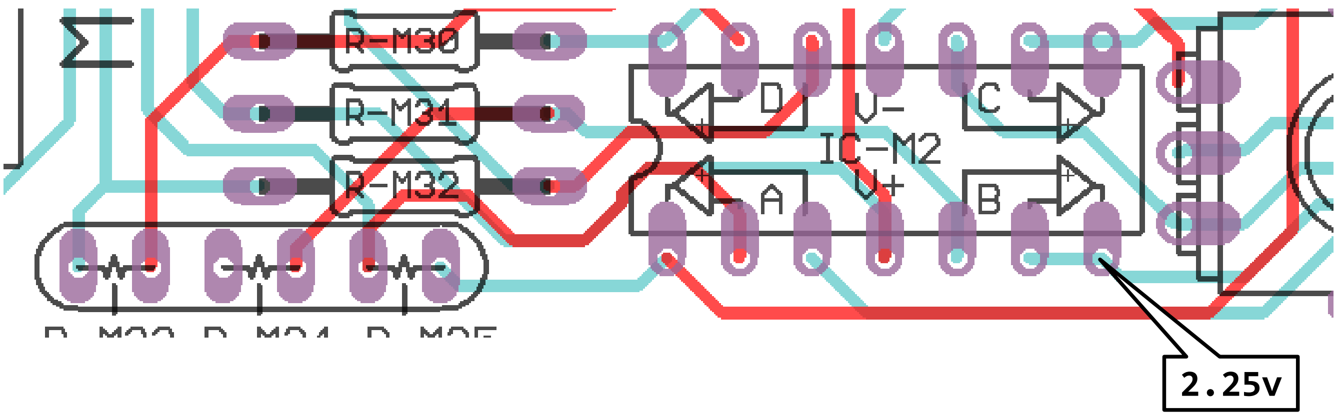
+3.3v GND -5v

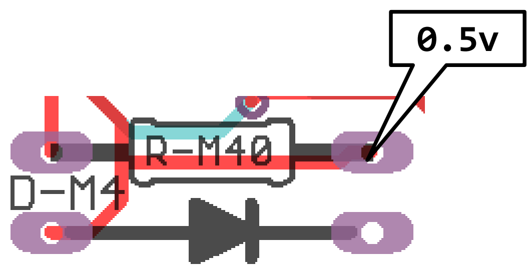



MIX
AM
PM
FM
FREQ
AMP

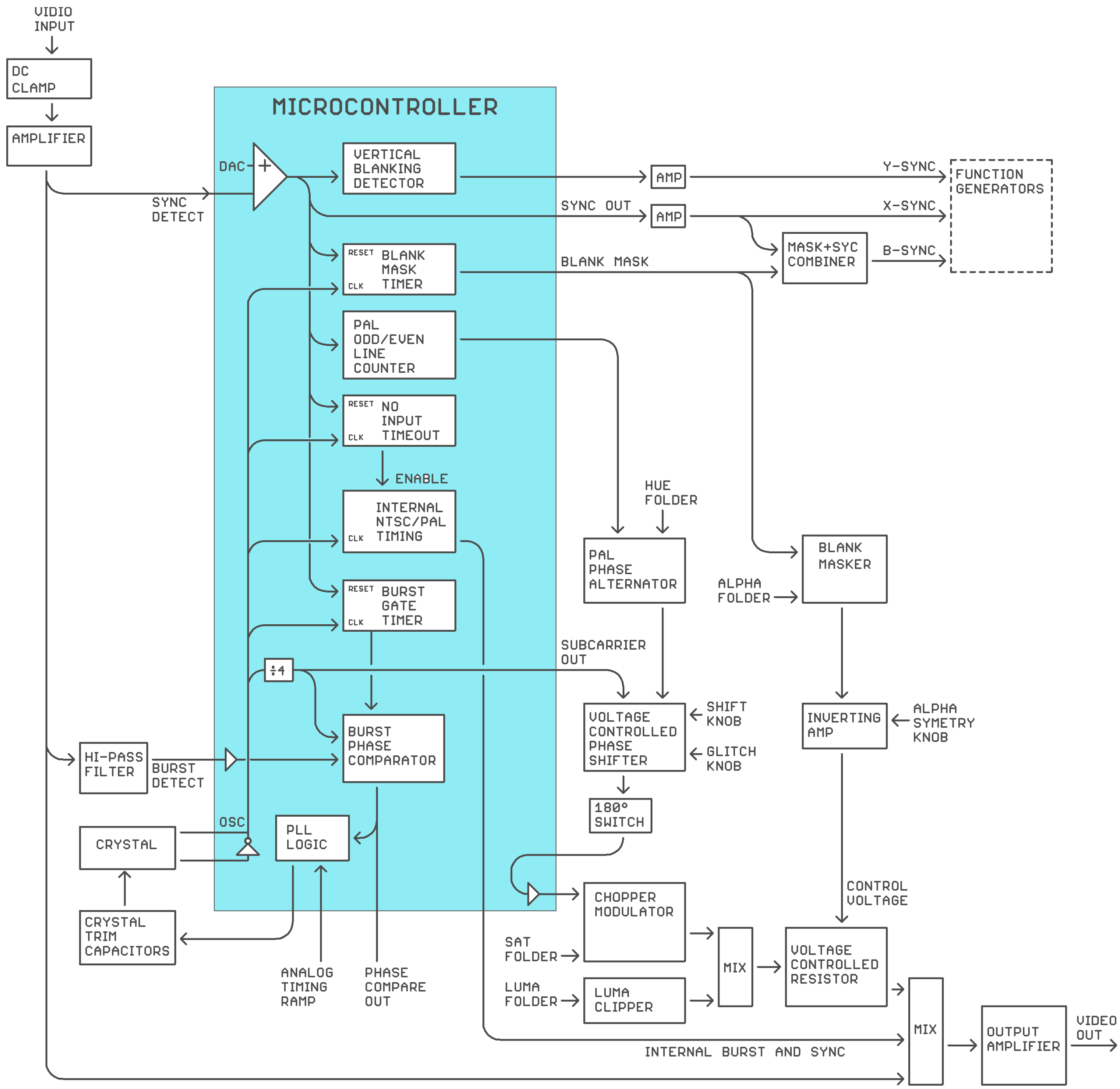
Voltage references

The function generators need two voltage references. They are produced once and shared among all four function generators. The 0.5V reference sets the symmetry of triangle, log, and sine waveforms. The 2.25V reference effects the shape of log and sin waveforms.

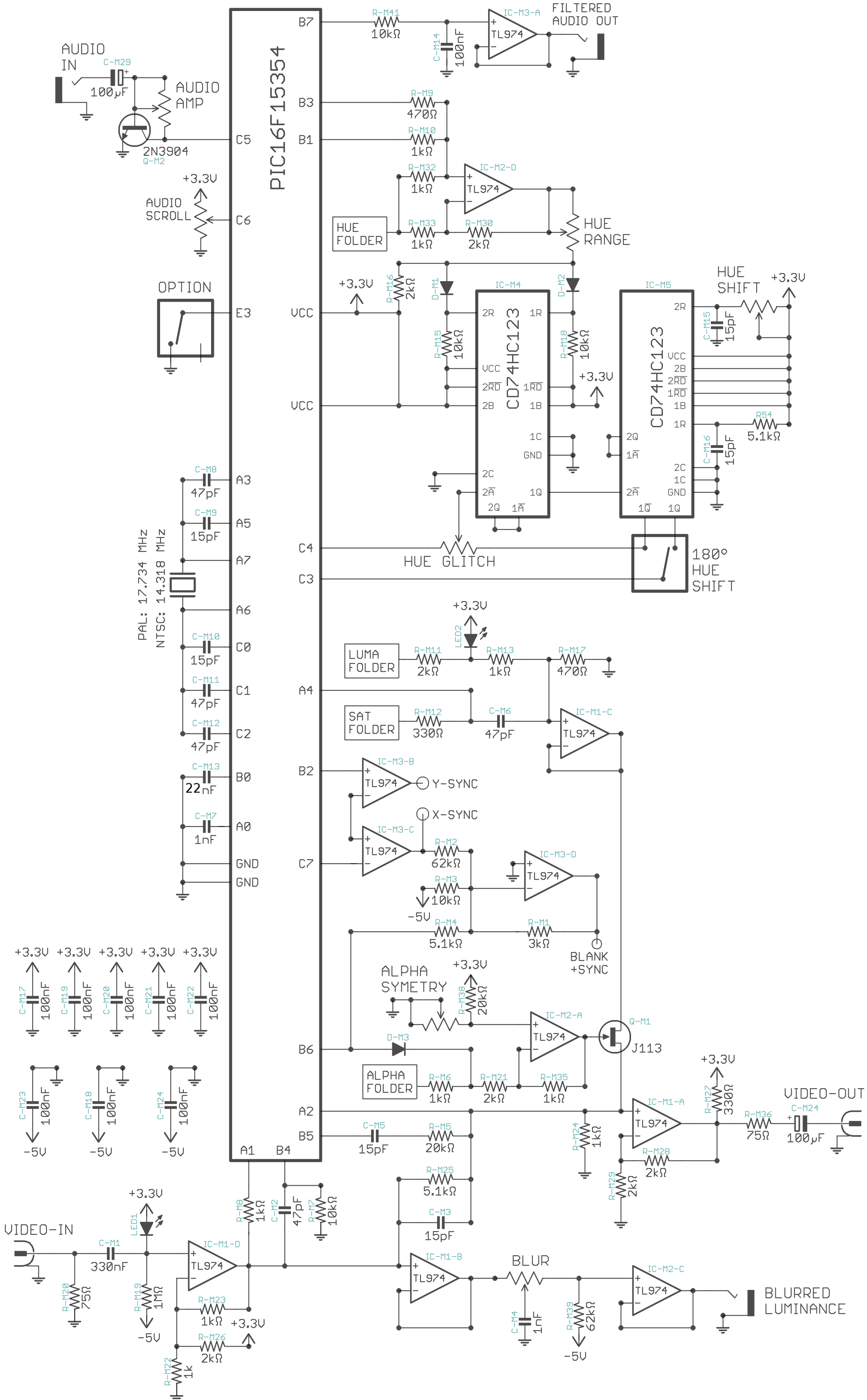




Video Encoder, Synchronizer, Mixer Block Diagram

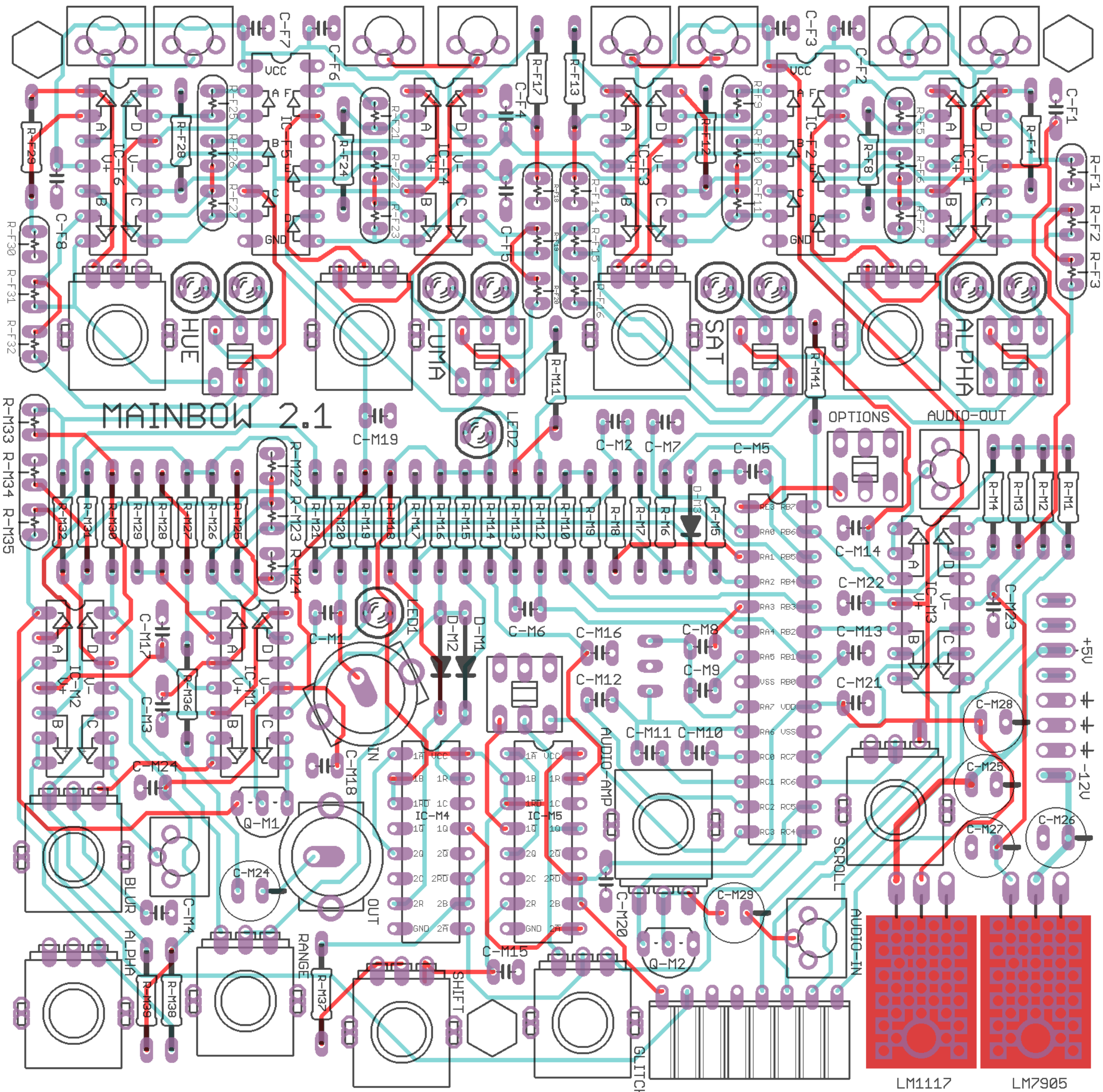


Video Encoder, Synchronizer, Mixer Schematic

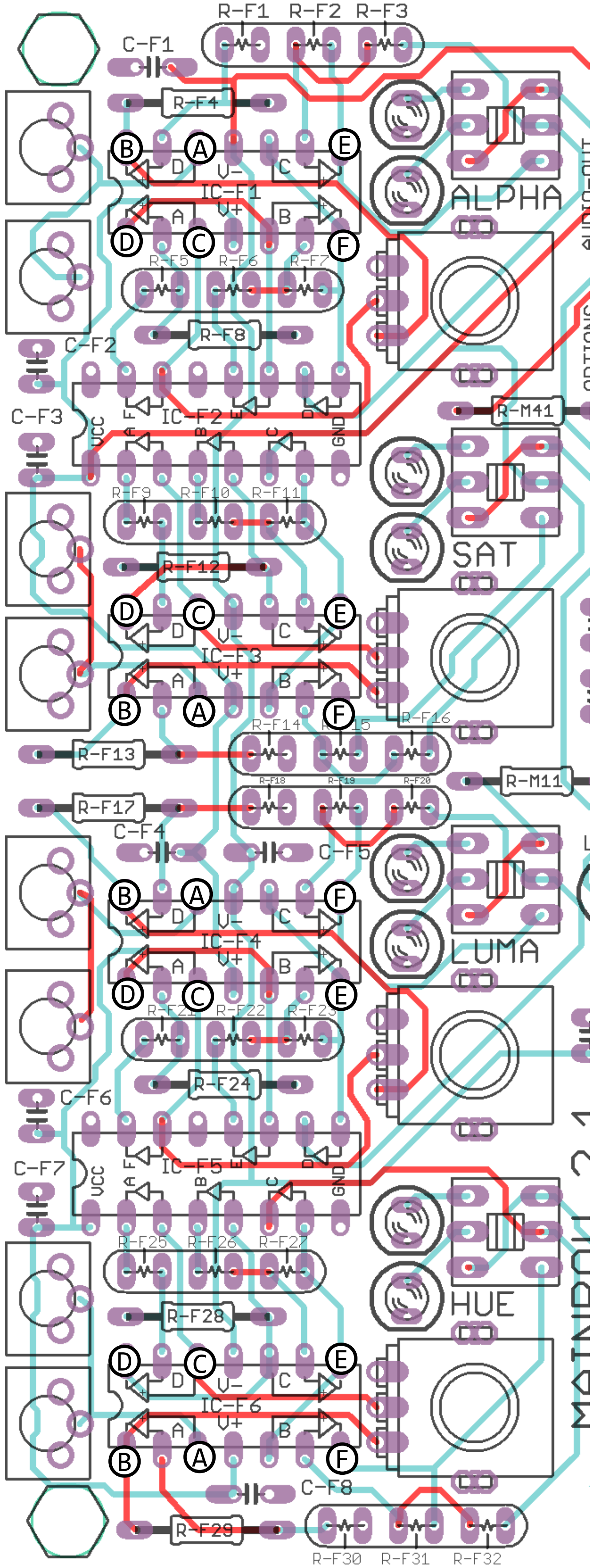


Video Encoder, Synchronizer, Mixer PCB (Names and Traces)

This PCB image names the components so they can be identified on the schematic.



Wave Folders



Mainbow's wave folders consist of an amplification stage, a potentiometer division stage, and three folding stages. A folding stage implements the following code in analog circuitry:

```
float Fold (float input){
   if(input > 1.5v)
      return (input - 1.5v) * 2;
   else
     return input *2;
}
```

The three folding stages perform this recursively. IE
output = Fold(Fold(Fold(input)));

The multiplication and subtraction are accomplished with an op-amp. The *if(input > 1.5v)* logic is accomplished with a CD74HC4050 buffer gate.

All four wave folders use the same circuit. The output of each stage is labelled to the left. The next page shows oscilloscope measurements taken from each stage.

A) Input from 3.5mm jacks.

B) Amplification by a factor of 4.

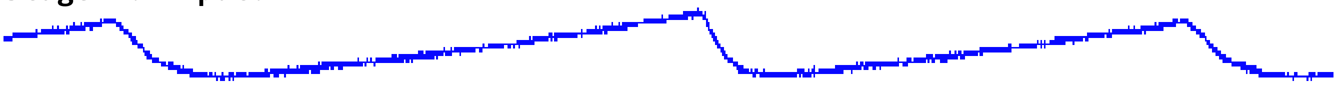
C) Potentiometer division.

D) First Wave fold.

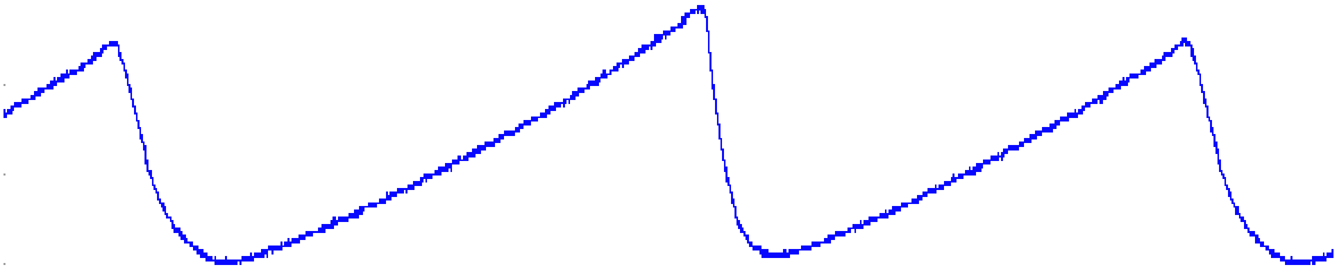
E) Second Wave fold.

F) Third Wave fold. Final output.

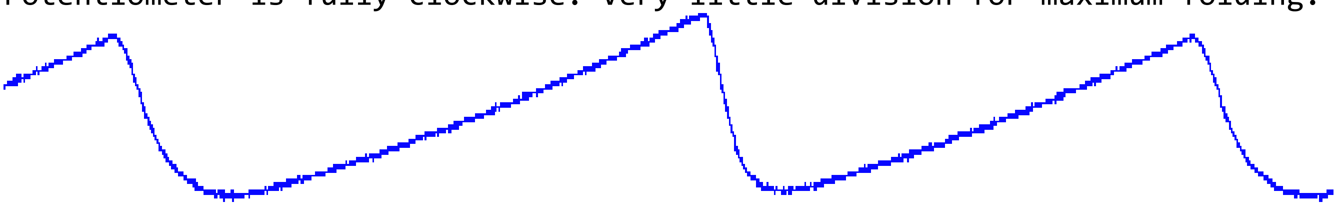
Stage A. Input.



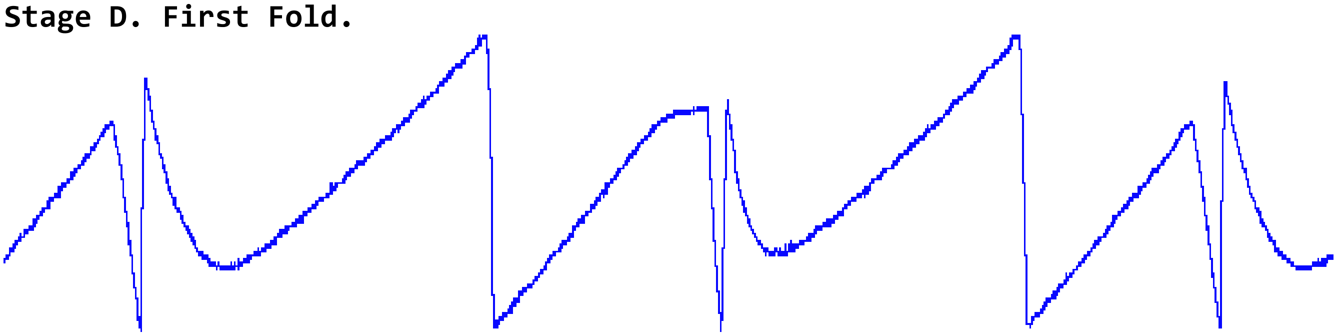
Stage B. Amplification.



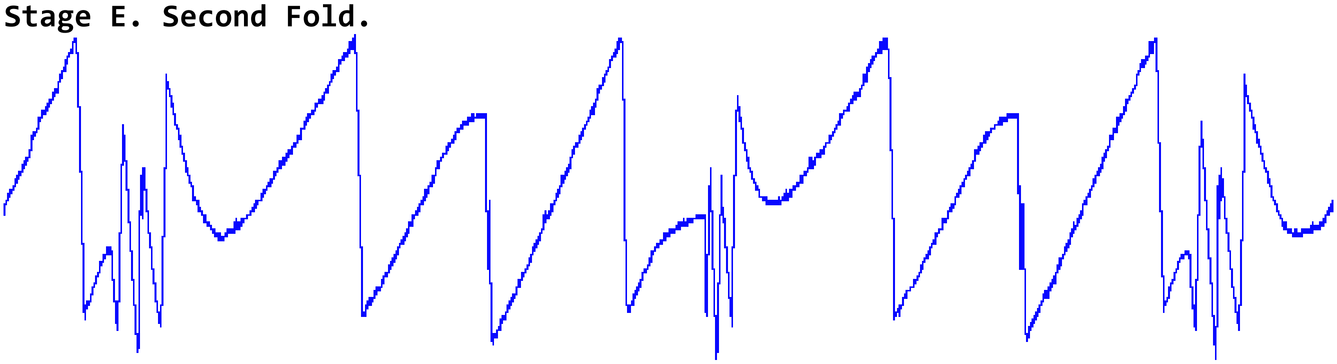
Stage C. Division.
Potentiometer is fully clockwise. Very little division for maximum folding.



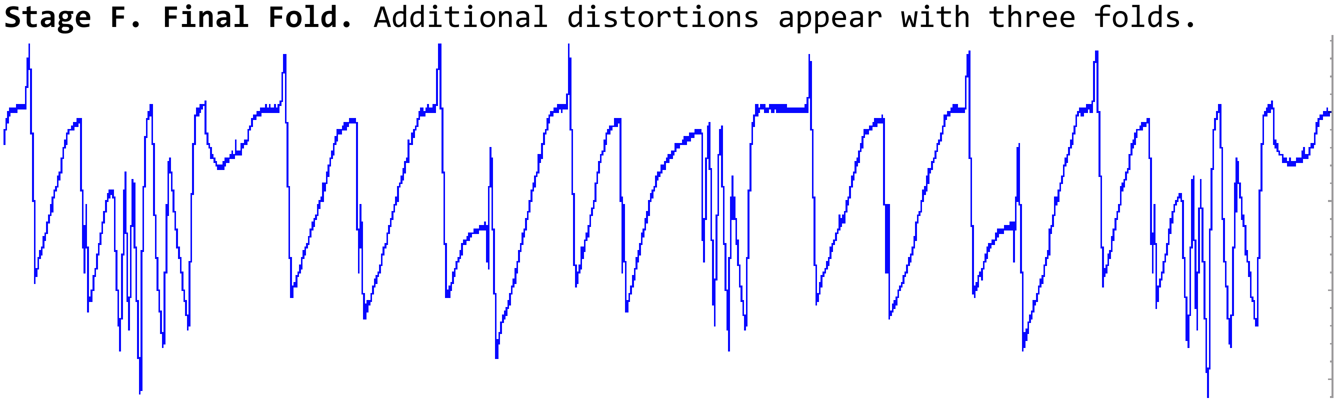
Stage D. First Fold.



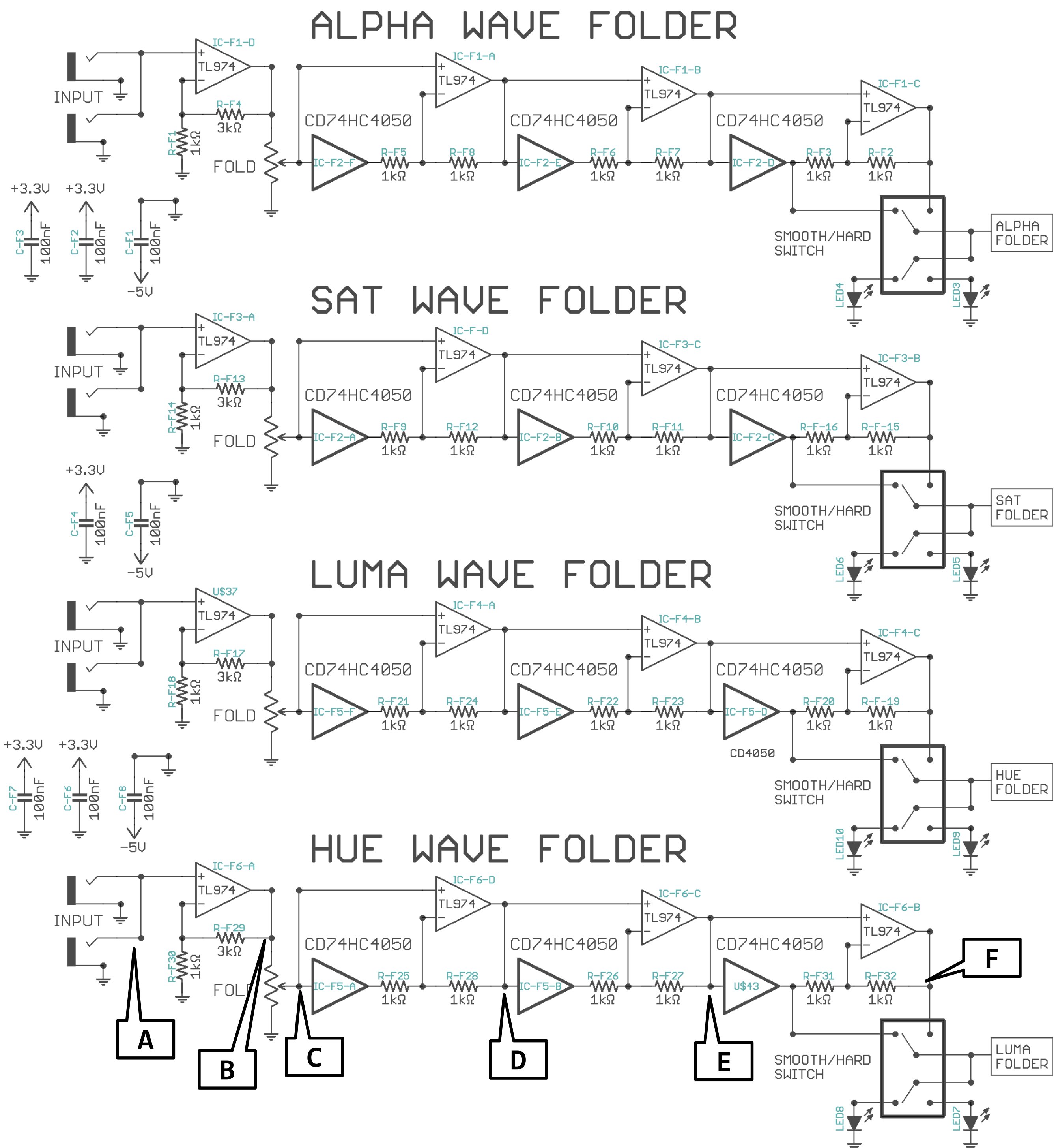
Stage E. Second Fold.



Stage F. Final Fold. Additional distortions appear with three folds.

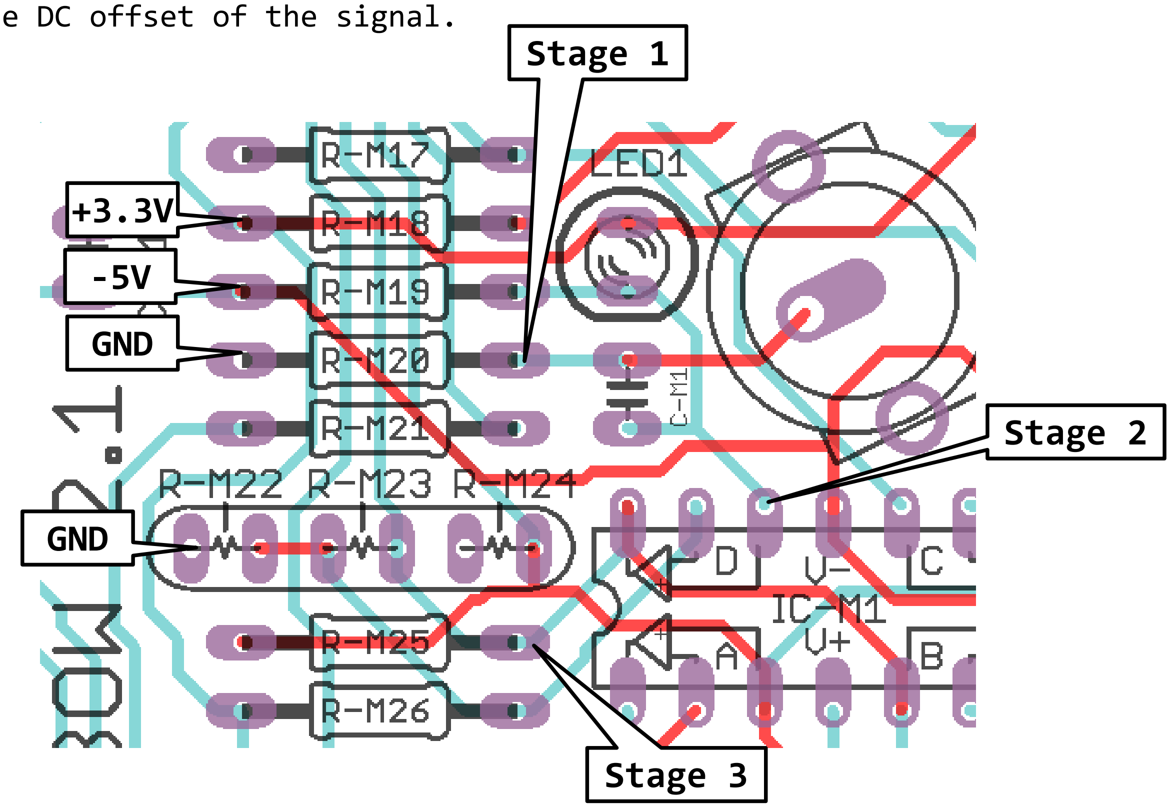


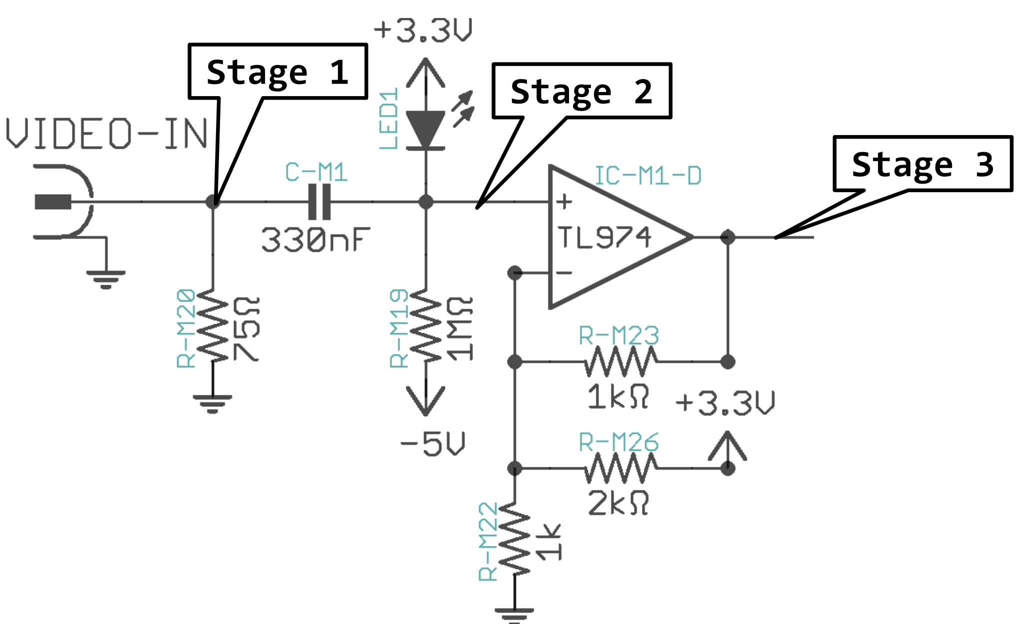
Wave Folder Schematics



Video Input Amplifier

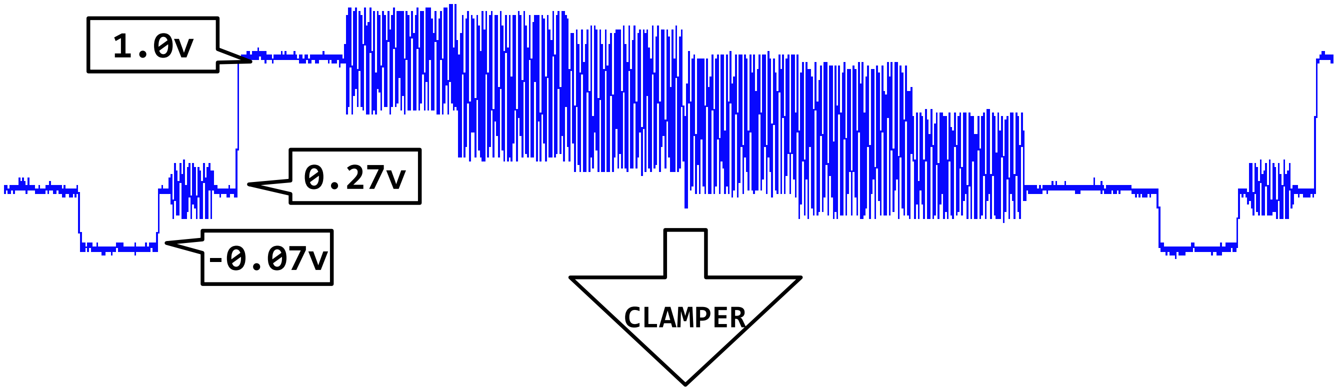
Mainbow will not synchronize or mix with an external video signal if this circuit is not working. This circuit also sets the black level voltage when Mainbow is generating its own internal video signal. Stage 1 is the video signal direct from the RCA jack using R-M20 as a pulldown terminating resistor. Stage 2 DC couples the video signal using C-M1, LED1, and R-M19 to form a clamper. LED1 serves as a 3v zener diode. Stage 3 amplifies and shifts the DC offset of the signal.





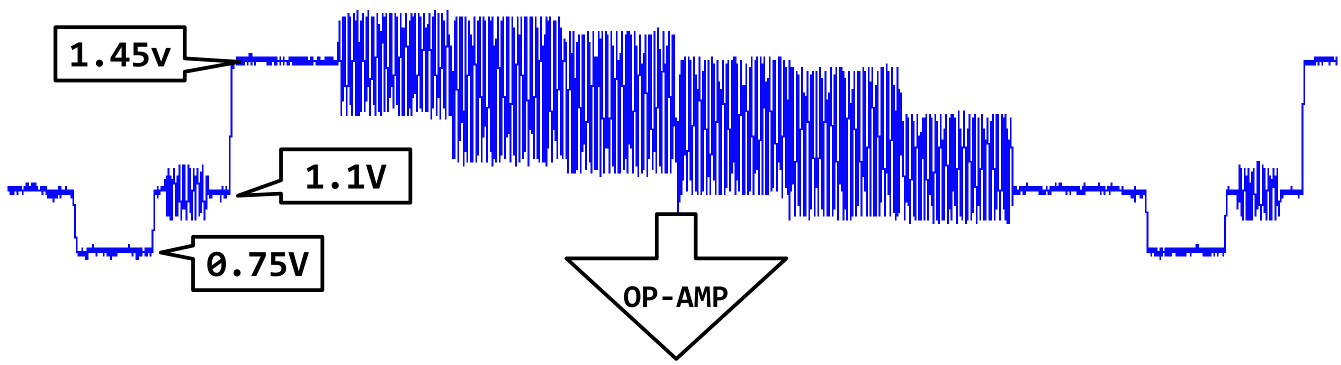
STAGE 1

This stage is AC coupled. Voltages will drift with changes in video luminance.

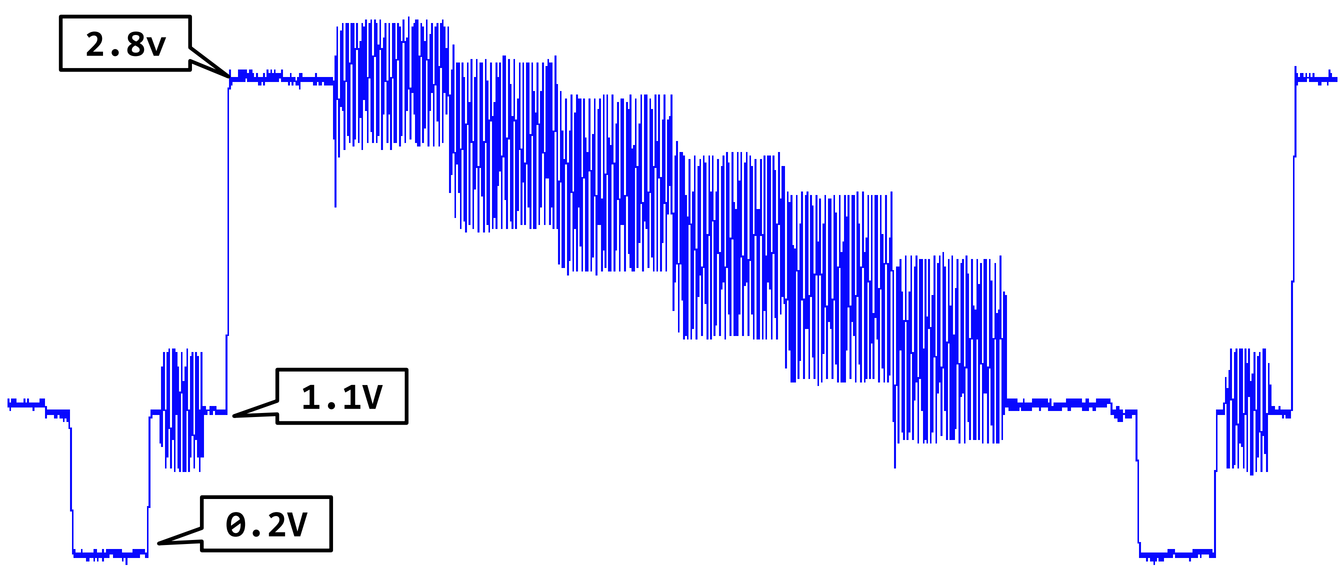


STAGE 2

Sync and blank voltage levels should now be constant.



STAGE 3

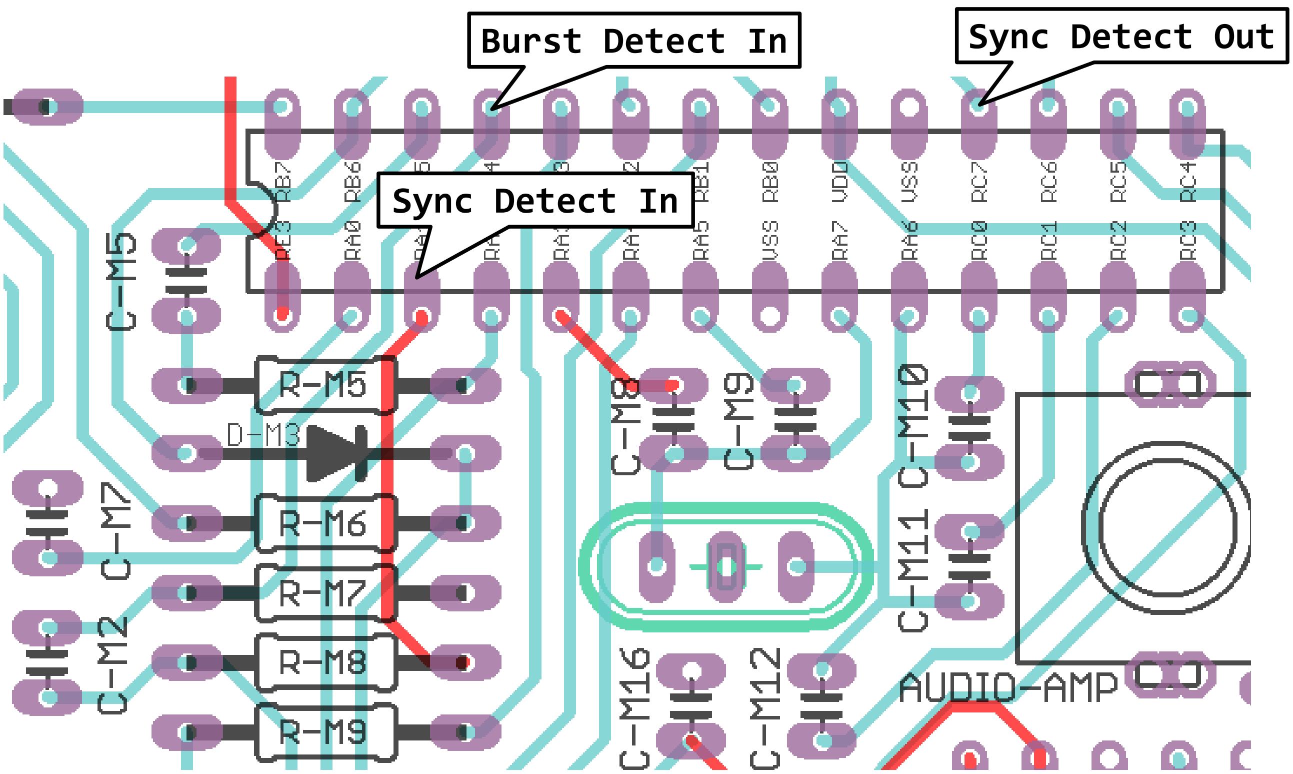


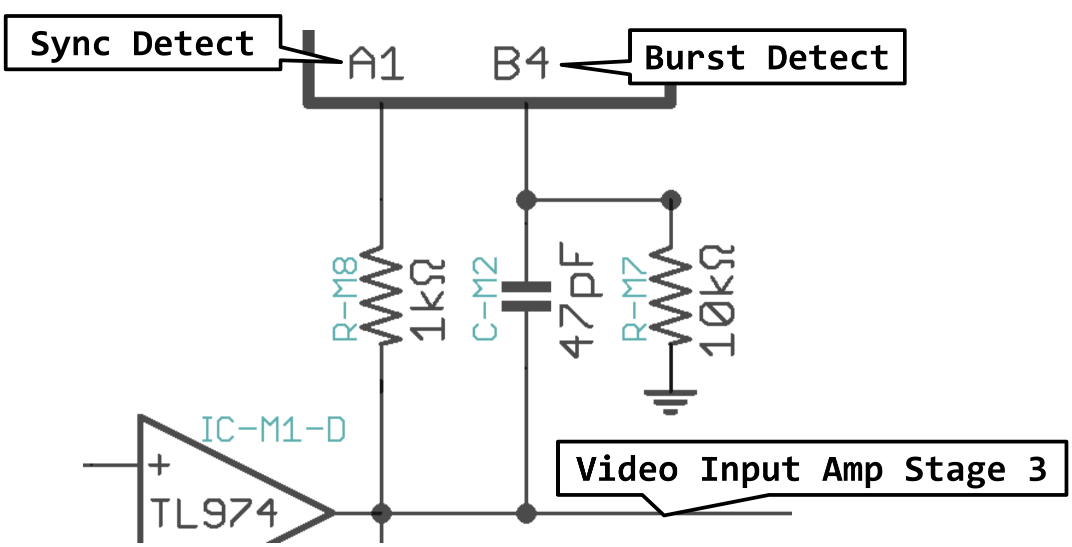
Sync and Burst Detect

The microcontroller detects sync pulses through pin 3 (A1). The signal at this pin should be almost exactly the same as the final stage of video input amplifier. R-M8 protects this pin from damaging negative voltages which can occur if the video input amplifier is soldered incorrectly.

Sync detection can be verified by checking microcontroller pin 18 (RC7).

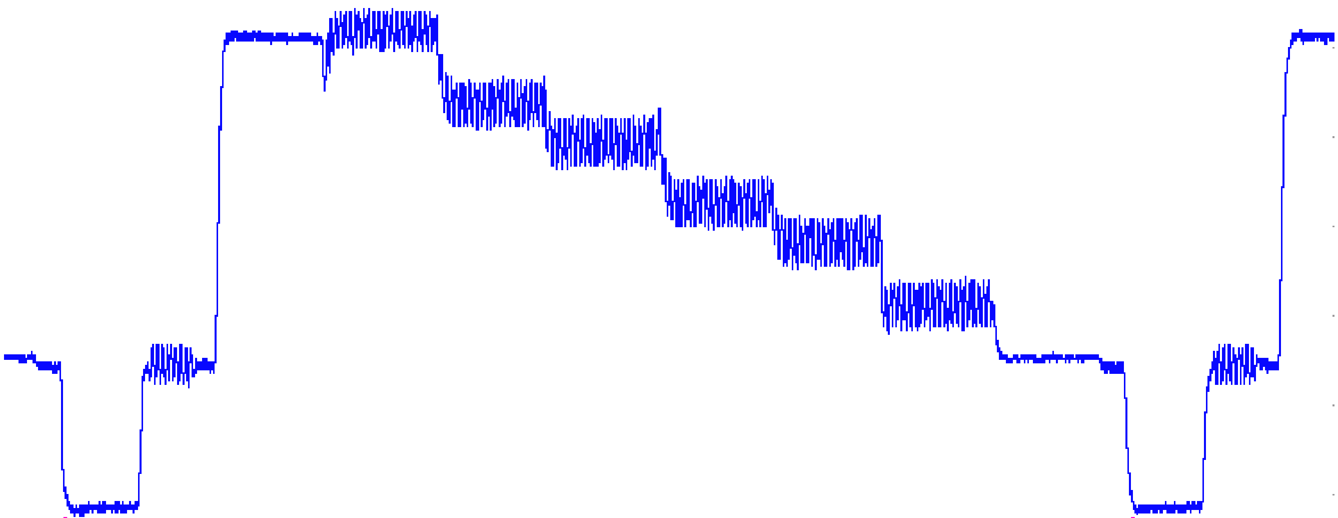
C-M2 and R-M7 form a high pass filter used to detect colour burst. Genlock will fail if this isn't working.



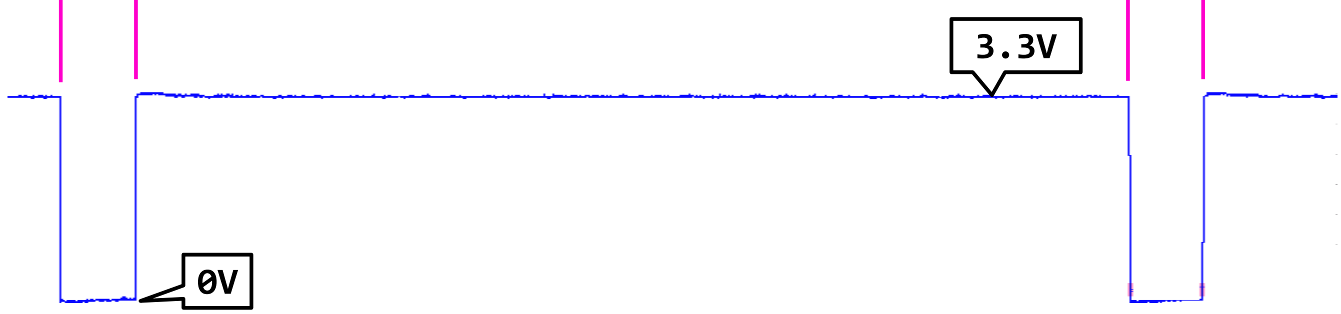


Sync Detect In

This measurement was taken with a 20pf oscilloscope probe. That's why burst and subcarrier levels are reduced.

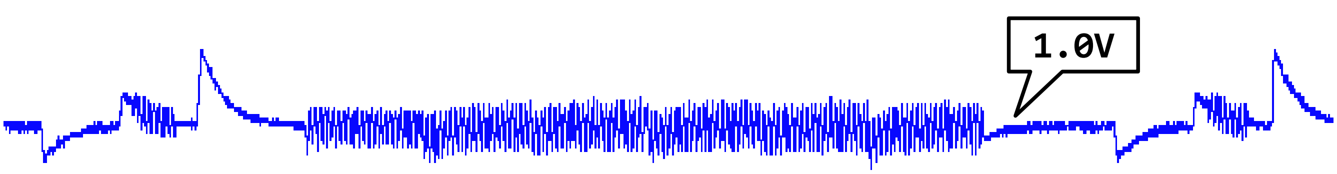


Sync Detect Out



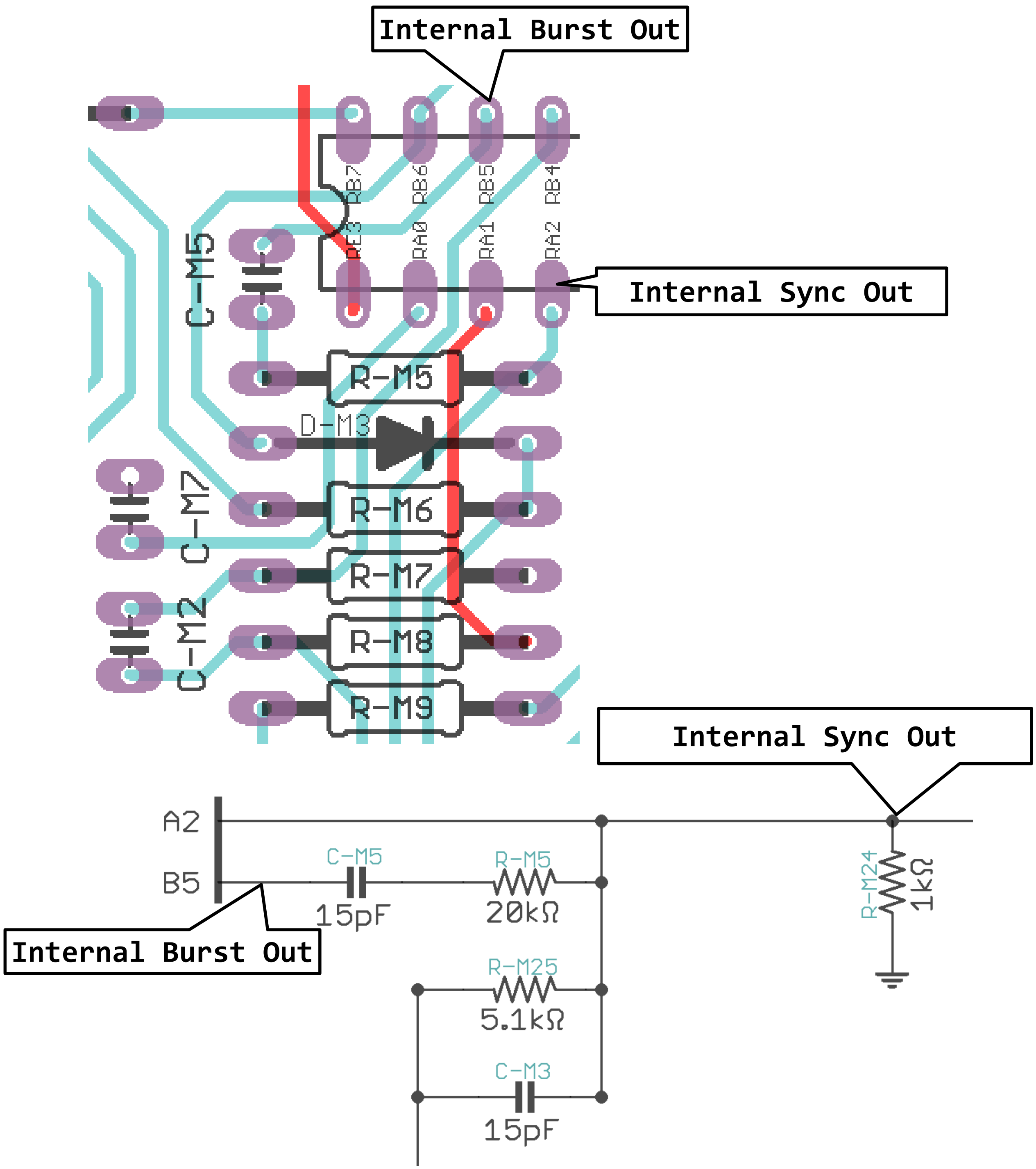
Burst Detect Input

The 20pF scope probe cuts down on the burst amplitude a lot. It is much greater in reality. The high-pass filter should centre the signal around 1.0V .

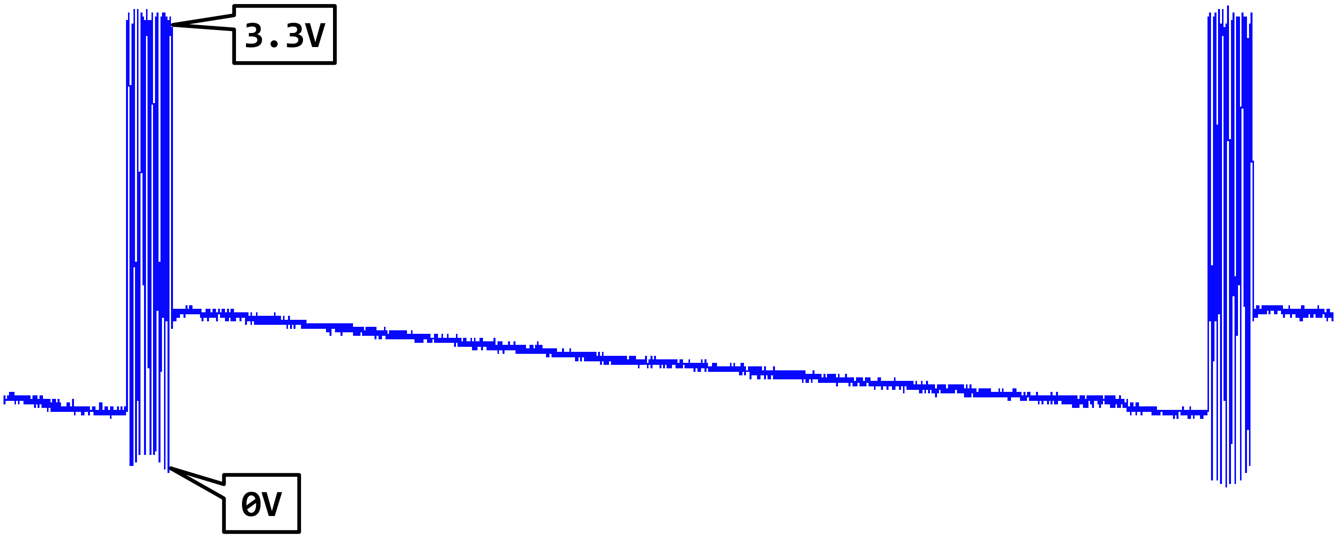


Internal Burst and Sync Generation

<u>To perform this test do not connect an external video signal</u>. Mainbow will begin to produce sync pulses through pin 4 (A2). Scoping this pin will also show the internally generated colour burst and video data. The colour-burst is produced by pin 26 (RB5) using C-M5 to AC couple it and R-M5 to reduce amplitude. Pin RB5 is in a Tri-State configuration and goes to Hi-Z outside of burst period. R-M24 is necessary for correct sync levels in both external and internal modes.

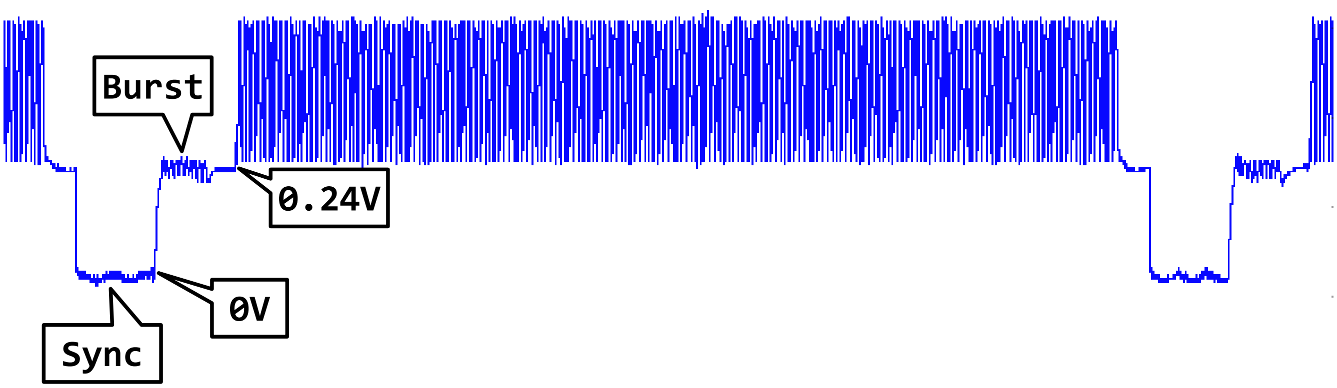


Internal Burst Out



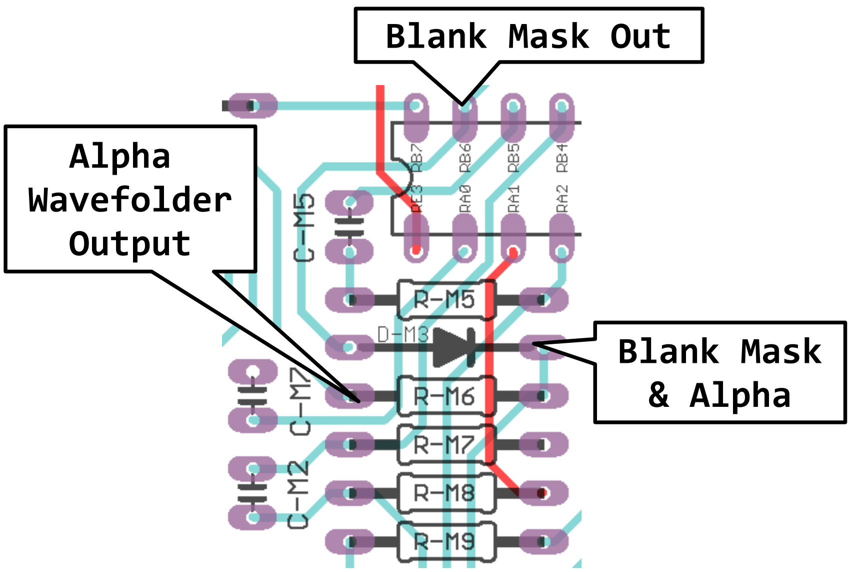
Internal Sync Out

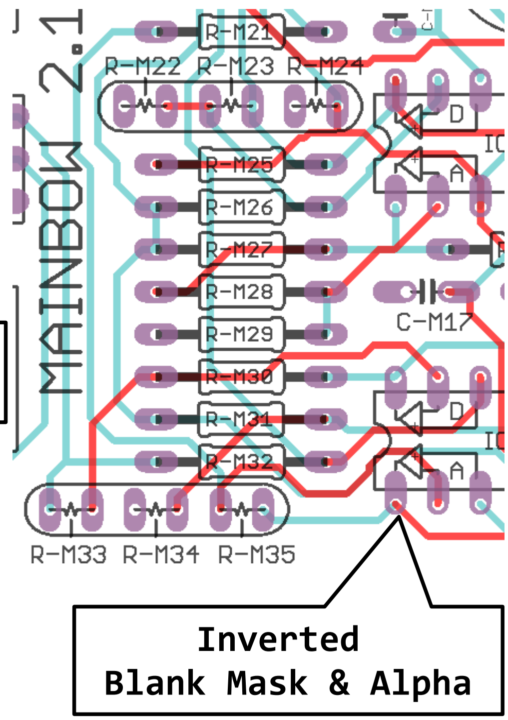
Colour-burst and video data are also present on this pin. The 20pF scope probe is causing a large drop in colour-burst and chroma subcarrier amplitude.

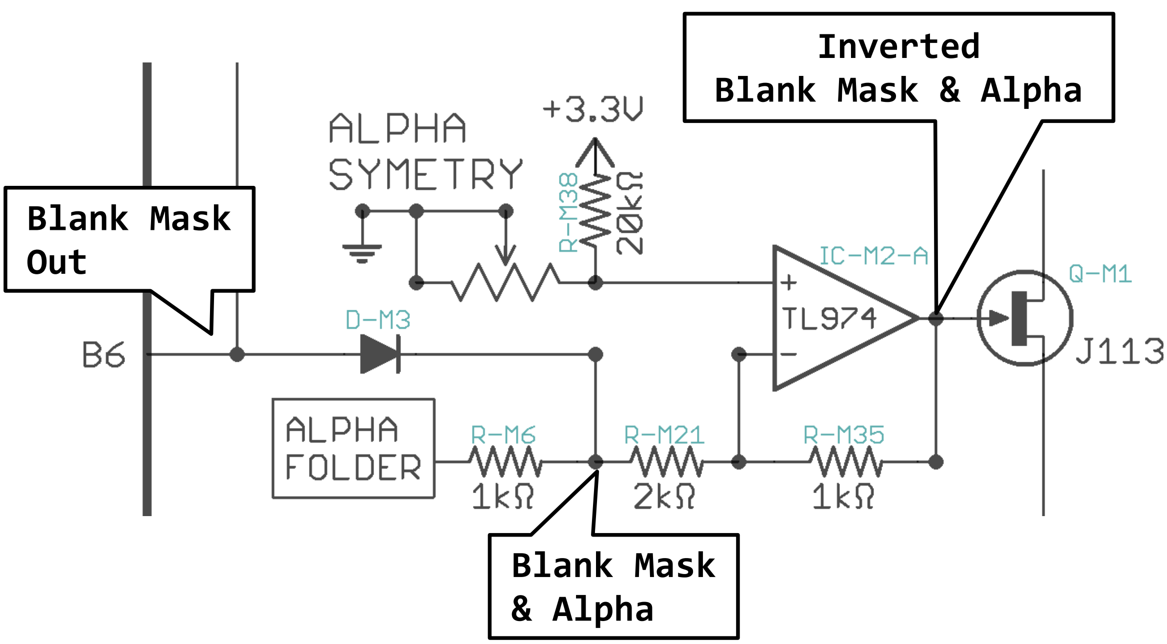


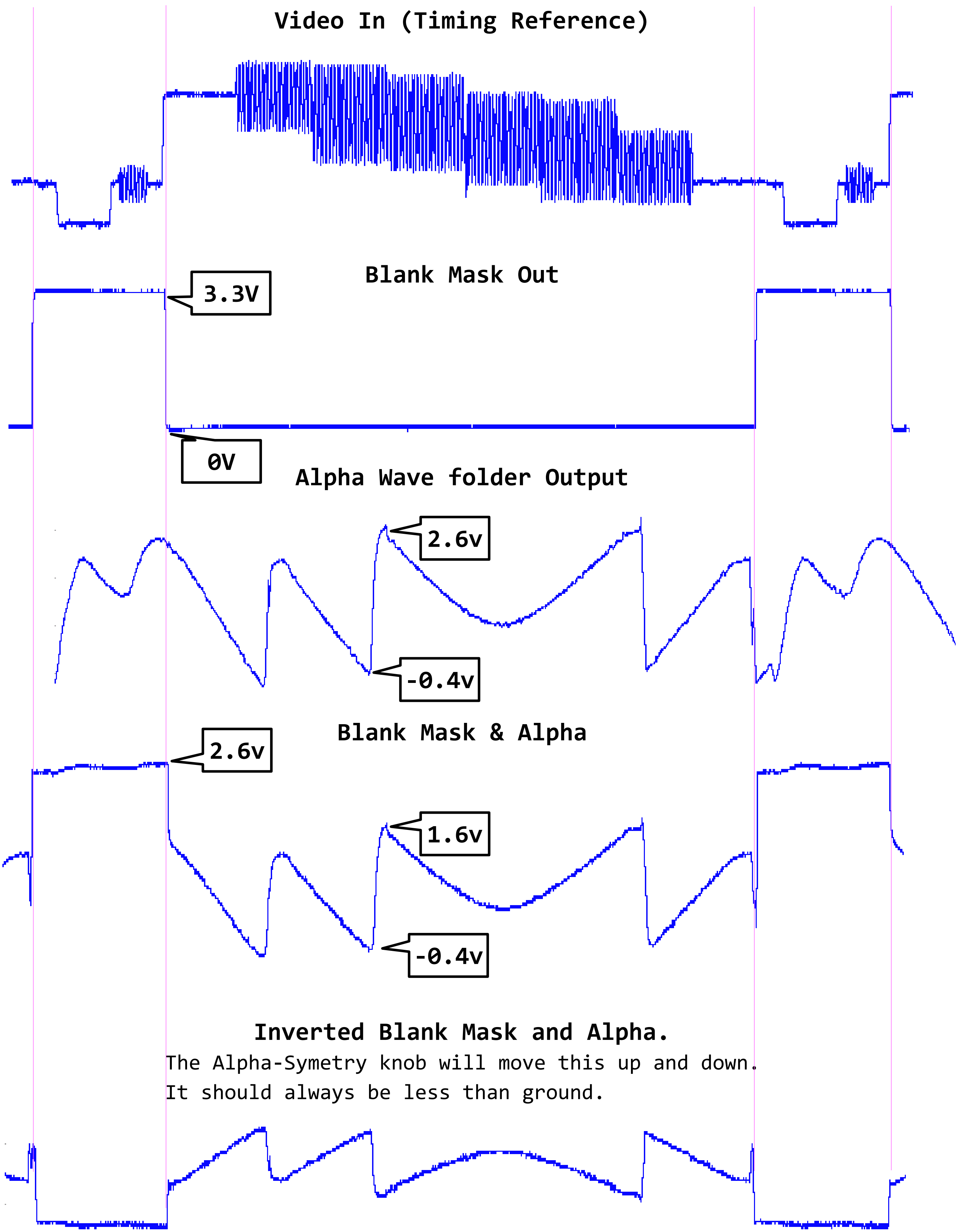
Blanking and Alpha Combiner

Mainbow prevents synthesized video from entering the video output during blanking intervals by controlling the transparency channel. During active video periods, transparency is controlled by the alpha wave folder. During blanking intervals this is overridden and taken to 100% transparency, blocking synthesized video from entering the video output. Microcontroller pin 27 (B6) is low during active video period and high during blanking period. D-M3 and R-M6 combines this with the output from the alpha wave folder.



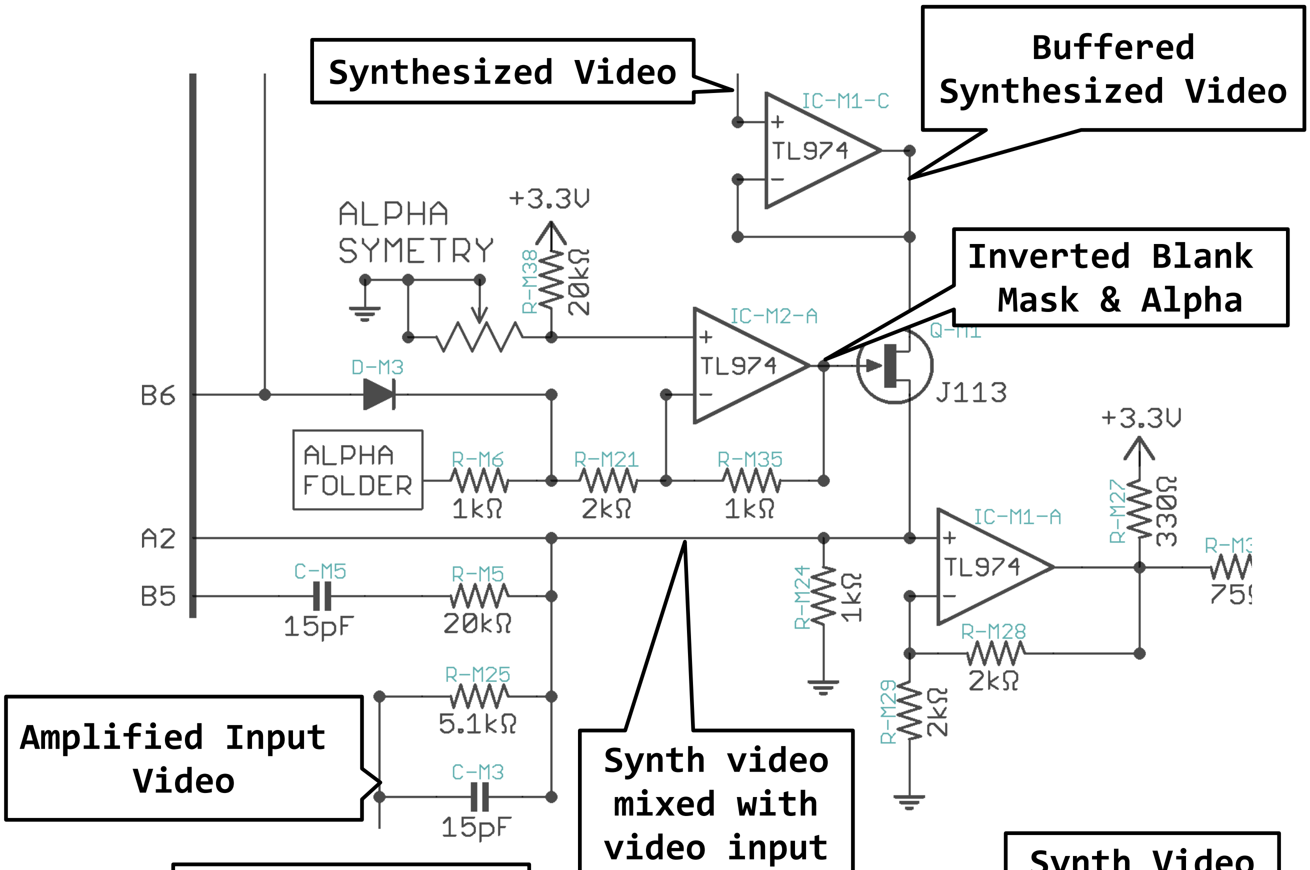


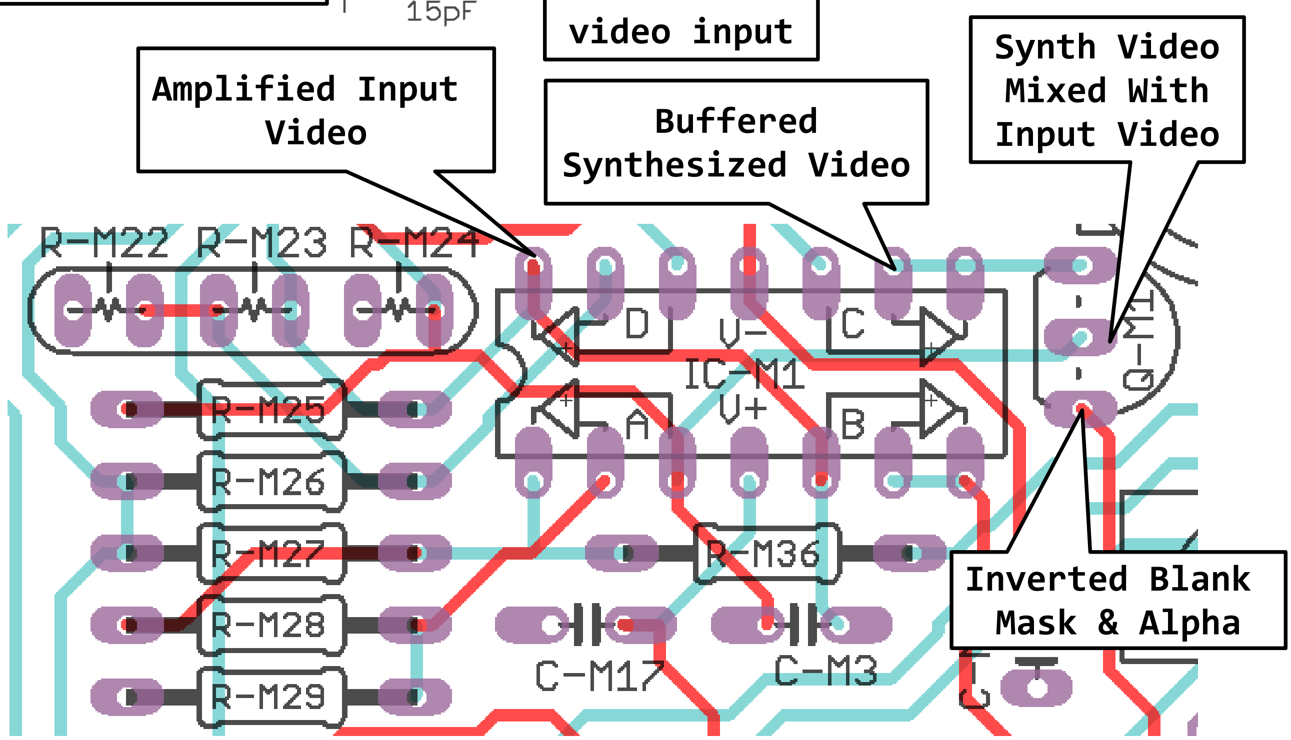



Video In (Timing Reference)
Blank Mask Out
3.3V
0V
Alpha Wave folder Output
2.6v
-0.4v
Blank Mask & Alpha
2.6v
1.6v
-0.4v
Inverted Blank Mask and Alpha.
The Alpha-Symetry knob will move this up and down.
It should always be less than ground.

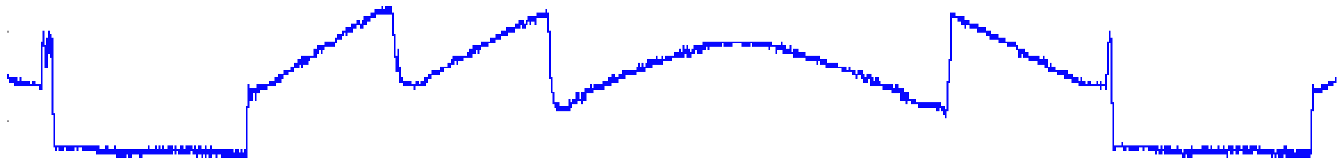
Voltage Controlled Video Mixer.

The inverted masked alpha channel is used to drive a J113 JFET. This acts as a voltage controlled resistor. It controls how much of the synthesized video mixes with the video input. It should completely block synthesized video during blanking intervals due to the blank mask.

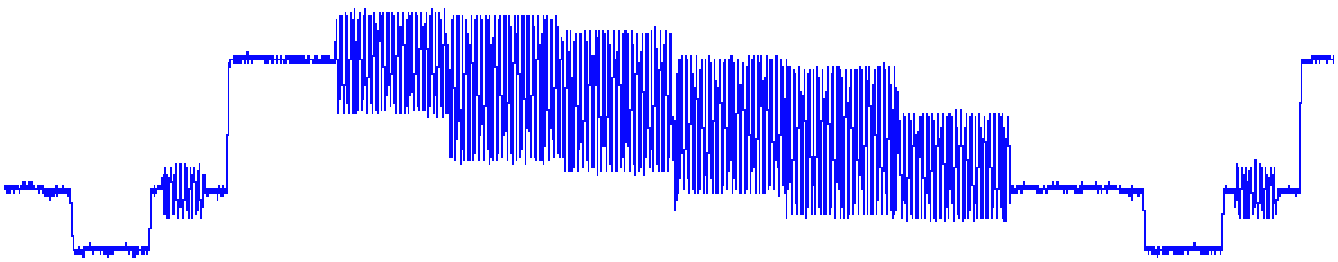




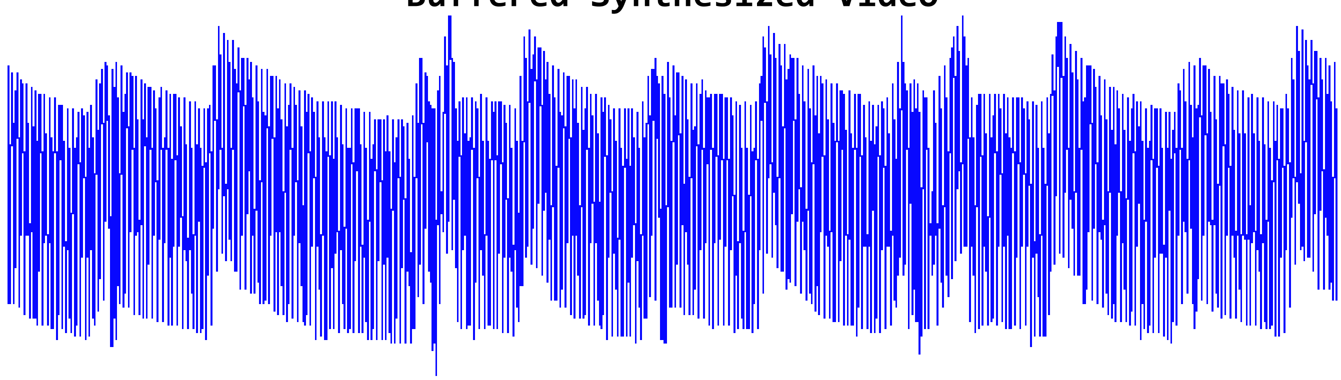
Inverted Blank Mask & Alpha.



Amplified Input Video

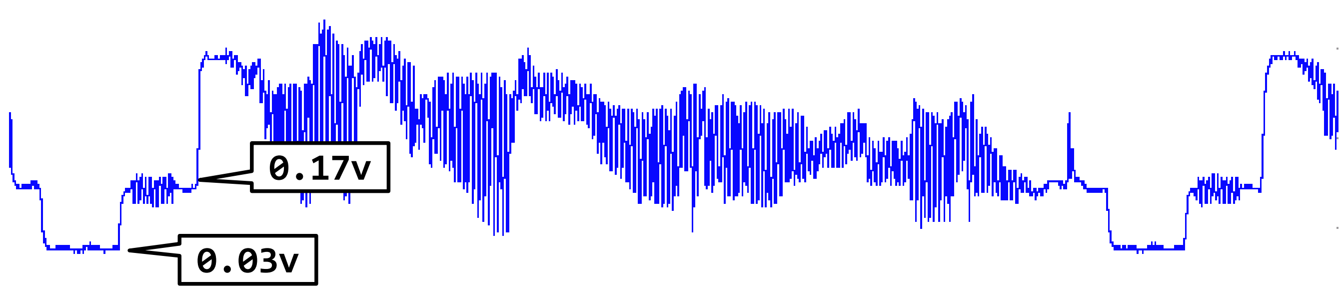


Buffered Synthesized Video



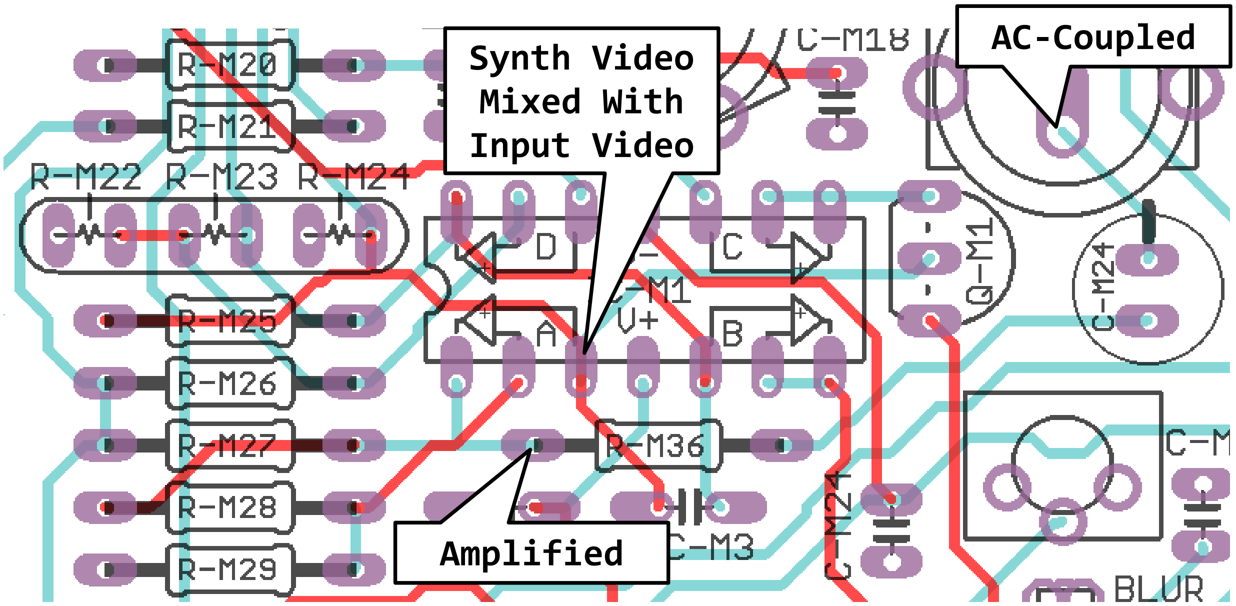
Synth Video Mixed With Input Video

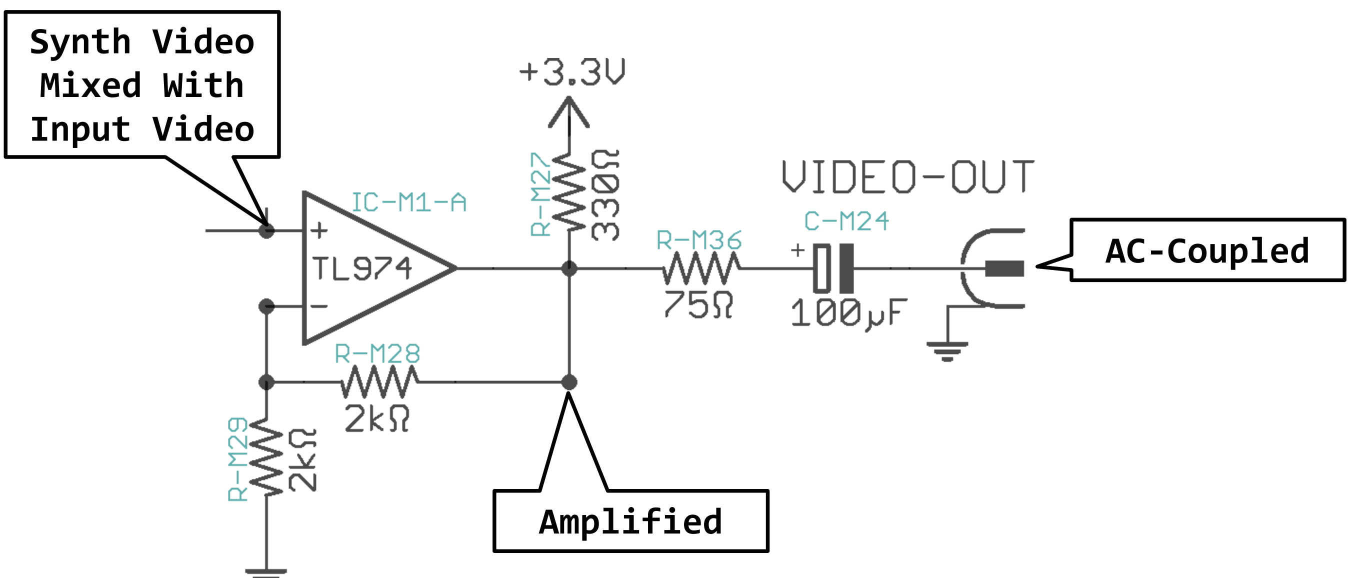
The 20pF oscilloscope probe is reducing the amplitude of colour-burst and chroma subcarrier.



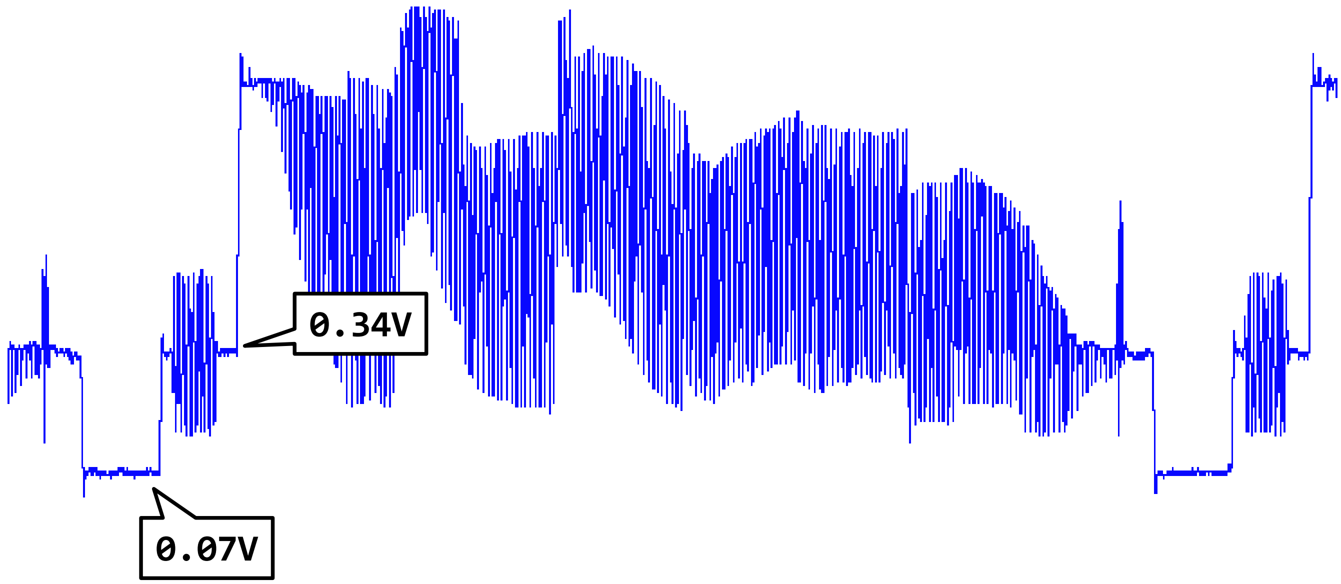
Video Output Amplifier.

This is the final output stage of the video synthesiser. It amplifies then AC couples the synthesized video mixed with the input video. R-M27 is an overdrive resistor. Very bright portions of the image will appear to clip and smear without it.



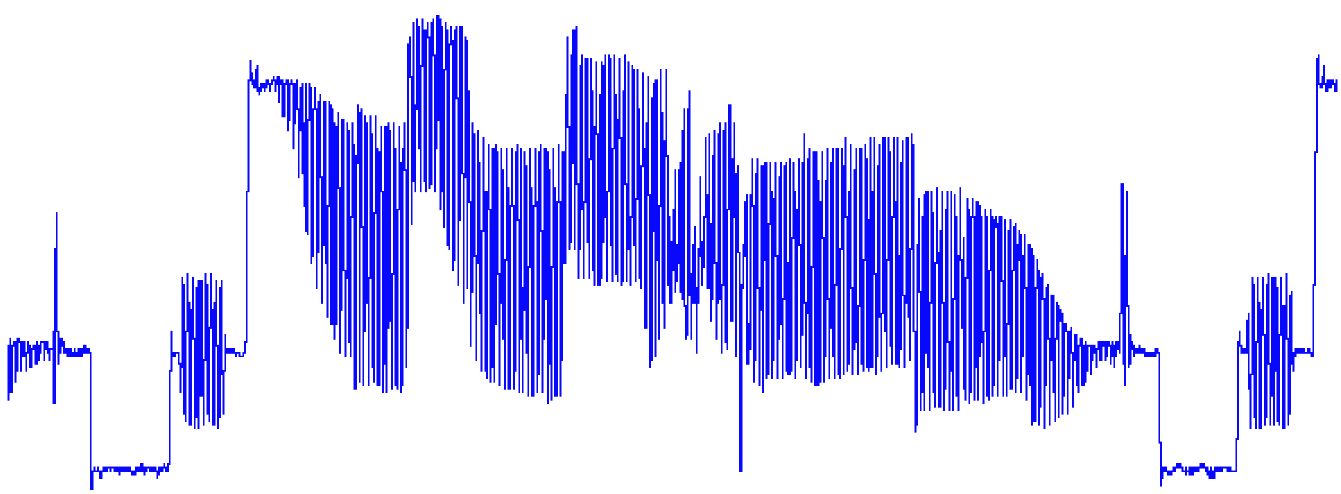


Amplified



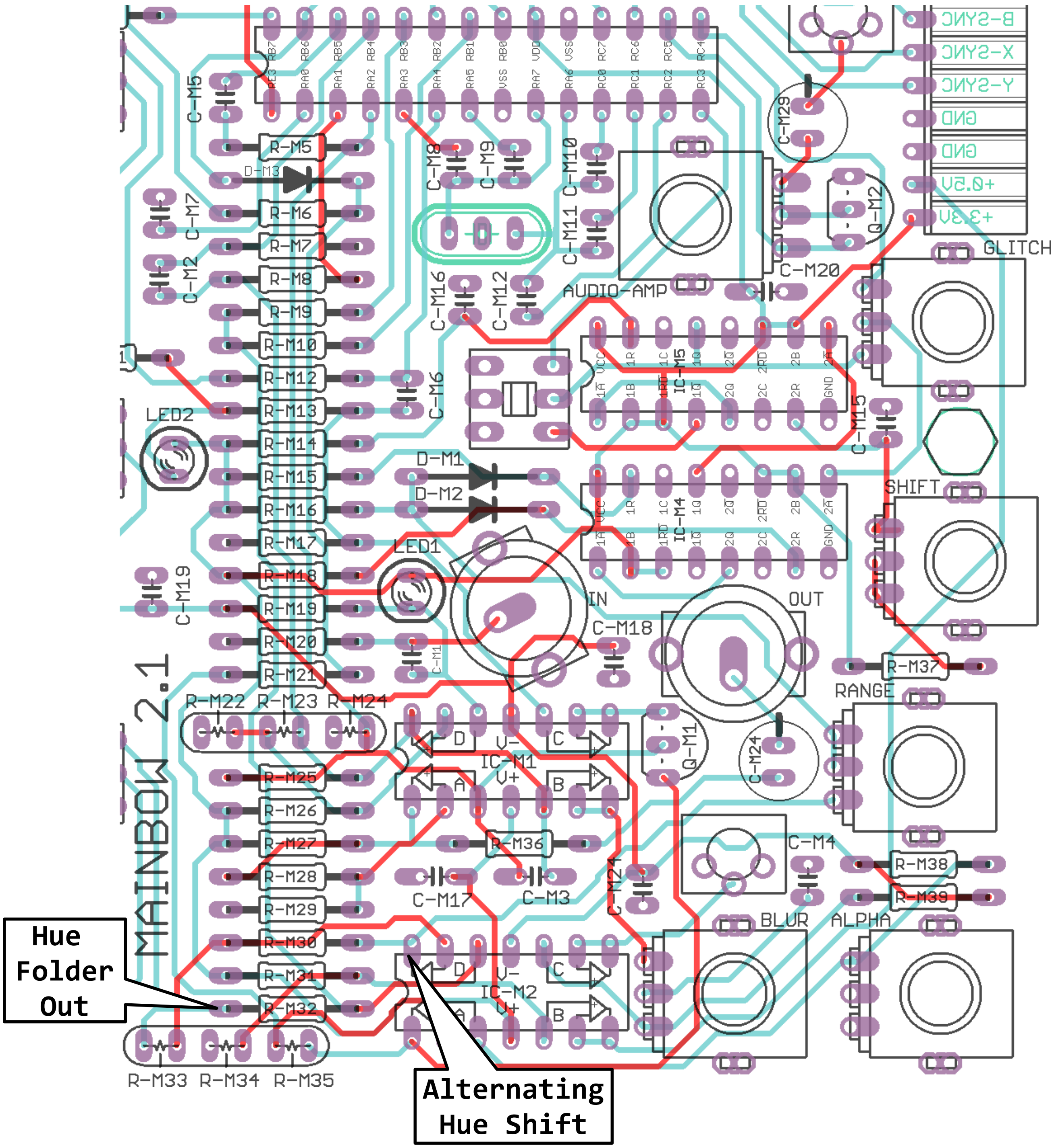
AC-Coupled.

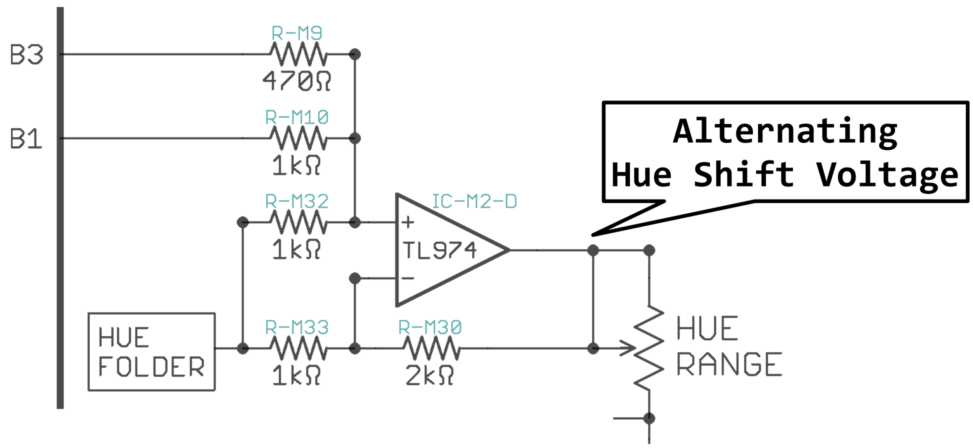
This was measured with nothing connected to the video output jack. That may reduce the amplitude.



PAL Alternator

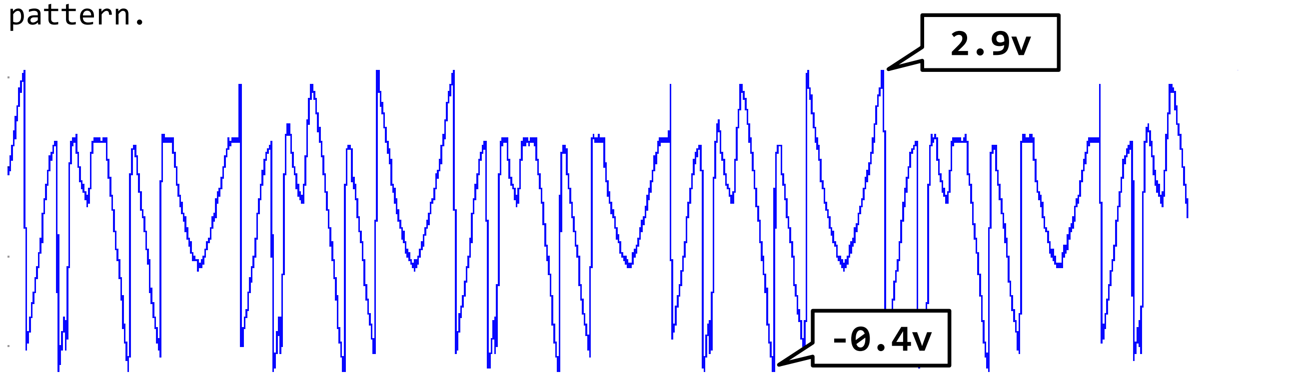
This circuit handles the colour subcarrier phase alternation required by PAL. It allows the Microcontroller to invert the output from the Hue Wave folder on alternating lines. This makes the voltage controlled hue phase shift rotate clockwise on odd lines and counter-clockwise on even lines. In NTSC there is no line phase alternation.



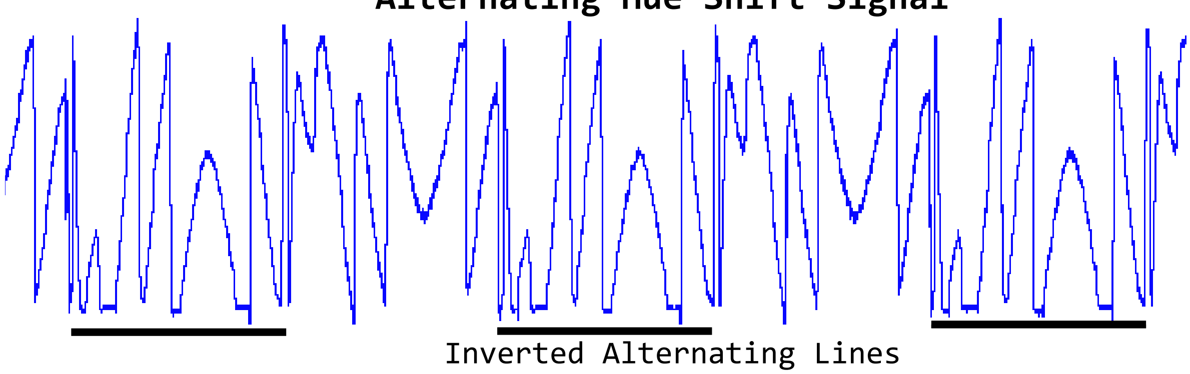


Hue Folder Output

This Graph shows six scanlines. Hue folder is being fed with a horizontal pattern.



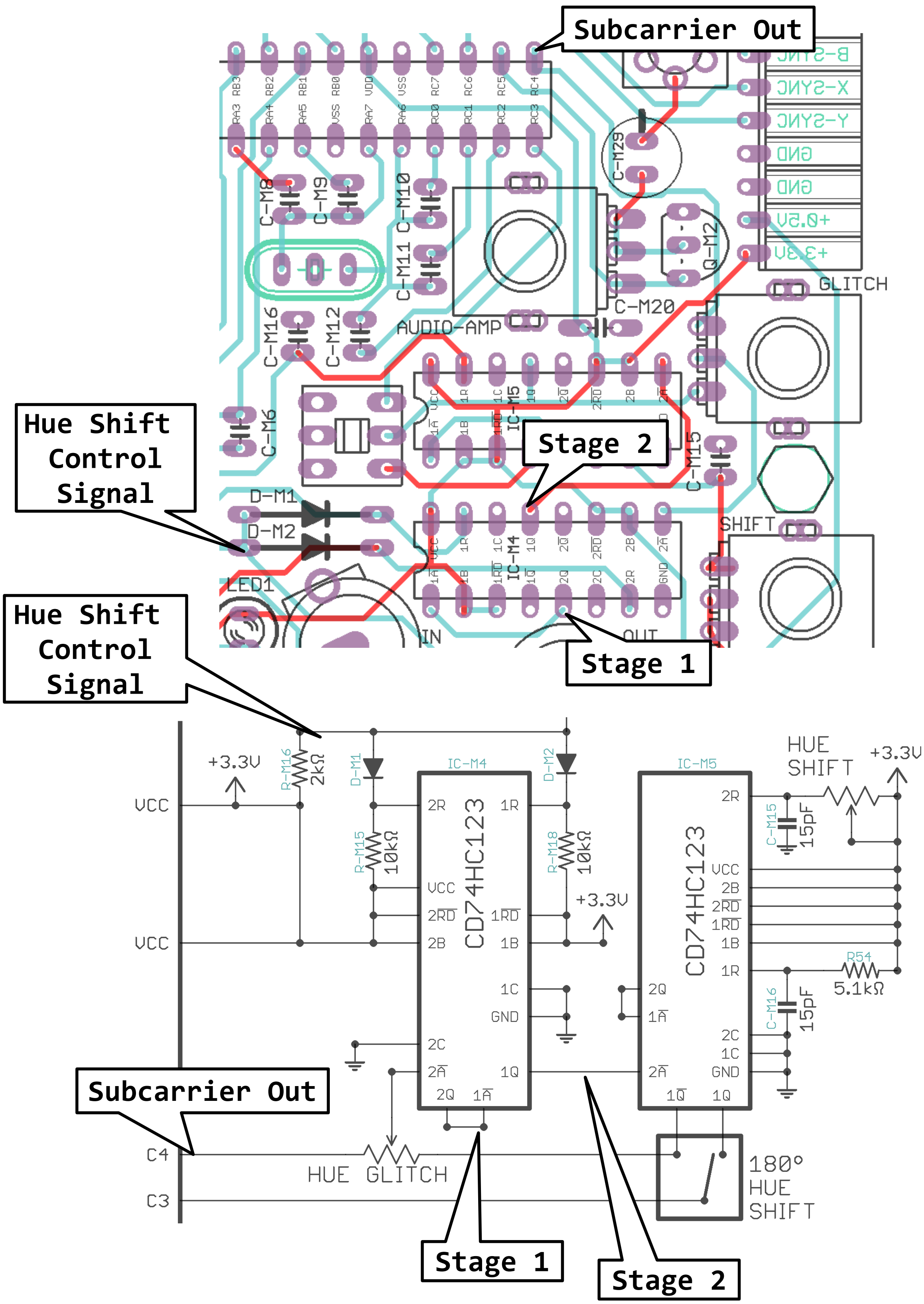
Alternating Hue Shift Signal



This is what the alternating hue shift produces in the final output. PAL can not produce the entire colour wheel without this phase alternation step. Without working phase alternation it will be limited to two hues on opposite sides of the wheel.

Voltage Controlled Subcarrier Phase Shifter

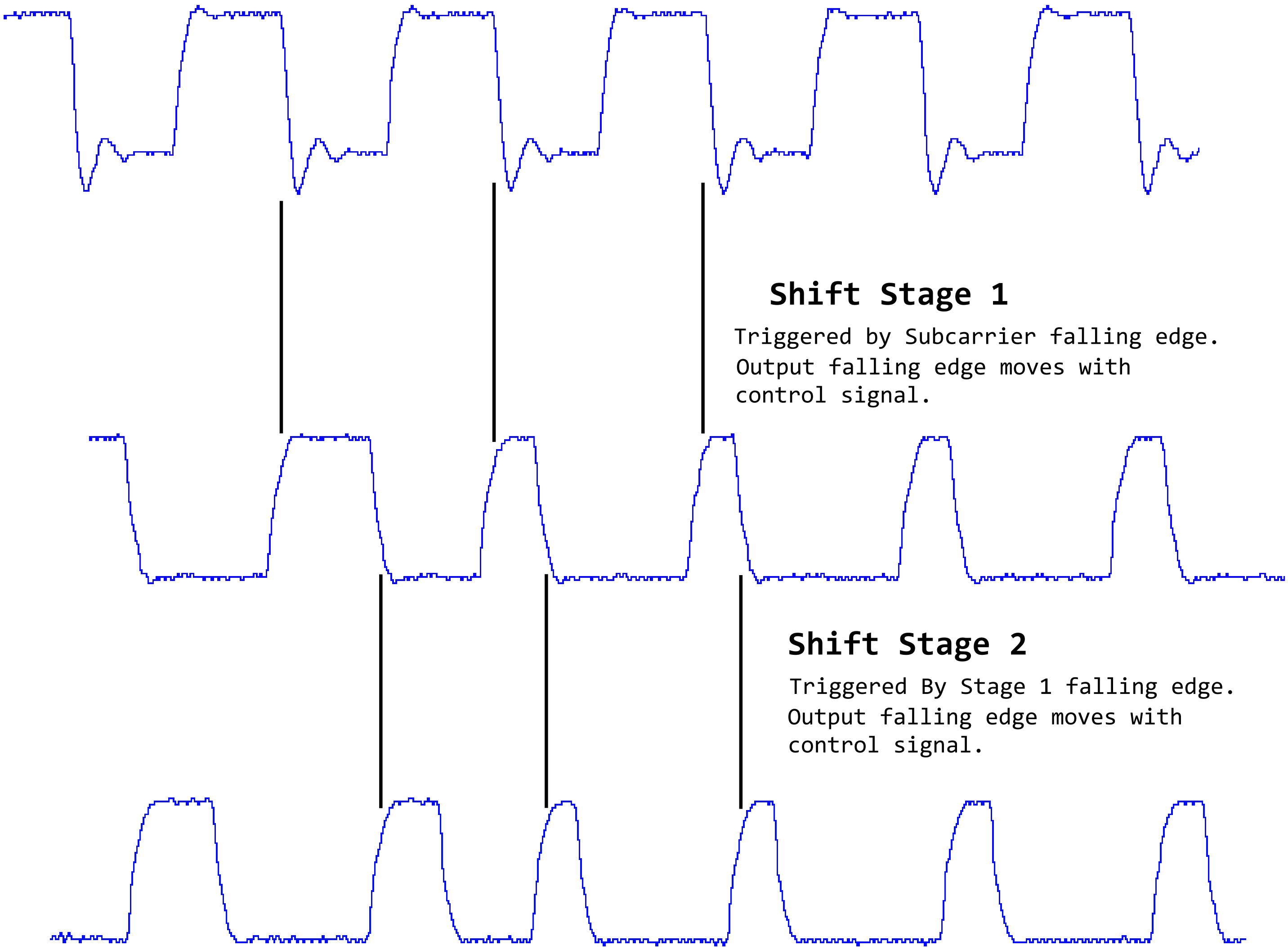
This circuit allows the hue shift signal to produce a voltage controlled phase shift of the colour subcarrier. For this test turn the glitch knob fully counter-clockwise. It intentionally interferes with the phase shift circuit. The circuit works by forming a two stage edge-triggered voltage controlled monostable delay with a CD74HC123.



Subcarrier Out

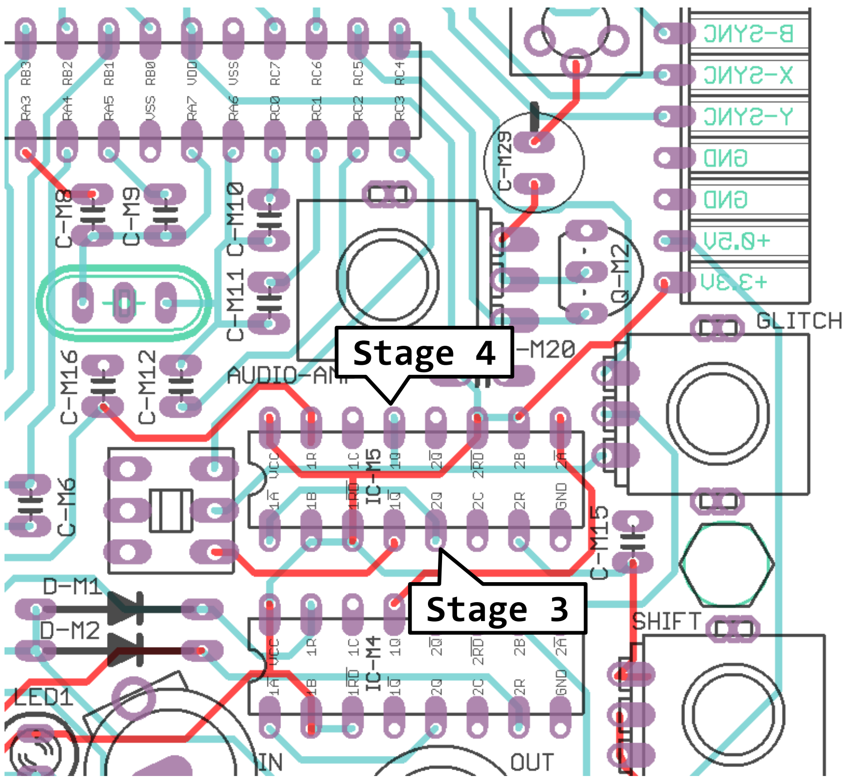
Digital Square Wave. 0v-3.3v.   NTSC: 3.58MHz   PAL: 4.43MHz

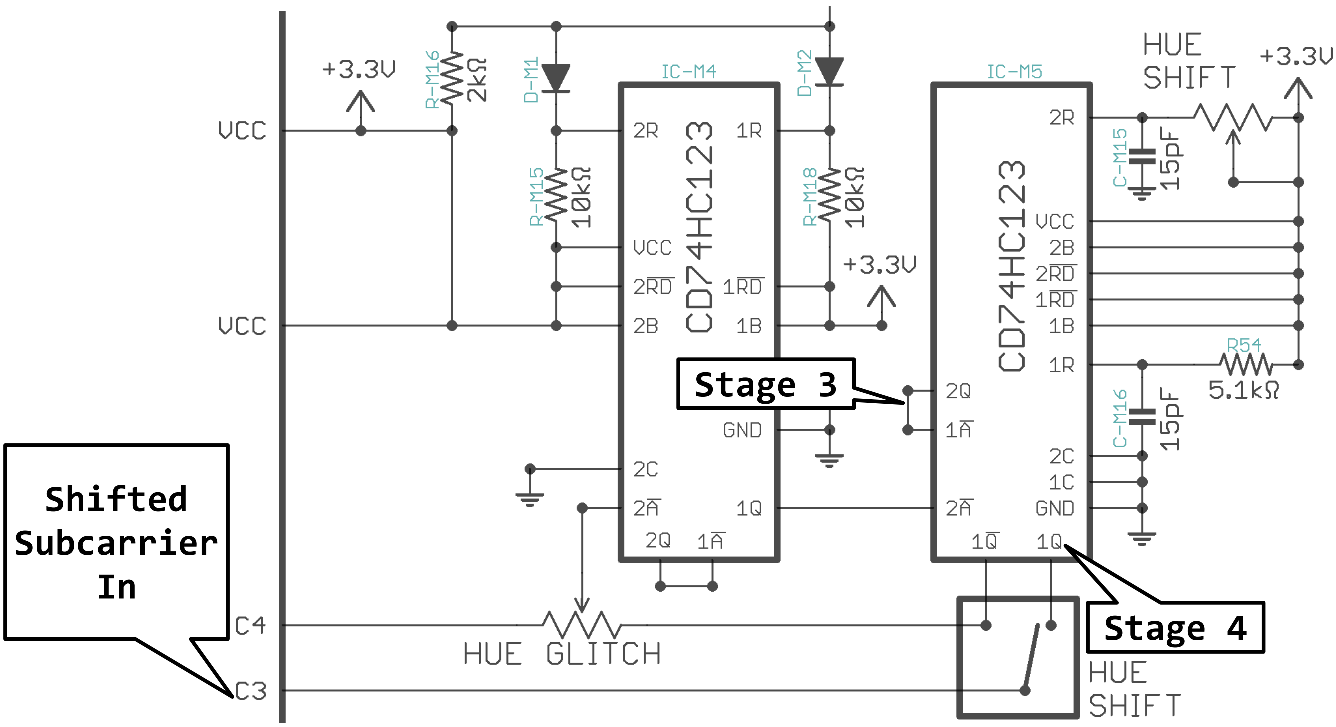
If you don't see a signal here there is an issue with the crystal oscillator.



Manual Hue Shift Control, Duty Cycle Corrector

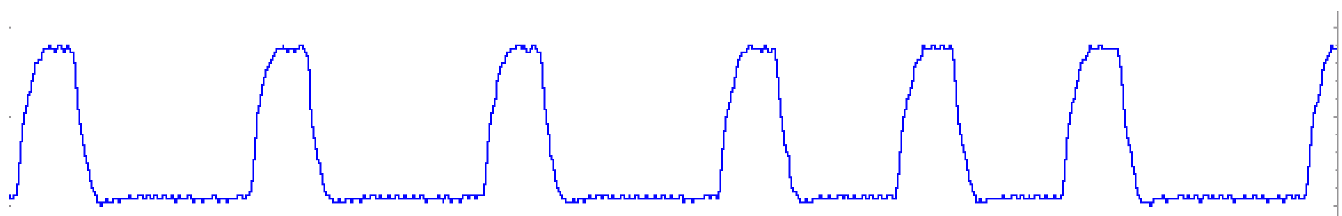
After the voltage controlled phase shift comes a potentiometer controlled phase shift. After that a constant monostable delay is applied to convert the waveform into a roughly 50% duty-cycle square wave. A switch allows this square wave to be inverted, resulting in a 180 degree phase shift. The output of the switch feeds to microcontroller pin 17 (RE3).





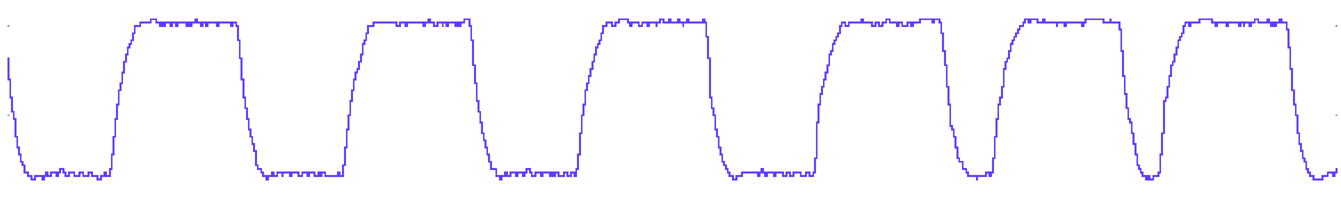
Shift Stage 3

The output rising edge is triggered by the falling edge of shift stage 2. The pulse width is controlled by the hue shift knob.



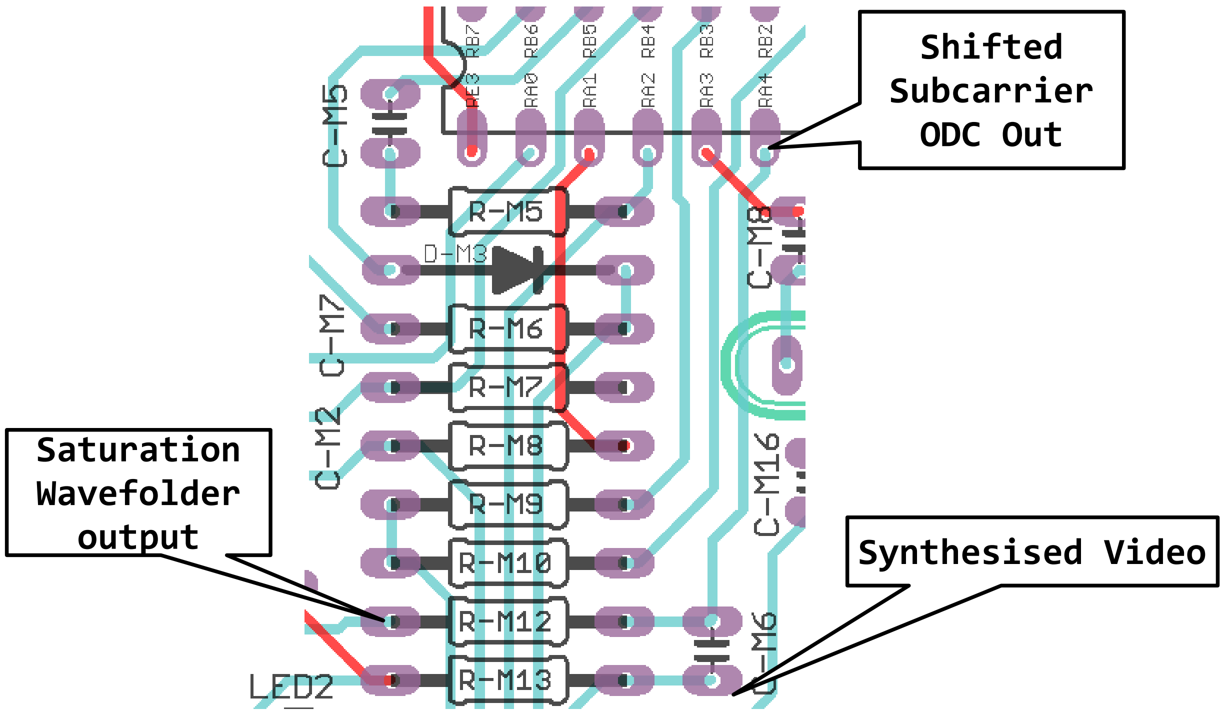
Shift Stage 4

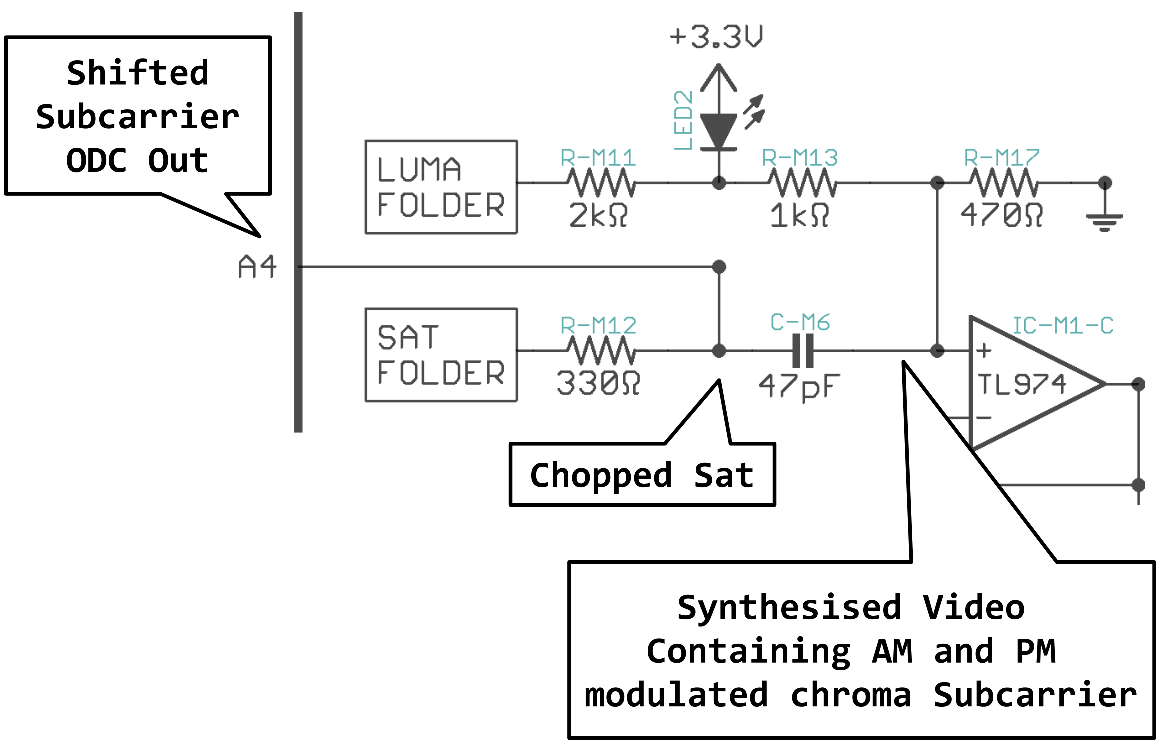
The output rising edge is triggered by the falling edge of shift stage 3. The pulse width is constant and roughly 50%. The phase is now controlled by both the shift knob and control signal.



Saturation Chopper Modulator.

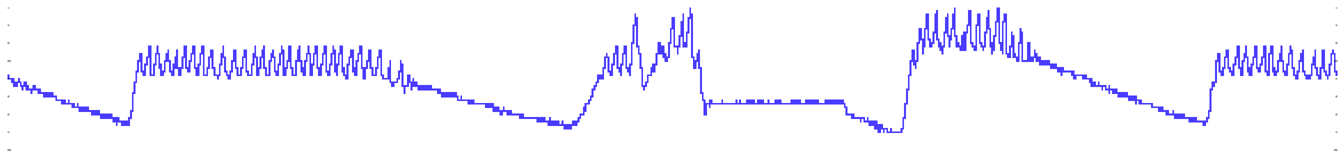
In analog video, colour saturation is determined by amplitude of the chrominance subcarrier. This circuit takes the hue phase shifted subcarrier and uses it to chopper modulate the saturation wave folder output. The resulting signal is converted to a sine wave and AC coupled to the luminance signal through C-M6.



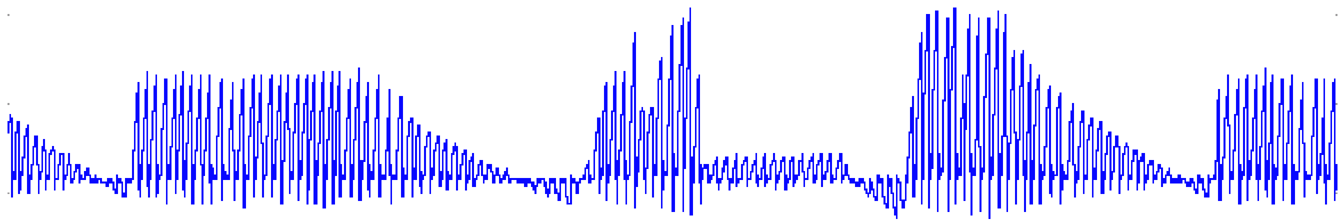


Saturation Wave Folder Output

Some of the subcarrier leaks back to this point.



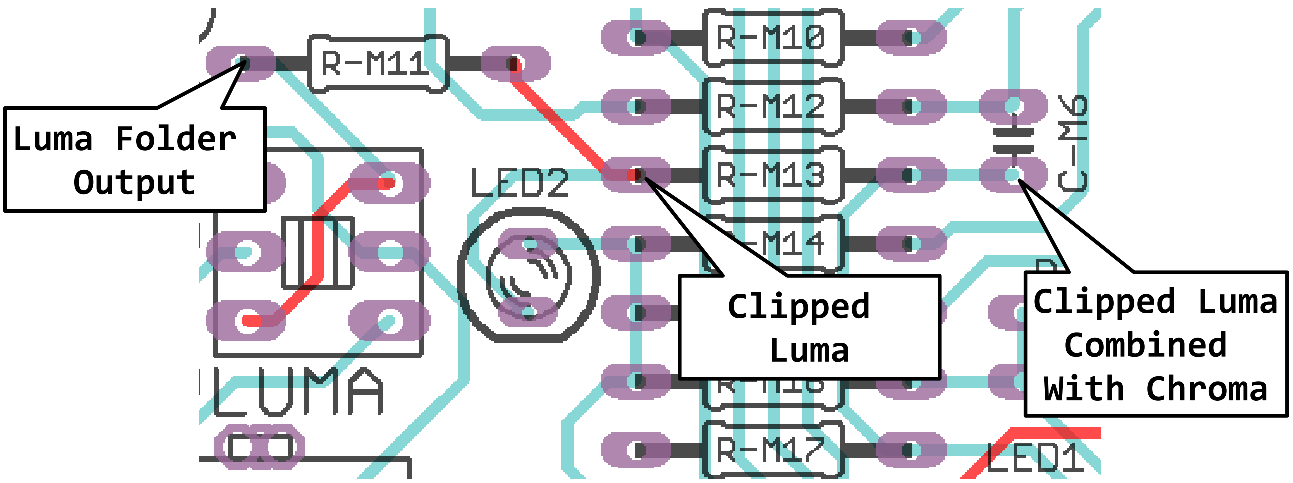
Saturation Signal Chopper Modulated by Phase-Shifted Subcarrier

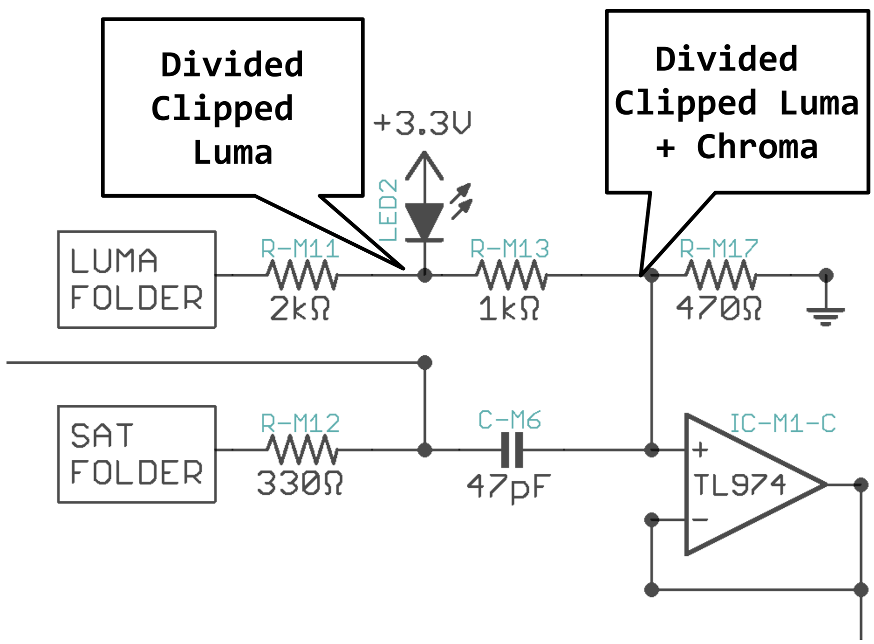


Luma Voltage Divider and Clipper

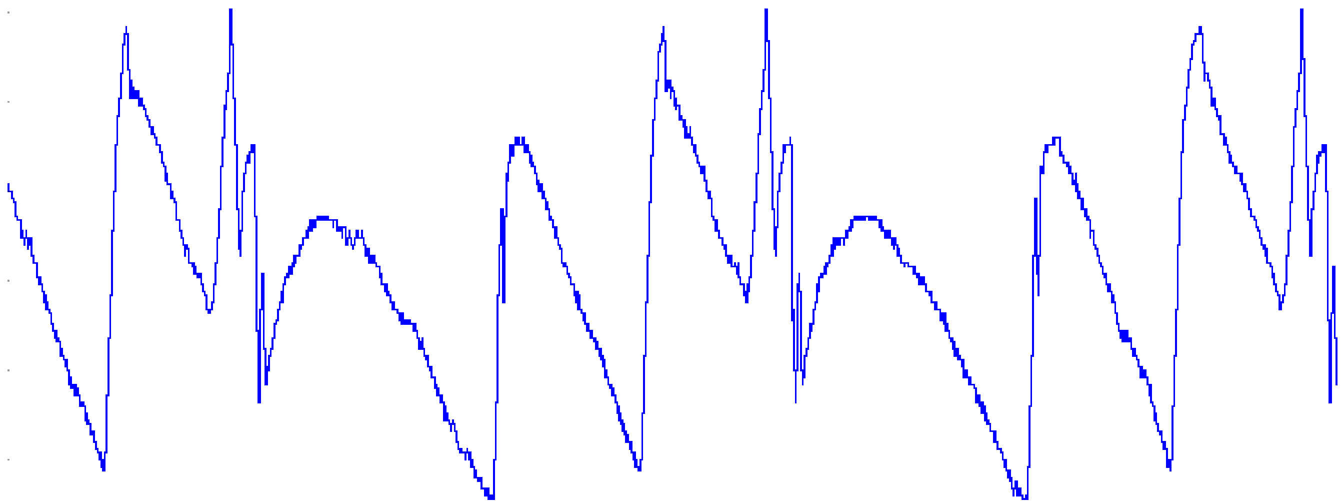
The purpose of this circuit is to prevent the luminance channel from going brighter than white or darker than black. TVs interpret luminance data incorrectly if a portion of the image is impossibly bright. If a portion of an image drops below black level, TVs interpret it in a sync pulse, resulting in a corrupted torn image.

The circuit uses LED2 as a 3V zener. It increases in brightness as the average output from the luminance wave folder decreases. This is roughly the opposite of how the hard/soft indicators LEDs change state.

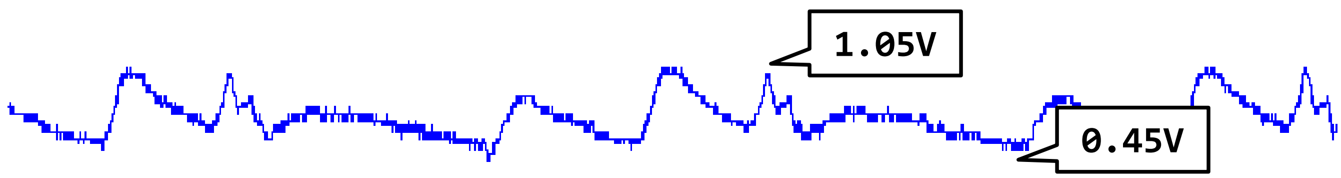




Luma Folder Output

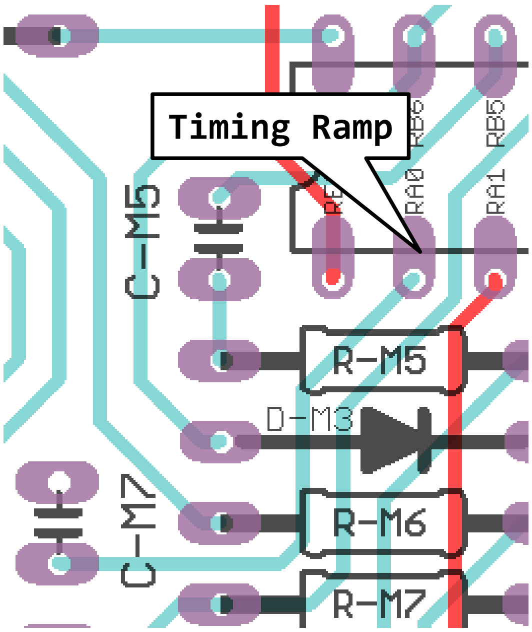


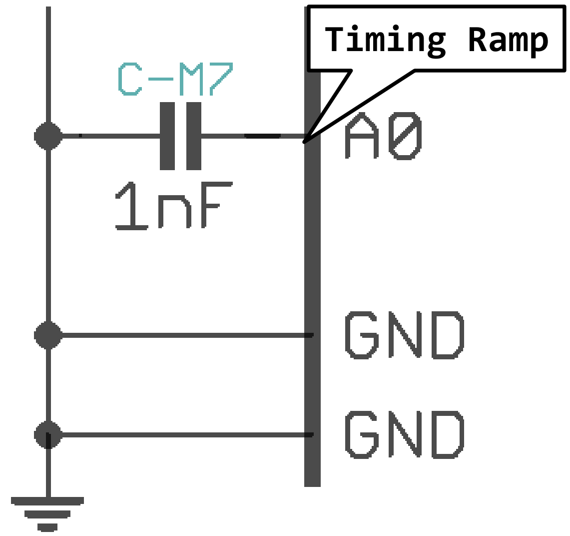
Divided Clipped Luma

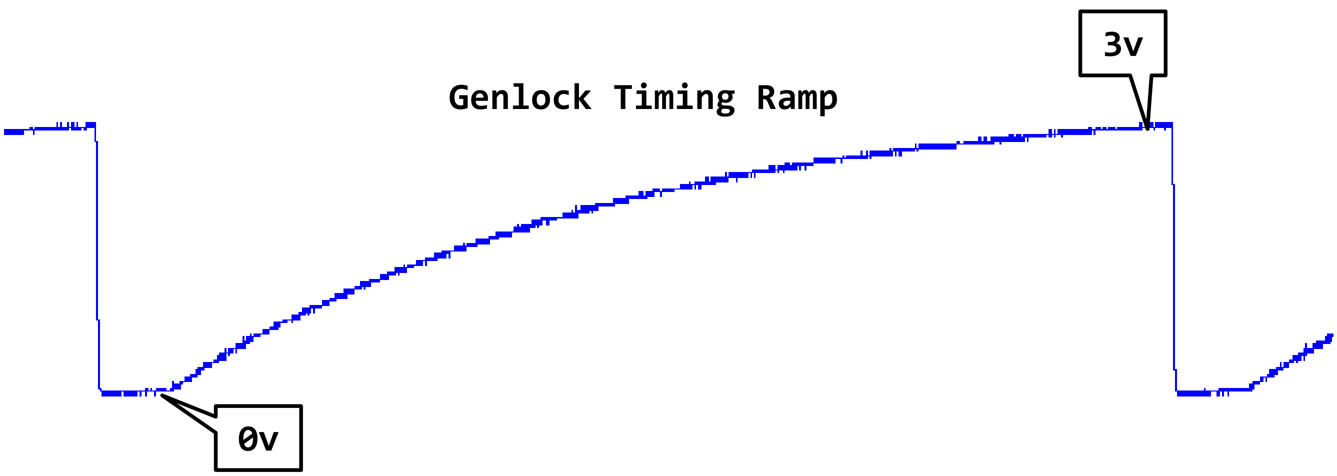


Genlock Timing Ramp

Microcontroller Pin 2 (RA0) should show the following timing ramp when an external video is applied. This is an essential part of the genlock system.





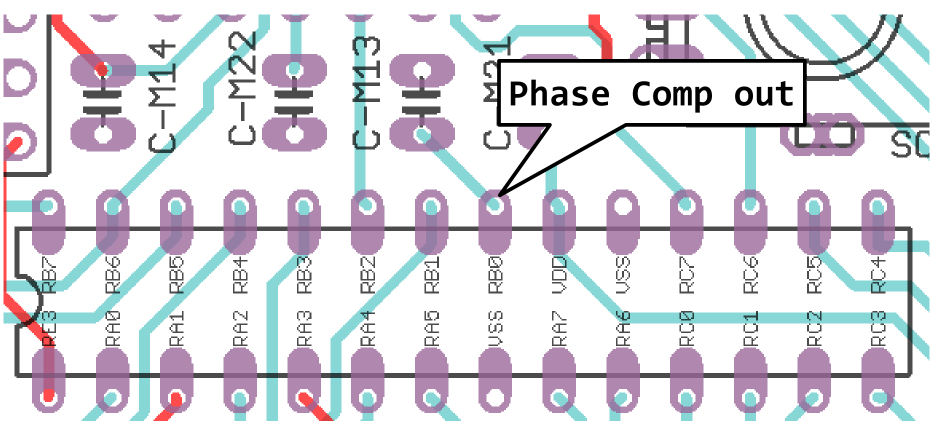


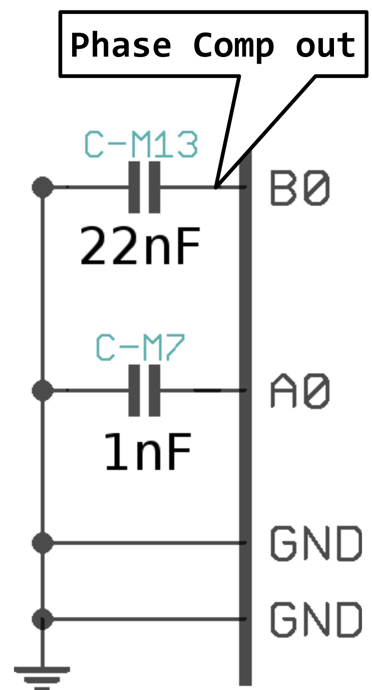
Genlock Phase Comparator

Mainbow internally divides its crystal frequency by four to produce its colour subcarrier frequency. The two crystals are 4x the subcarrier frequencies used in their respective video formats.

Mainbow's crystal sourced subcarrier frequency is phase compared to the colour burst of external video signals. The output of this phase comparator is present on Microcontroller pin 21 (B0). It is used to make small adjustments to the crystal frequency. This results in the crystal oscillating at exactly 4x the colour burst frequency present in the video input. This means Mainbow's chrominance subcarrier is at exactly the same base frequency as the video source. Locking the oscillators together like this is necessary to mix synthesized colour with the external video colour. Small variations between the oscillator frequencies are interpreted as hue shifts so frequency drifts are interpreted as rainbows.

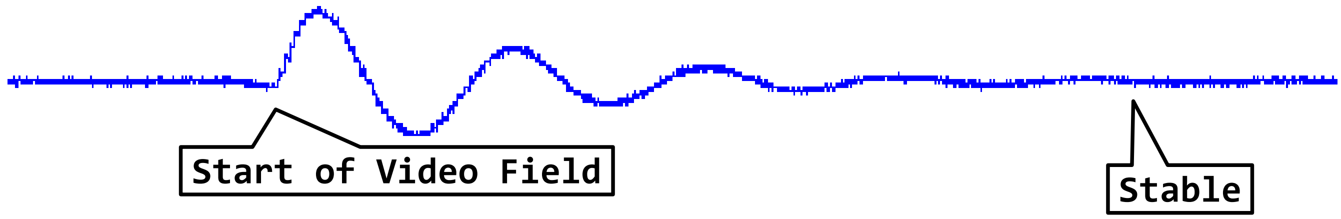
Microcontroller pin 21 (B0) shows an analog voltage representing the difference in phase between the input video colour burst and Mainbow's subcarrier. When genlock is achieved it will be a fairly stable voltage. When the system is out of genlock it will show a waveform representing the changing phase difference. This may be clipped by 3.3v and 0v. The number of waves per video frame will correspond to the number of rainbow lines per video frame.





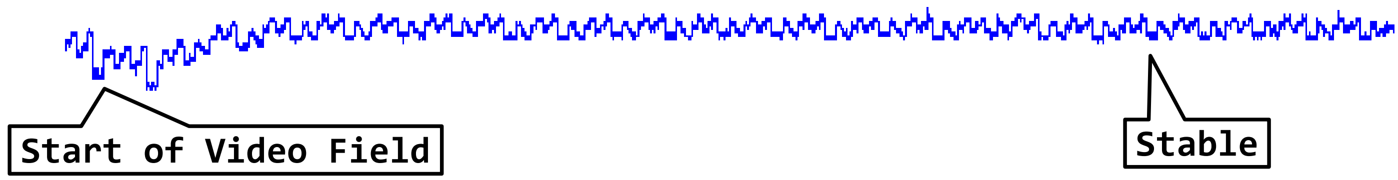
Genlock Achieved (NTSC)

There can be some slight oscillation at the start of a video field.
The stable voltage changes based on the frequency of the input burst.



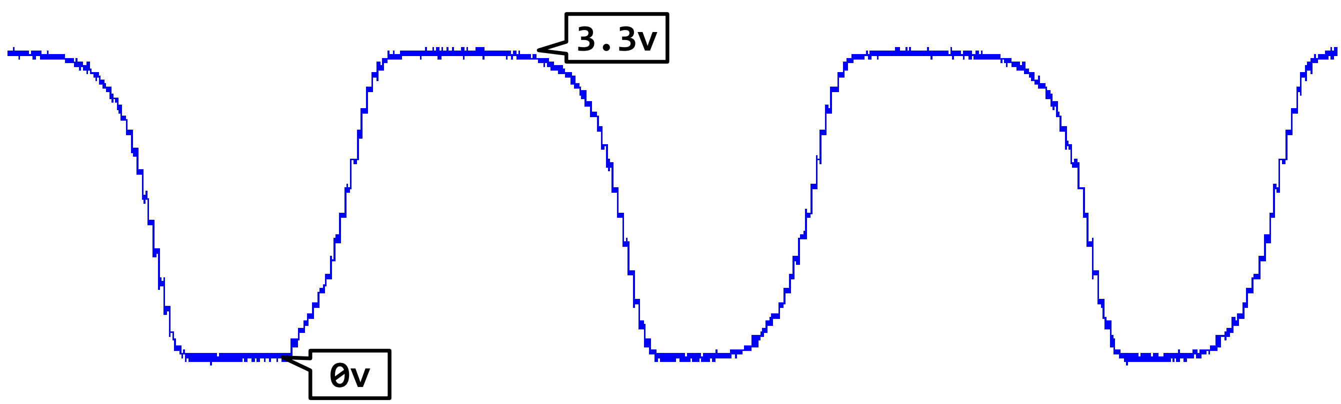
Genlock Achieved (PAL)

Pal has this jagged shape due to the burst alternating 90° each scanline.



Genlock Broken

This was produced by disabling Genlock using the GC/GF option. Phase comparator is working but not being used to adjust the crystal.

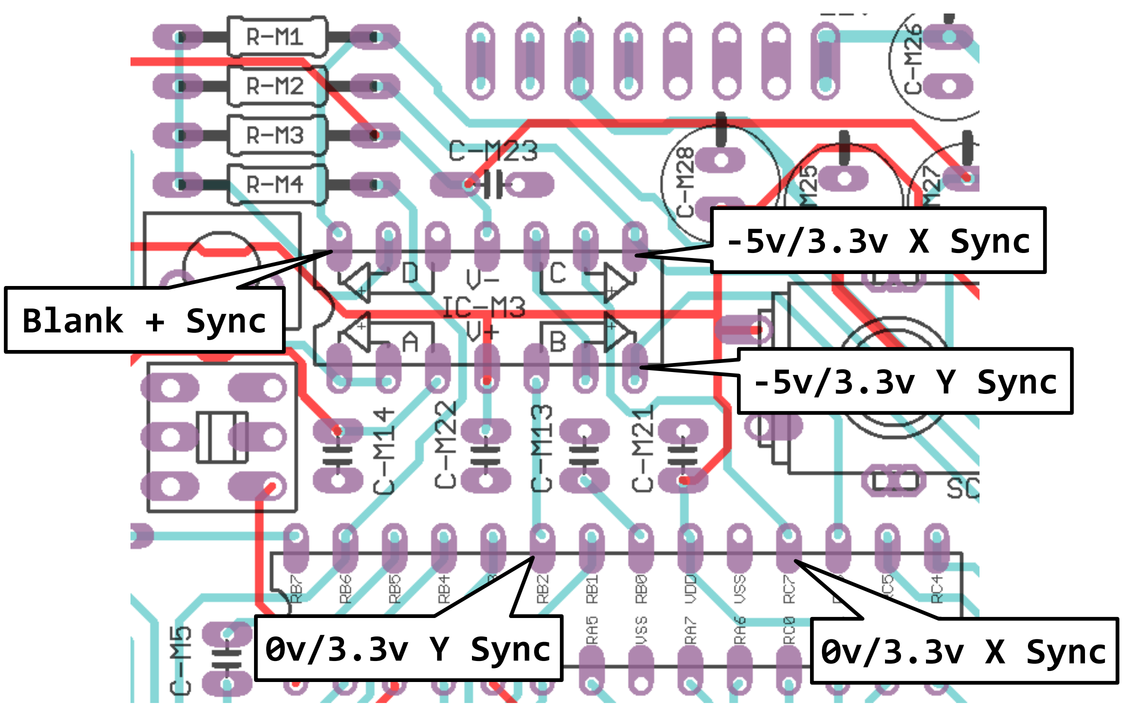


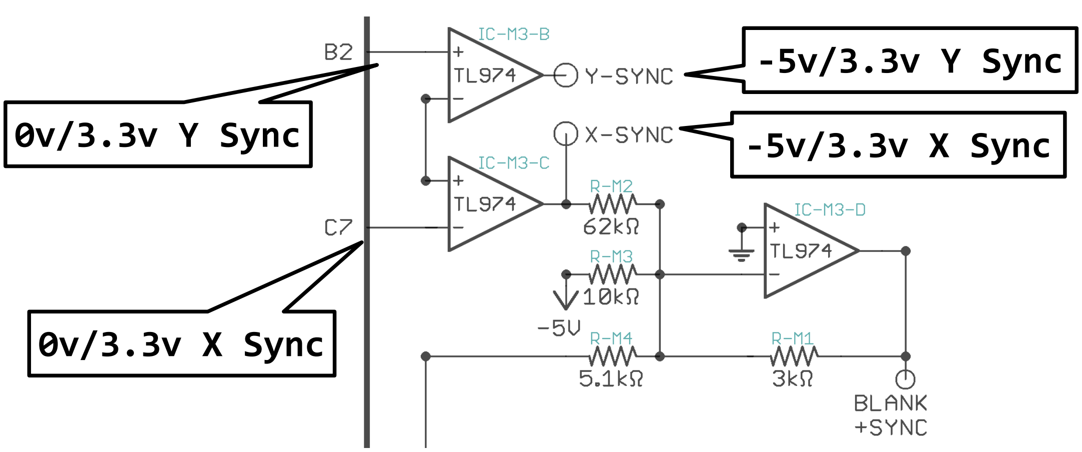
X, Y , B Output to Function Generators

The function generators need synchronization pulses to make stationary X and Y mode waveforms. When these signals are low (-5v) the function generators are free to oscillate. When the signals are high (+3.3v) the function generators reset to a state defined by their PM inputs.

The microcontroller identifies the scanline sync pulses and vertical blanking interval. These are output as 0v-3.3v signals. A pair of op-amps (acting as comparators) amplify them to -5v/+3.3v.

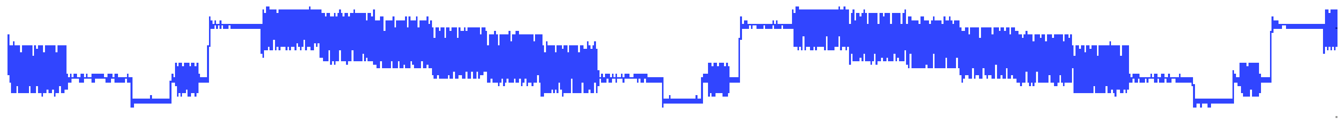
The Sync+Blank (B-sync signal) combines sync pulses and blanking mask into a single waveform. It is sent to the function generators and used to generate their monochrome video output.



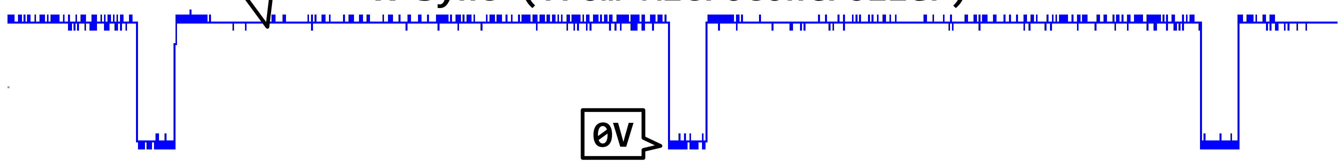


Video In (Timing Reference)

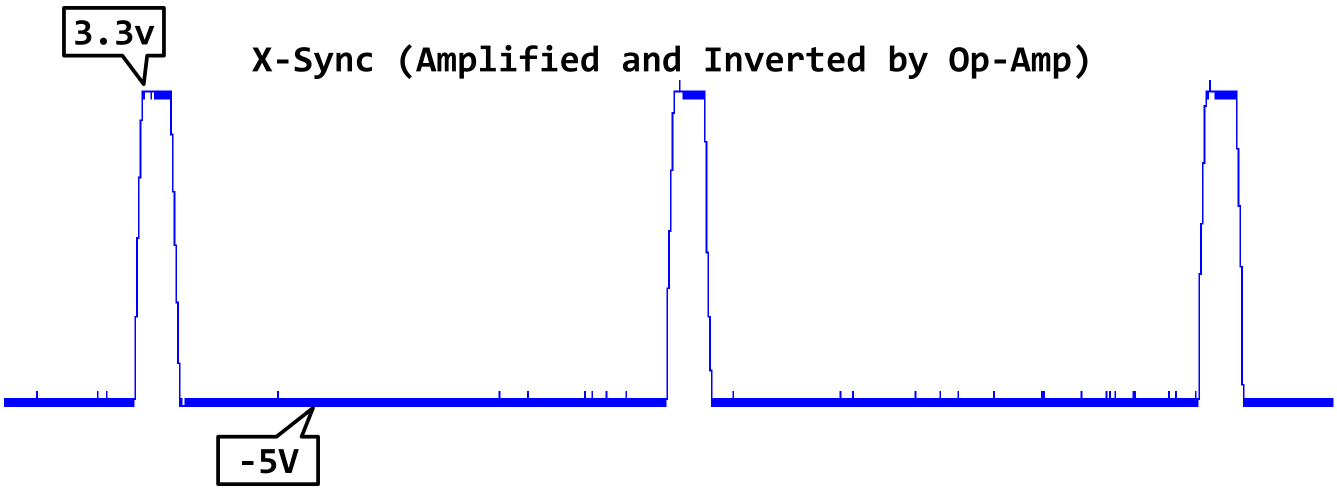
This shows three scanlines.



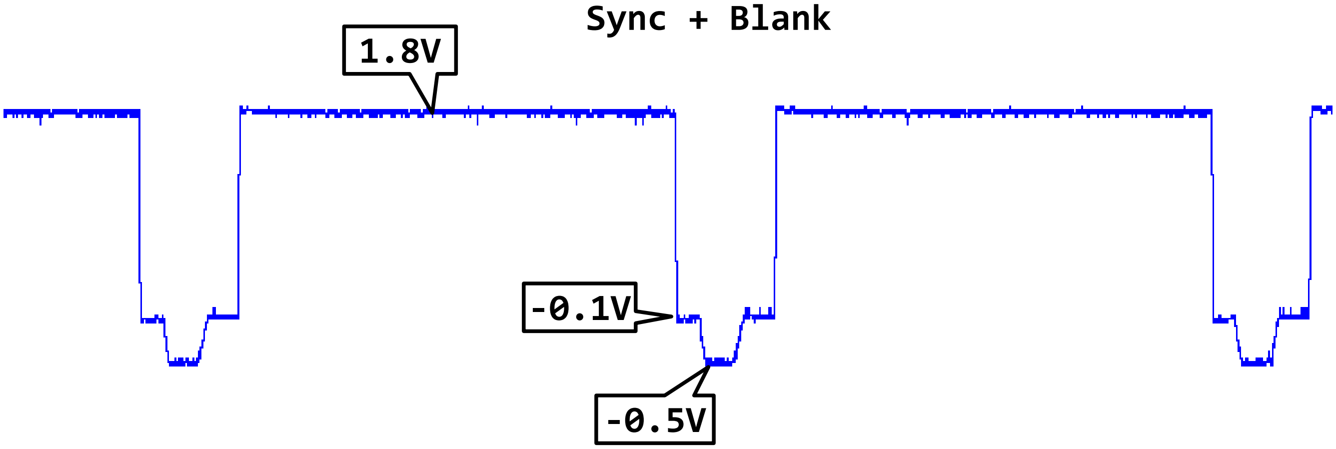
X-Sync (from Microcontroller)



X-Sync (Amplified and Inverted by Op-Amp)

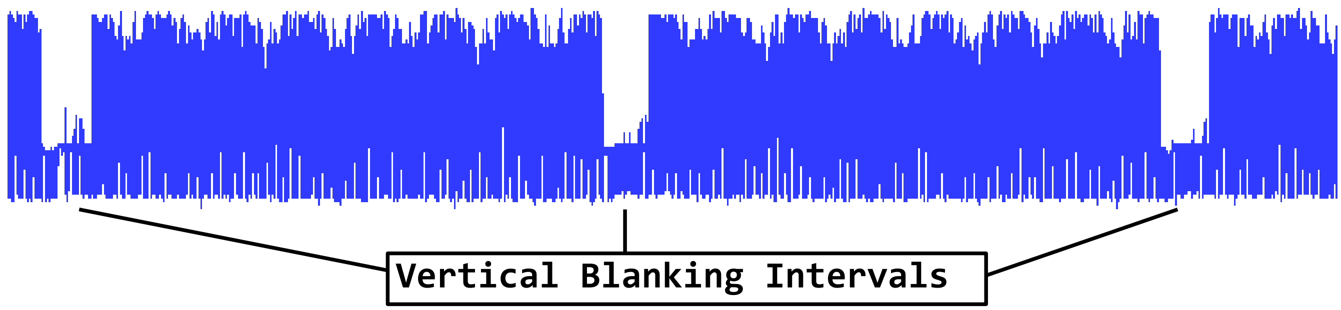


Sync + Blank

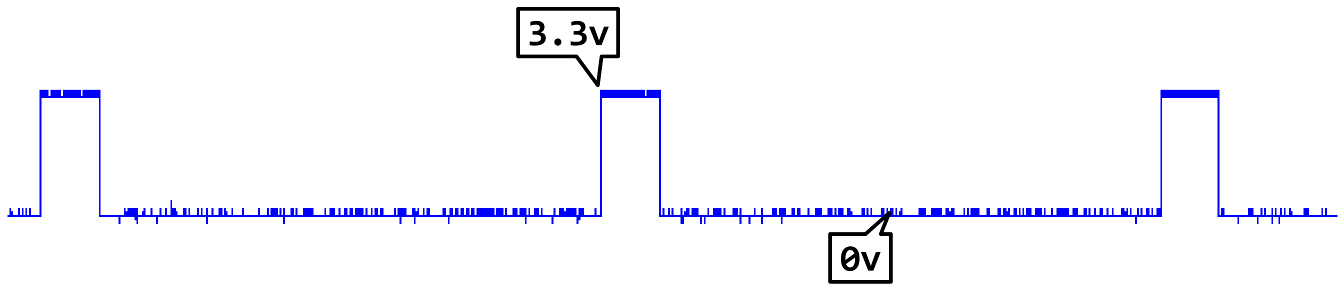


Video In (Timing Reference)

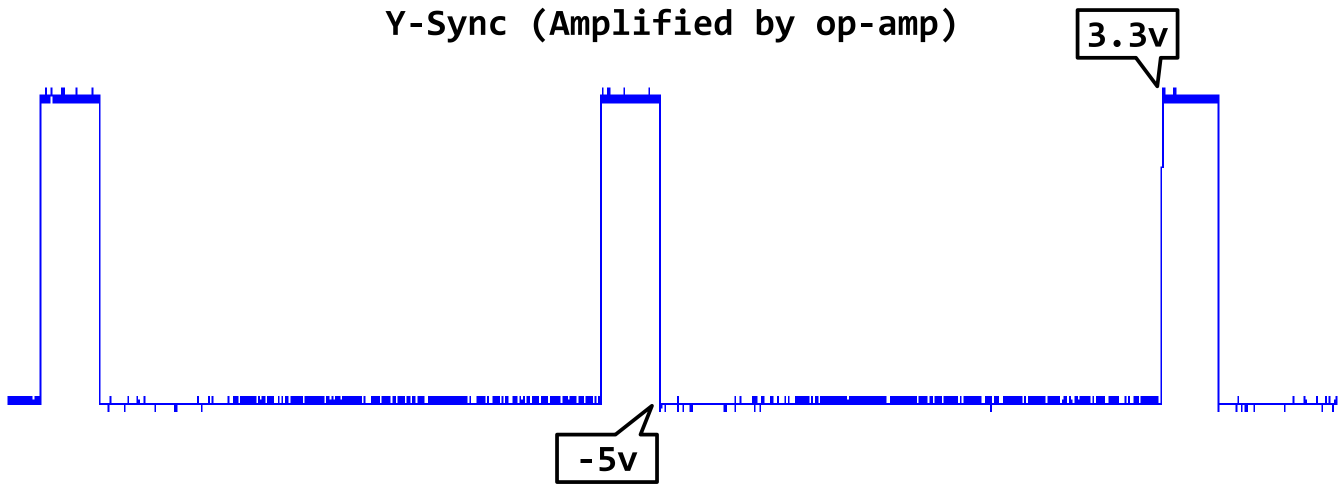
This shows three video fields.



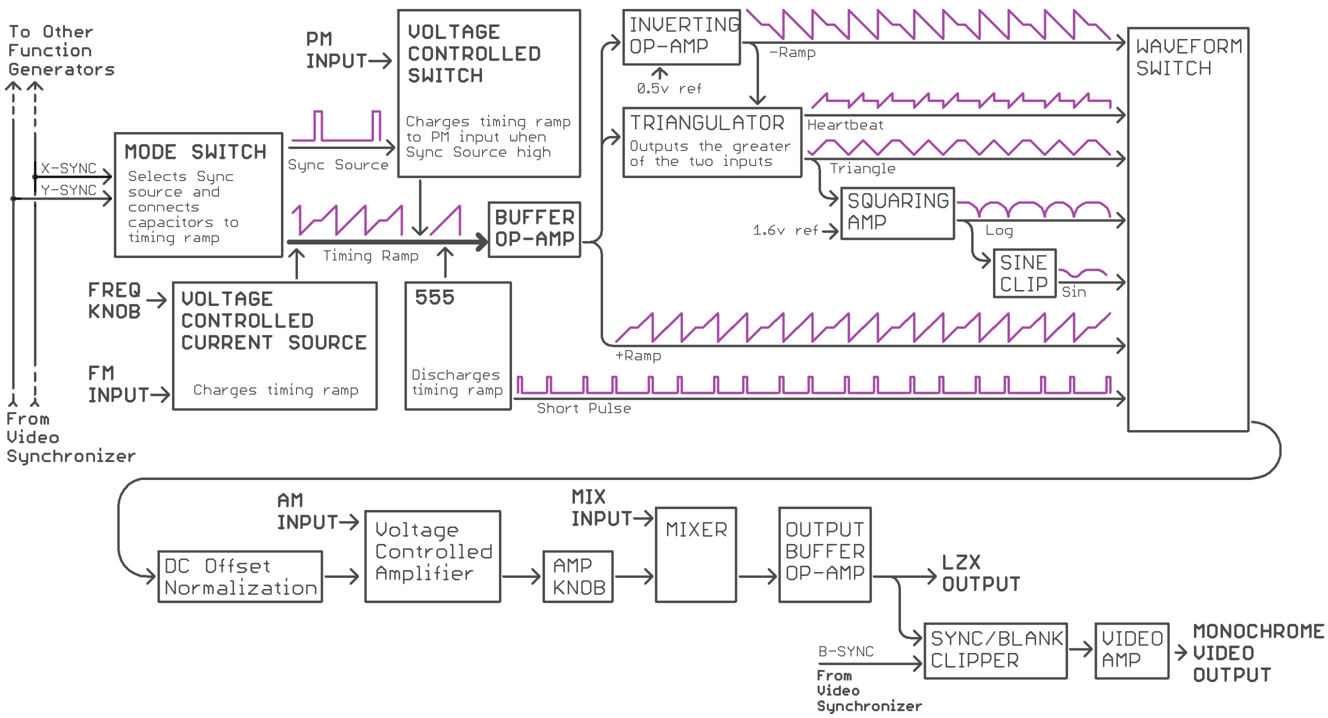
Y-Sync (From Microcontroller)



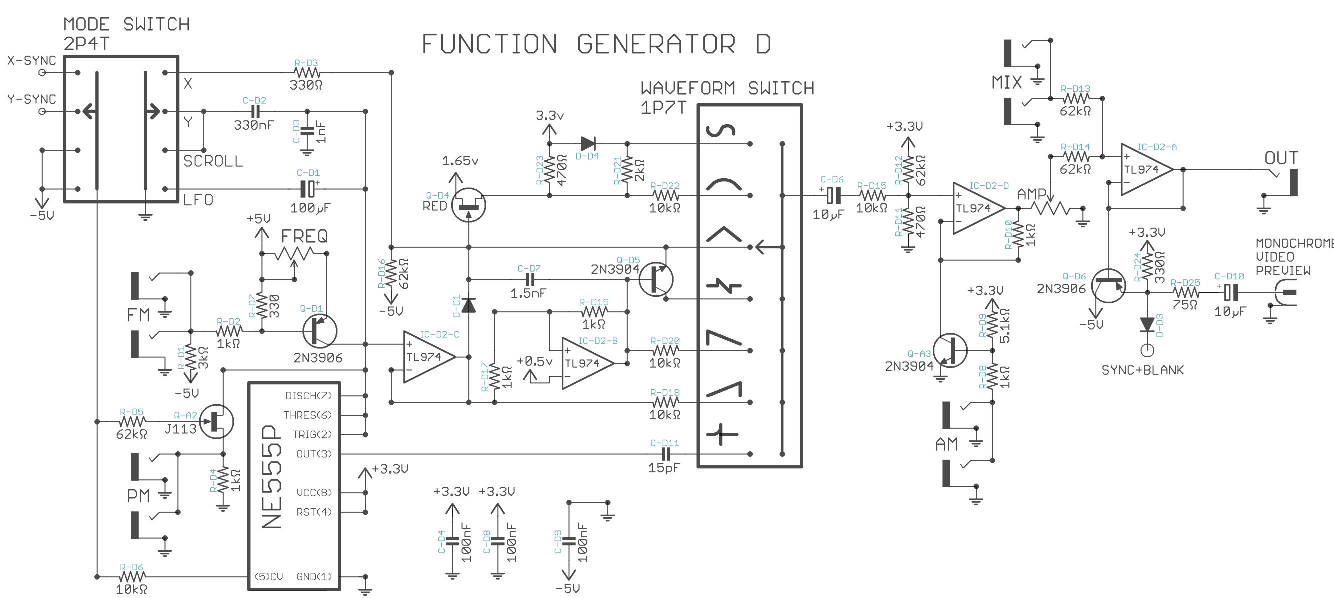
Y-Sync (Amplified by op-amp)



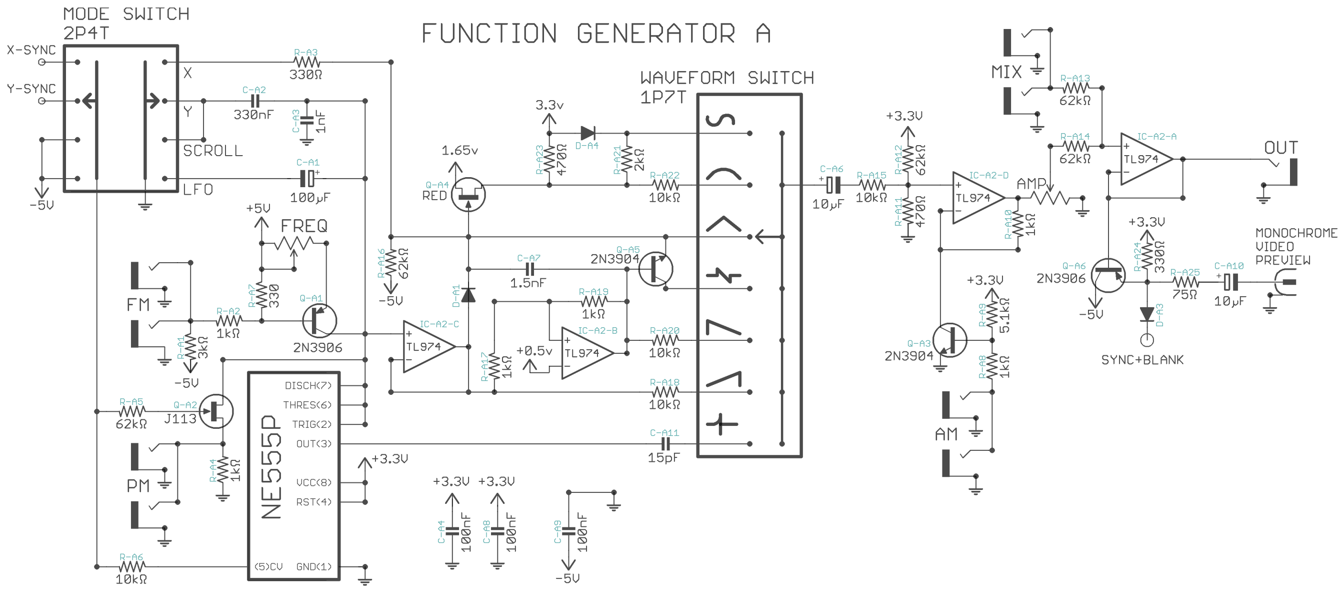
Function Generator Block Diagram



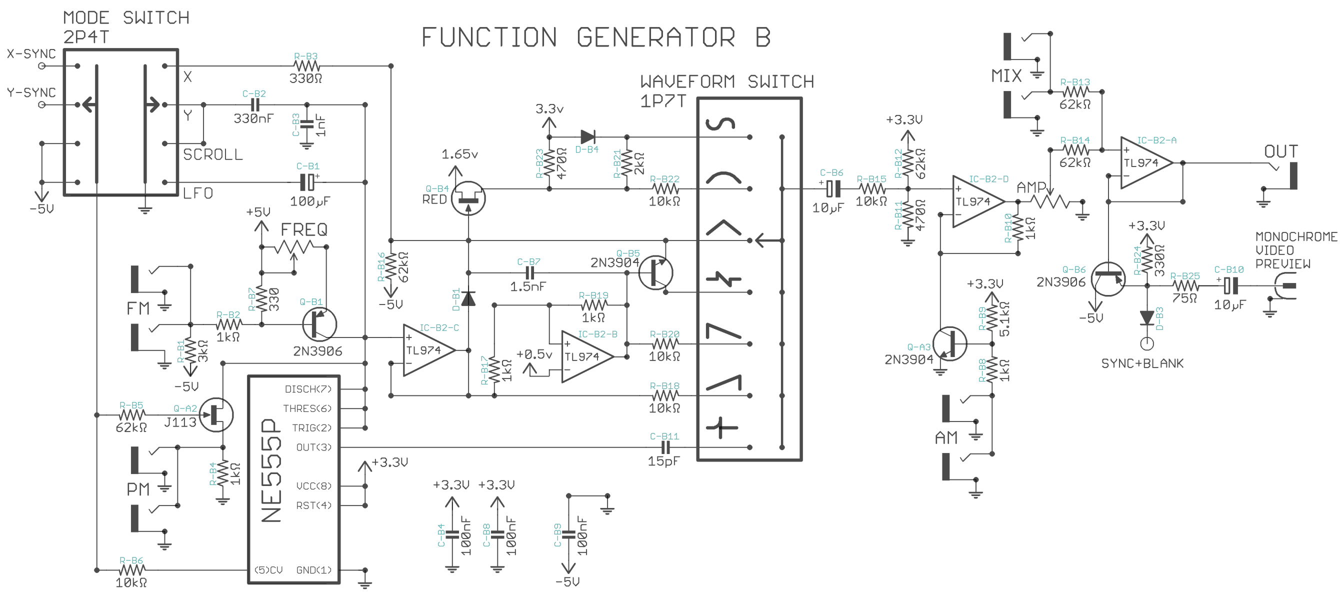
Function Generator Schematics



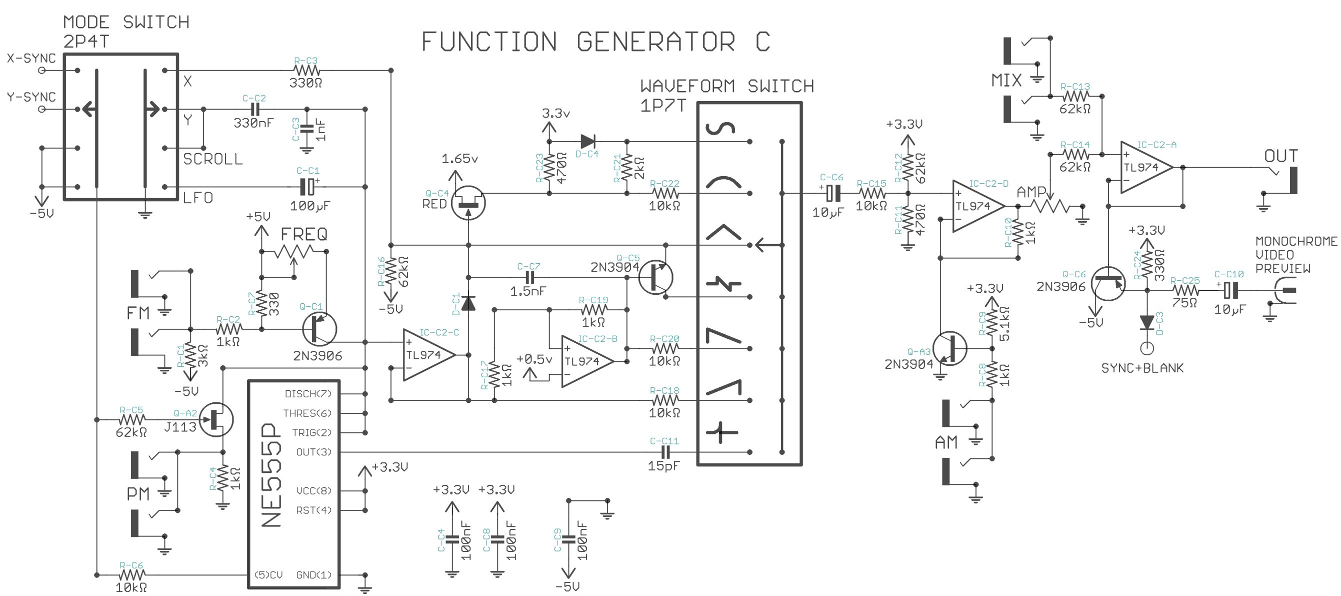
FUNCTION GENERATOR A



FUNCTION GENERATOR B

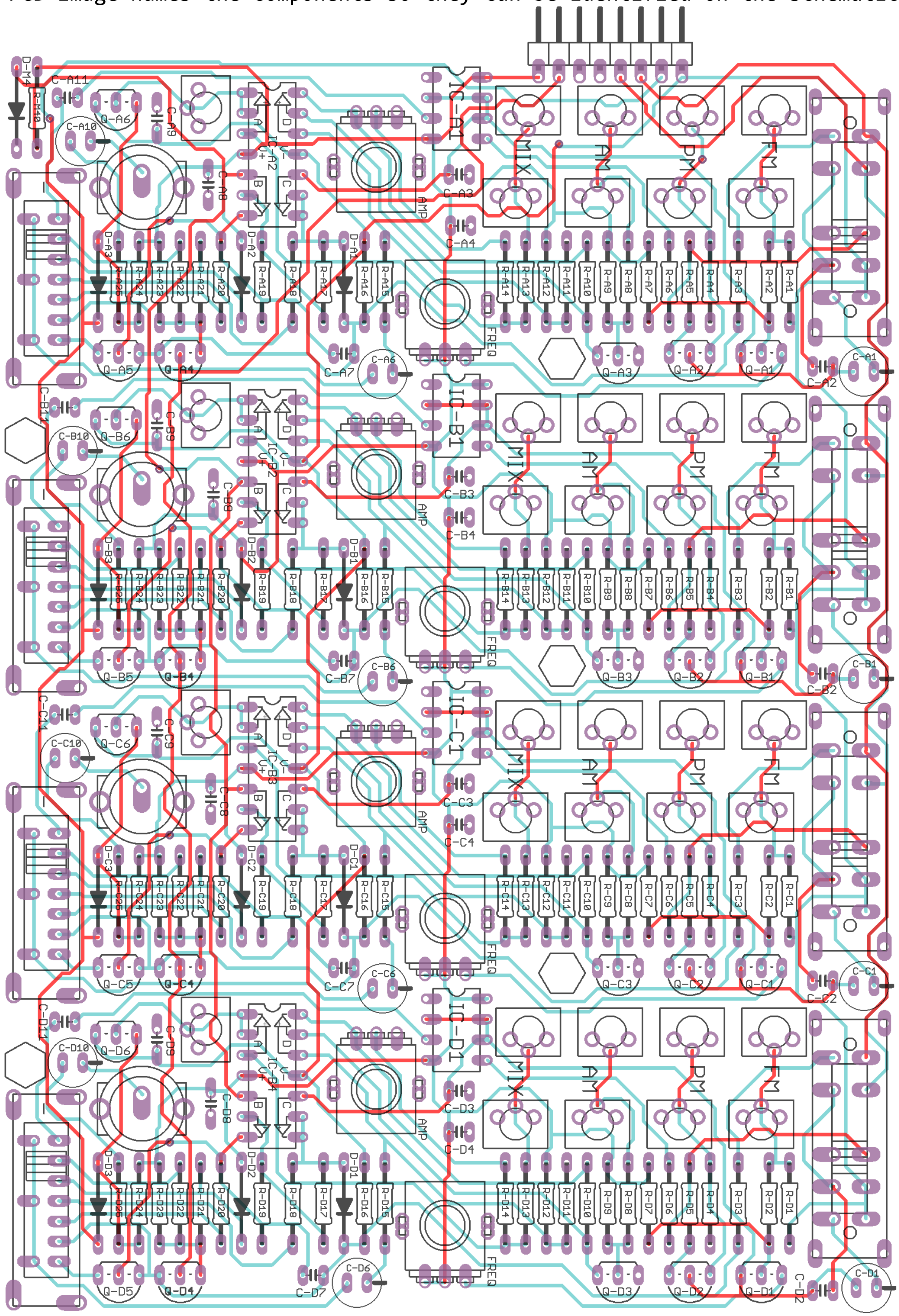


FUNCTION GENERATOR C



Function Generator PCB (Names and traces).

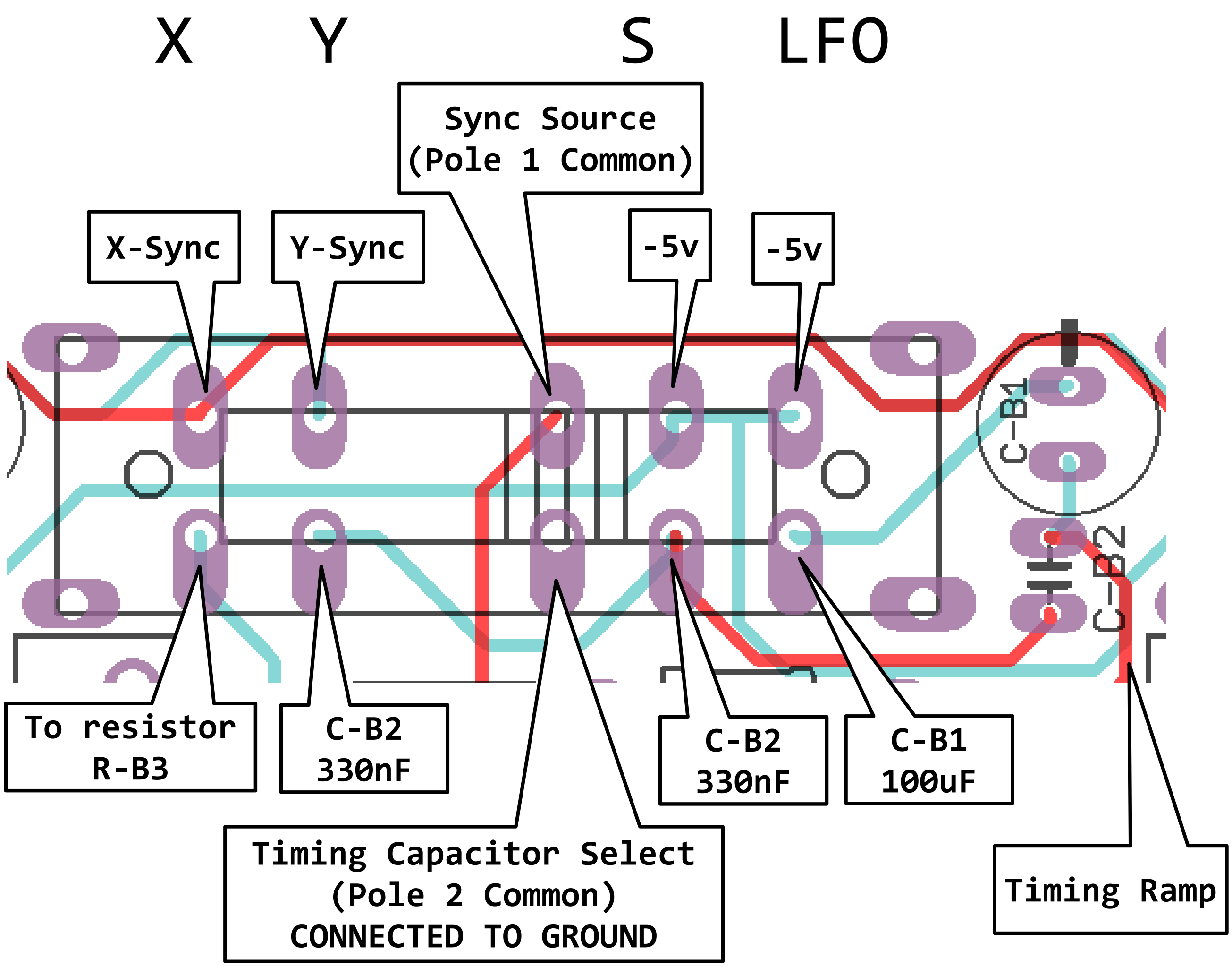
This PCB image names the components so they can be identified on the schematic.



Function Generator Mode Switch

Oscillation Mode is set with a 2P4T switch that simultaneously selects synchronization sources and timing capacitors. Increasing capacitance on the timing ramp slows it down. Capacitors always have a lead connected to the timing ramp signal, and are enabled by connecting their opposite lead to ground.

Selecting -5v as a sync source lets the oscillator run freely. This is used to produce scrolling and LFO oscillations.

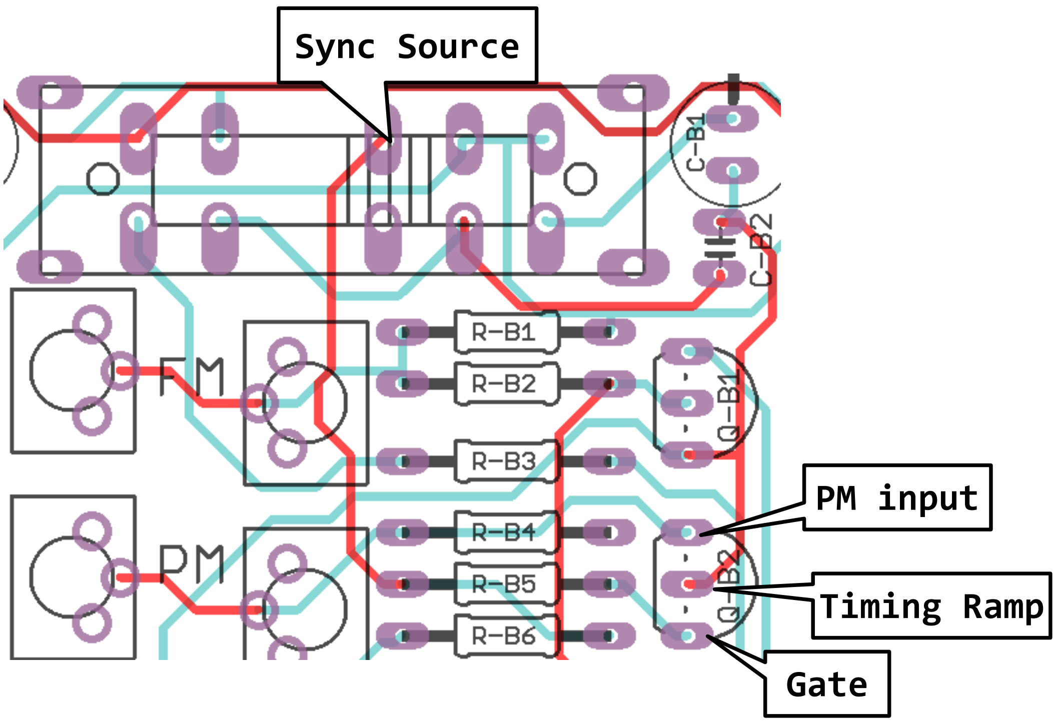


In X-Mode timing comes from a capacitor C-B3(1nF) which is permanently soldered to the timing ramp signal and ground. In this position the mode switch connects R-B3 to ground which improves the shape of waveforms at higher frequencies.

Failure to solder a sync pin will result in the oscillator constantly being held in a reset state instead of oscillating. Not soldering the common pin will effect all modes.

Function Generator Phase Modulation

PM works by setting the timing ramp to a starting position while the sync source is high. The starting position is defined by the PM input signal. When the sync source goes low the timing ramp is released to oscillate from that starting position.



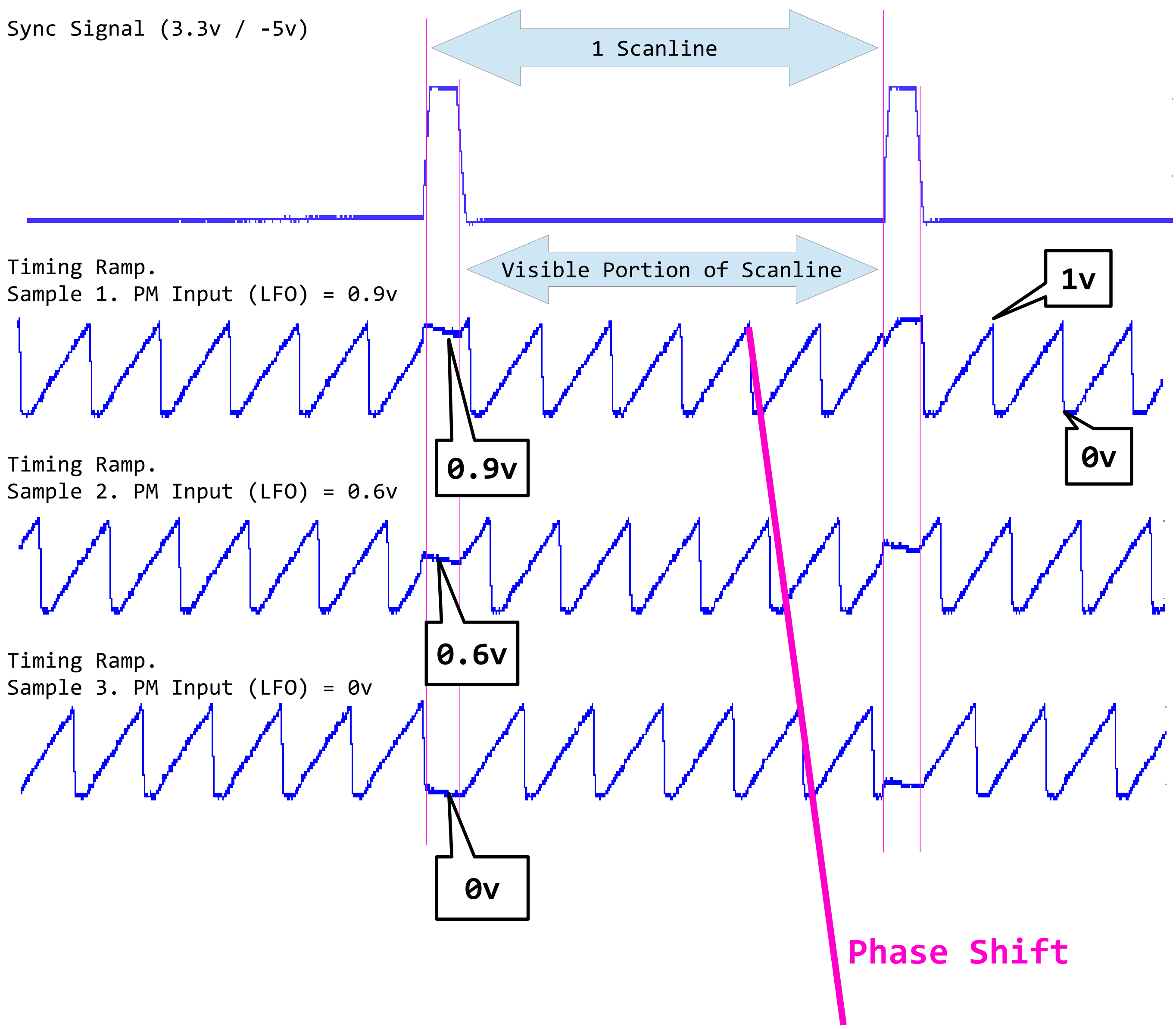
Q-B2 is a J113 JFET acting as a voltage controlled switch. When the sync source is high the switch closes. This charges the timing capacitor to the same voltage as the PM input.

The 555 should not be allowed to enter a discharge state while the PM input is controlling the timing capacitor. This would result in a fight over control of the timing capacitor voltage. This is solved by also connecting the sync source to the 555's CV pin through R-B6.

R-B4 pulls the sync input to ground when there are no wires in the jack. It produces a default state of the timing capacitors going to ground when the sync signal goes high.

Phase Modulation Example

In this example the mode switch is set to X. The PM input is fed by an LFO. The sync signal is high during invisible (blanking) portions of the scanline, so all you see on TV is the timing ramp moving right.

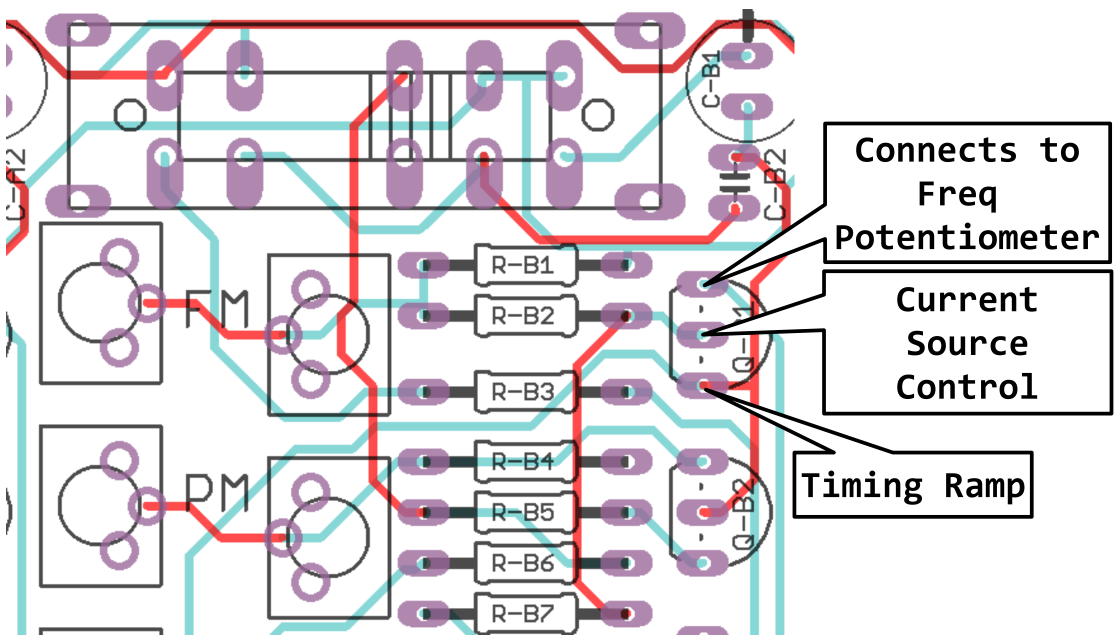


Function Generator Voltage Controlled Current Source (Frequency Modulation)

The timing capacitor is charged by a voltage controlled current source to produce the timing ramp. This is produced by Q-B1 (2N3906). Charging a capacitor with a current source results in its voltage rising linearly. Using a voltage controlled current source lets the FM input signal control the charging rate. The charging current is also limited by the Freq potentiometer.

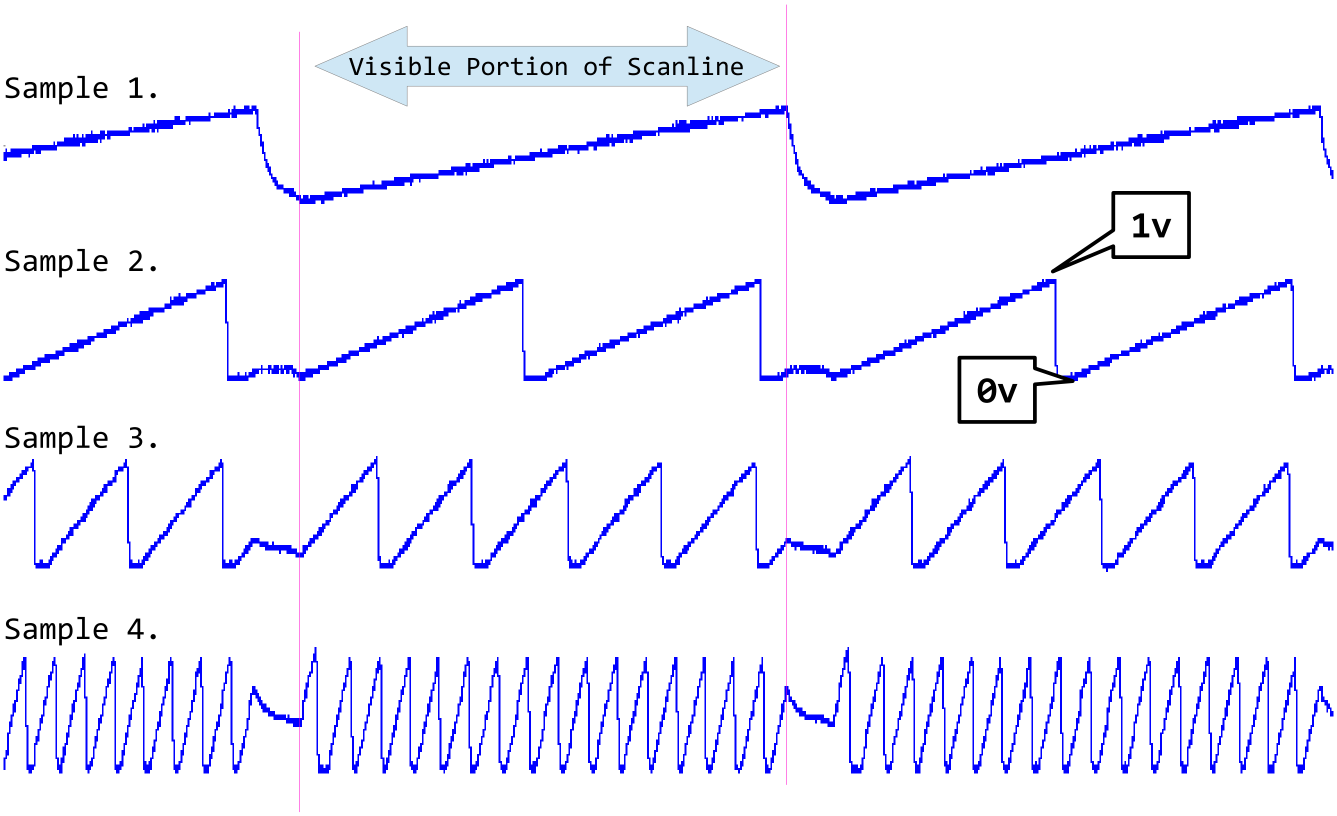
When the timing ramp reaches 1v it is discharged by the 555 then released to rise again. 555s normally charge and discharge their timing capacitor between 1/3 and 2/3 Vcc. This 555 is charging and discharging between 0v and 1v because R-C6 (10k) is pulling its control voltage pin towards -5v.

RB2,RB7 form a voltage divider that brings the 0v-1v FM input to a level within the sensitivity range of the current source control. RB1 sets a default FM input for when there is no cable connected to the input jacks.



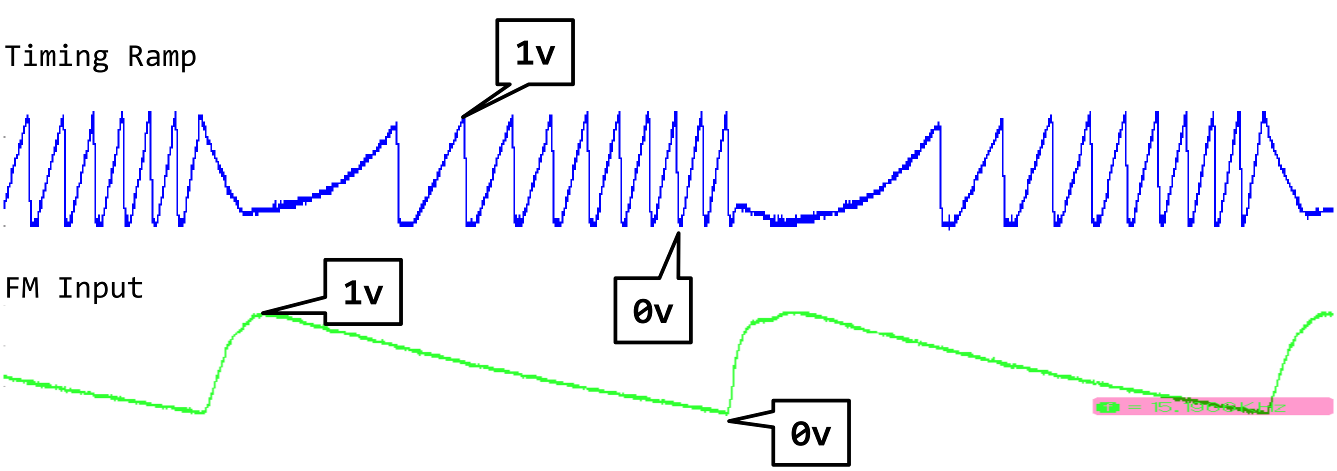
Function Generator Freq Knob Demonstration.

Function Generator is in X mode. There is no FM input. The Freq knob is turned further clockwise between each sample. Scope probe is on the timing ramp signal.



Function Generator FM Demonstration

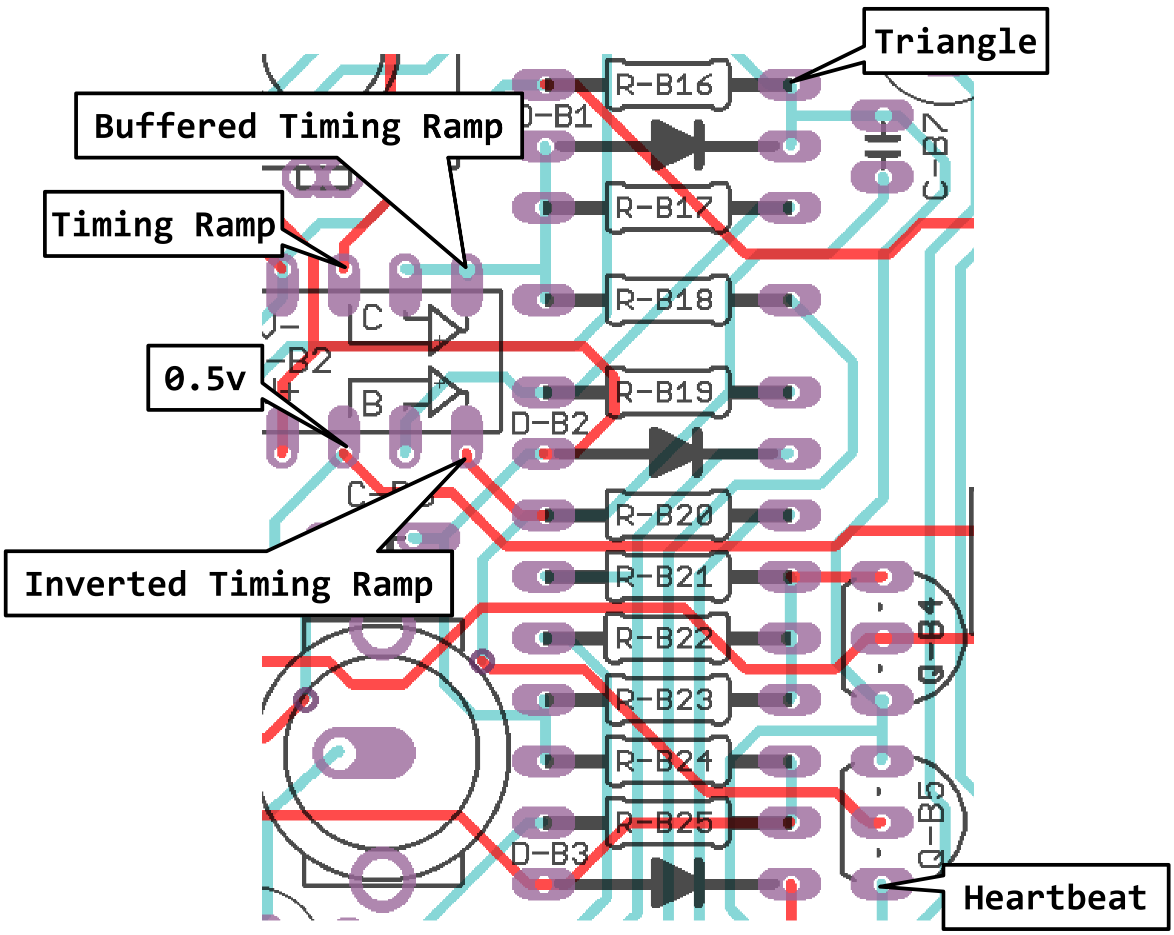
Function Generator is in X mode. FM input is a second function generator also in X-mode. It has been set to make a negative ramp stretching across an entire scanline. FM input multiplies the number of oscillations set by Freq knob.



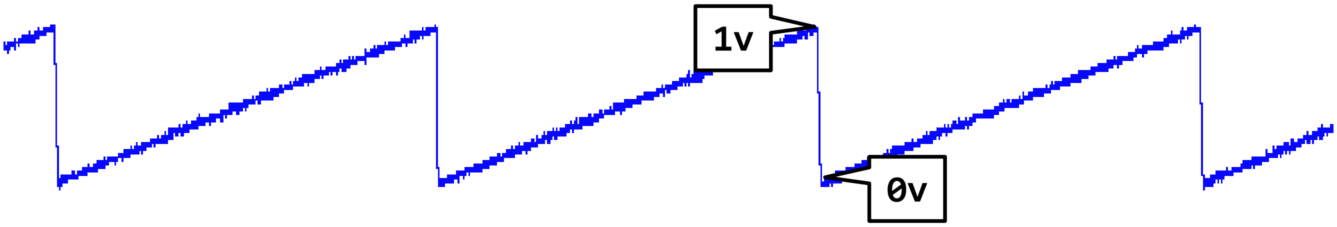
+Slope, -Slope, Triangle, and heartbeat.

The positive slope is generated by running the timing ramp though an op-amp buffer. An inverting op-amp circuit turns the positive slope into a negative slope. A 0.5v virtual ground is used to flip the signal over this axis rather than 0v.

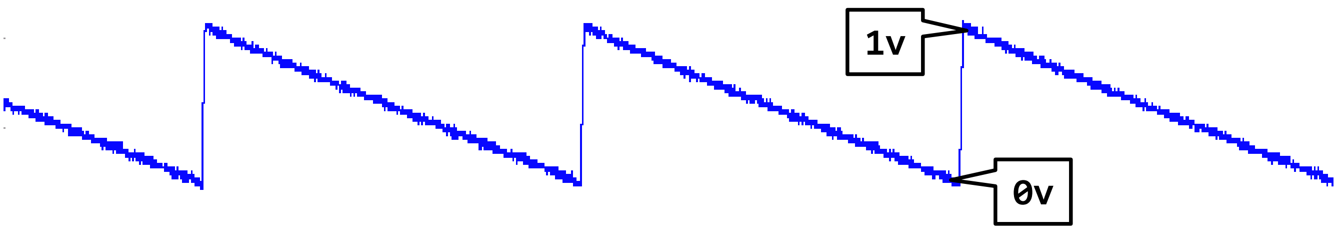
A pair of semiconductors combine the +slope and -slope in a way that selects the lower of the two signals. This produces a triangle wave. One of these semiconductors is a diode and the other is a 2N3904 Collector – Base. The emitter of this transistor will show a negative slope only while the negative slope is less than the positive slope (half the waveform). The output is Hi-Z otherwise. This will result in a waveform resembling an EKG heartbeat after passing through the DC offset normalization stage.



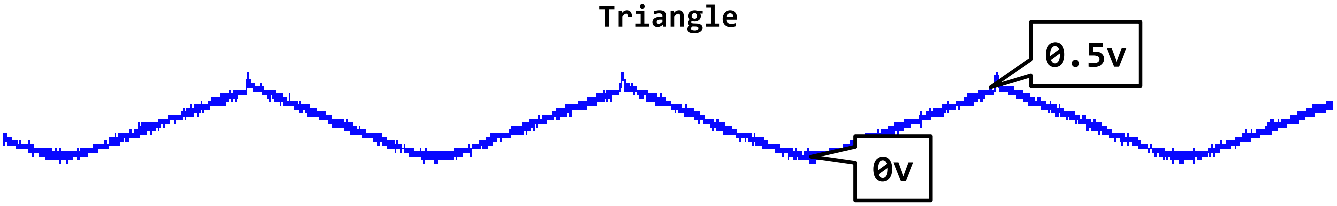
Buffered Timing Ramp (+slope)
This should be identical to the timing ramp signal



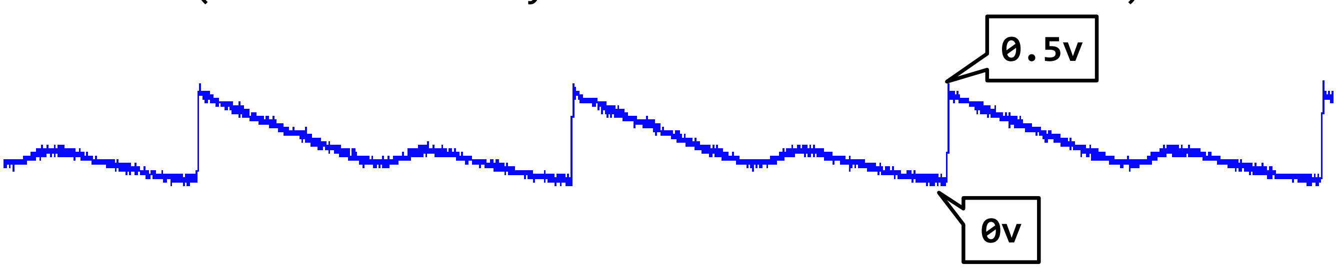
Inverted Timing Ramp (-slope)



Triangle



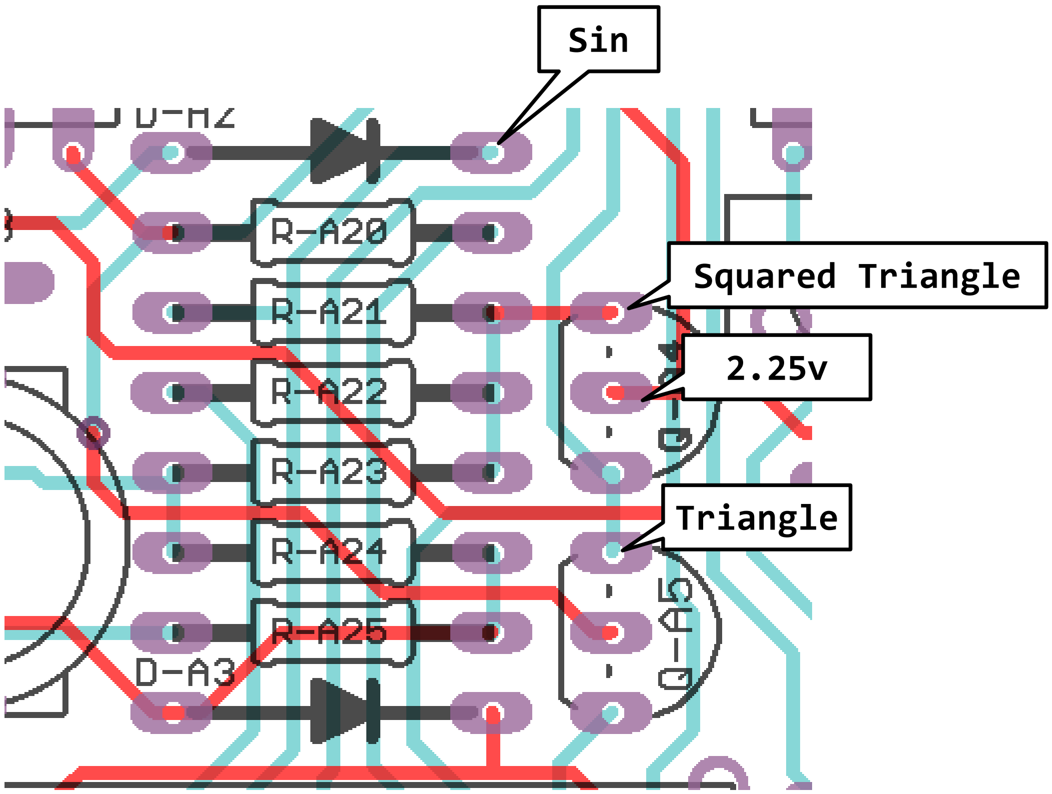
Heartbeat.
(This will look very different after AC normalization)



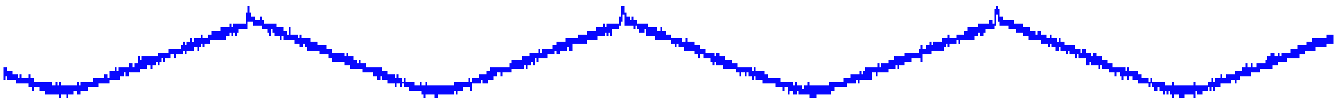
Squaring Amp and Sin Clipper.

The log wave is generated by running the triangle wave through a nonlinear squaring amplifier. This consists of a J113 which has been tested and selected to amplify at a specific voltage. It is painted red to differentiate it from the other J113s used in the kit.

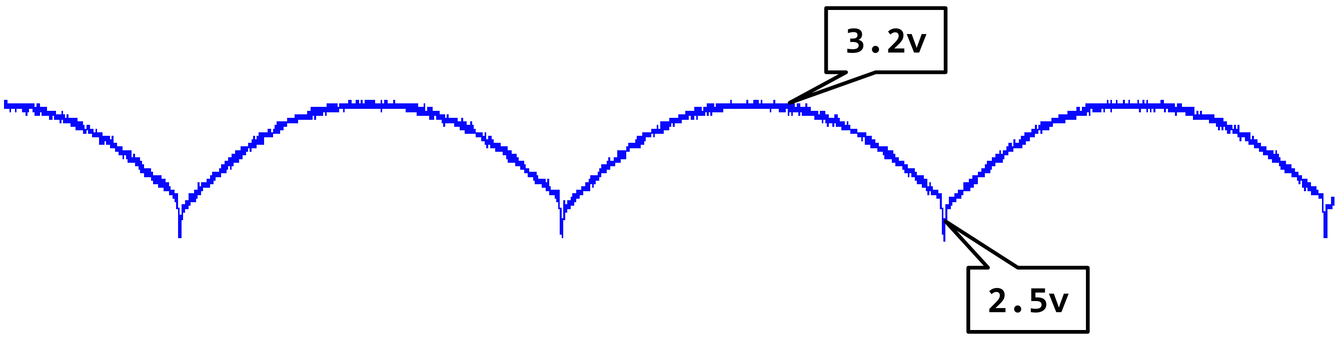
The sin wave is generated by using a diode to clip the bottom of the log wave. The low voltages involved make this bottom clipping also nonlinear.



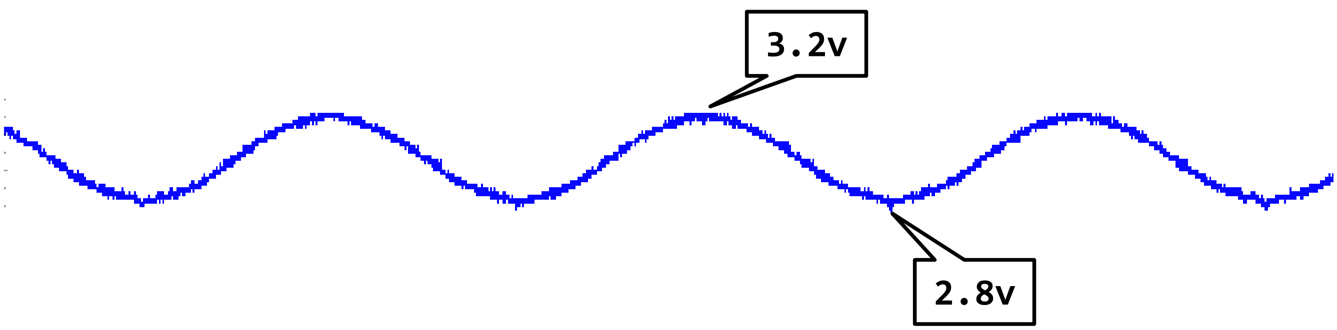
Triangle (input to squaring amp)



Squared Triangle (Log)

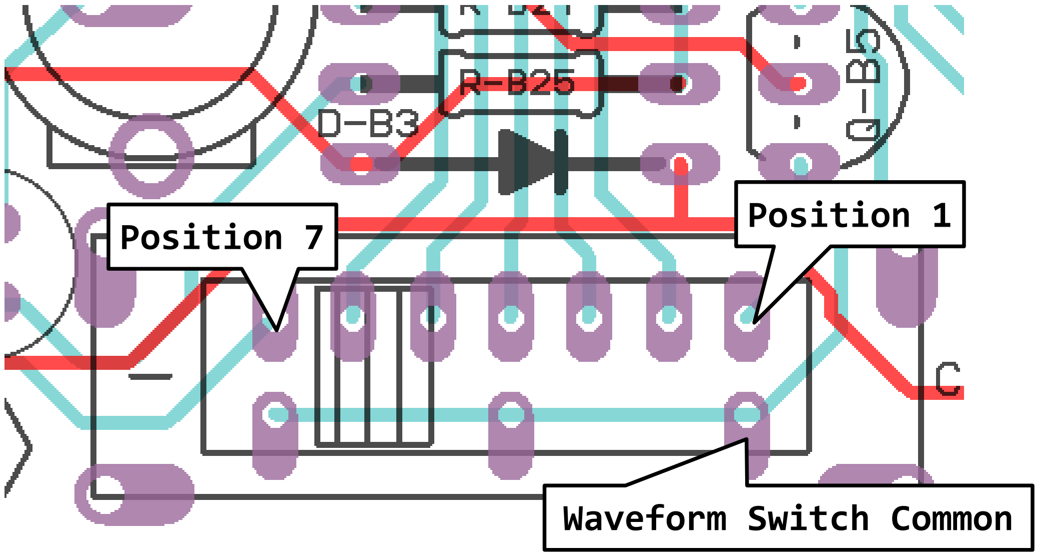


Sin.



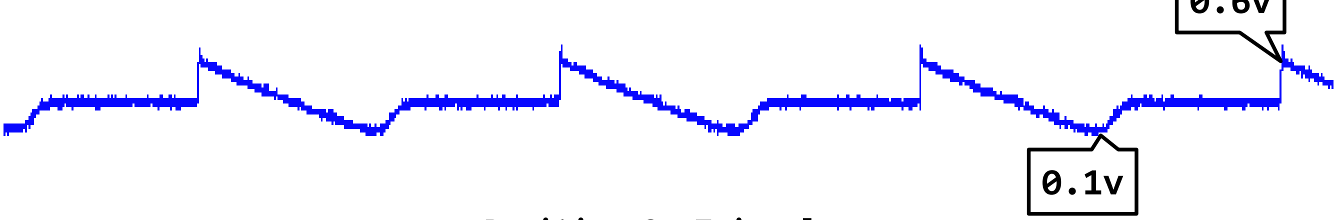
Amplitude Normalization and switch output.

The seven waveforms have a wide range of amplitudes. For example the sin wave is 0.4v peak-to-peak while the ramp waves are 1v peak-to-peak. The higher amplitude waveforms run through resistors before entering the waveform select switch. This brings all waveforms to similar amplitudes. They are boosted back up to 1v signals in the amplitude modulation stage.

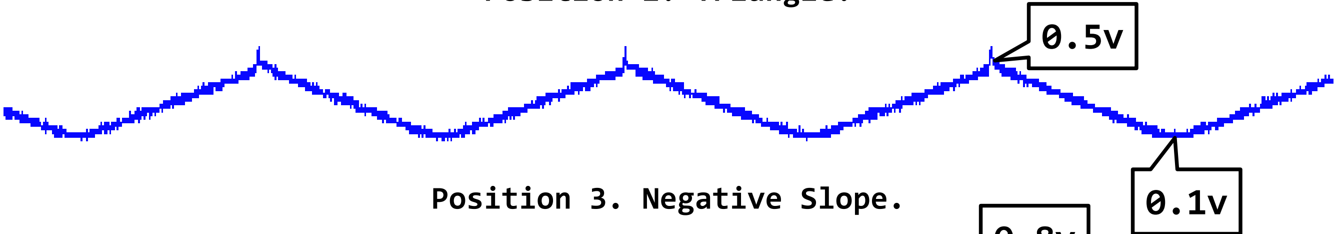


The following table shows the output of the Waveform switch in each position. The function generator is operating in scroll mode so the waveform is not interrupted by PM sync pulses.

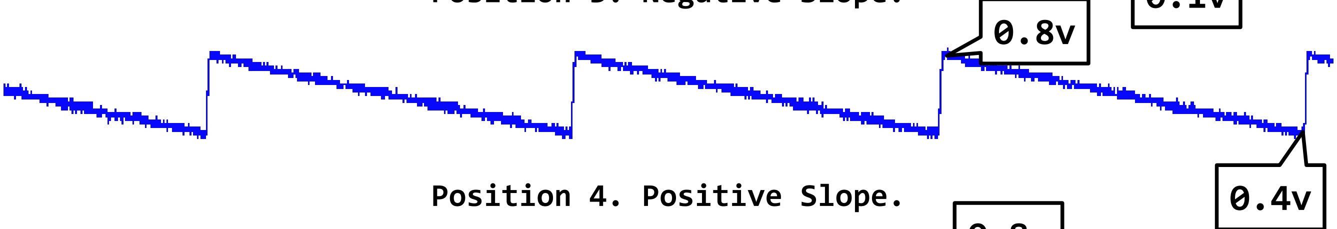
Position 1. Heartbeat.



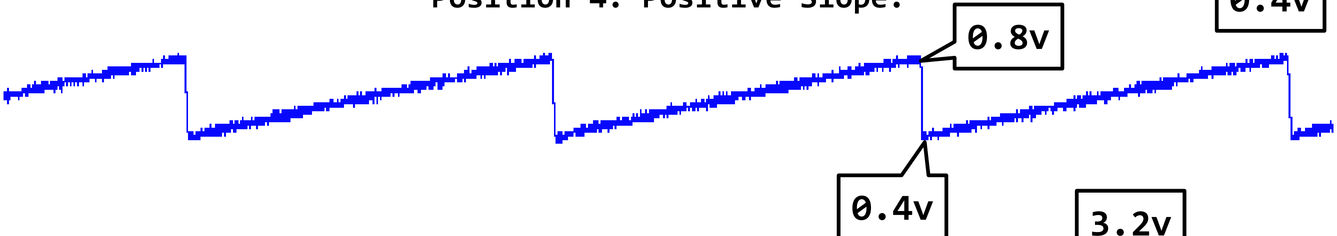
Position 2. Triangle.



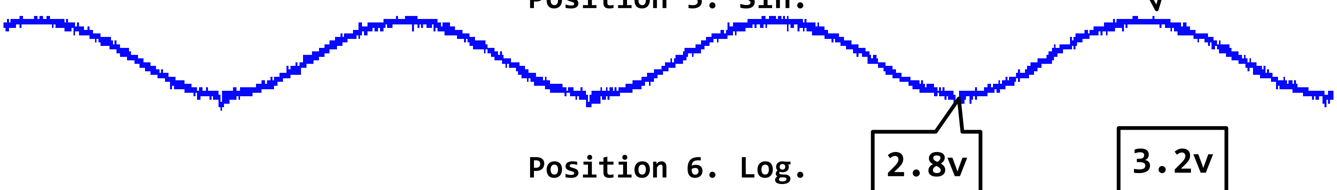
Position 3. Negative Slope.



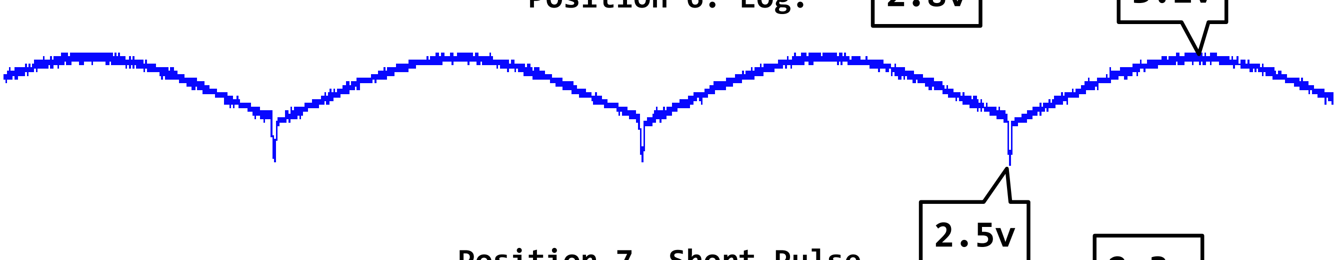
Position 4. Positive Slope.



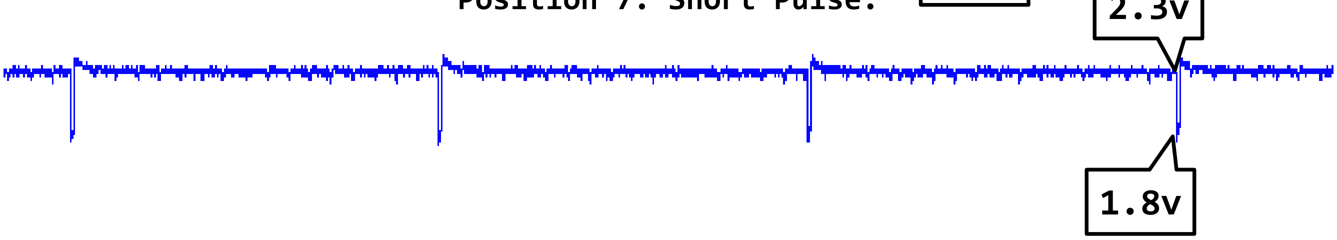
Position 5. Sin.



Position 6. Log.



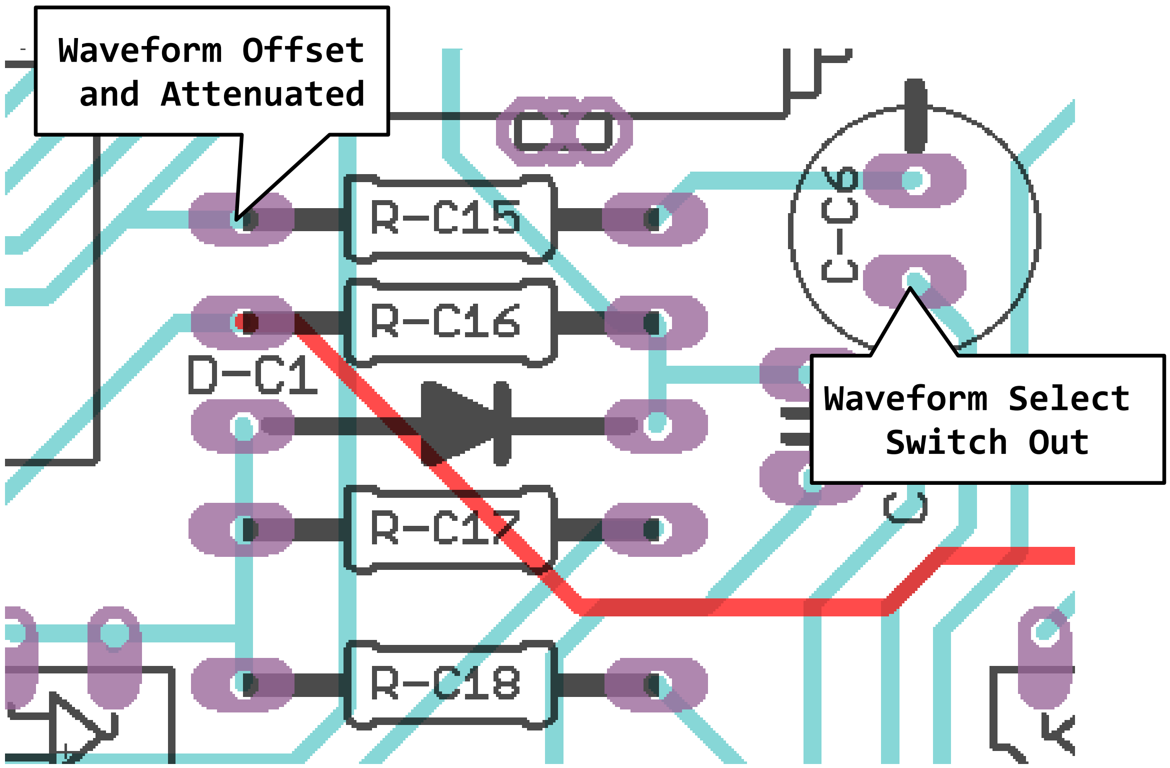
Position 7. Short Pulse.



DC offset Normalization and Attenuation.

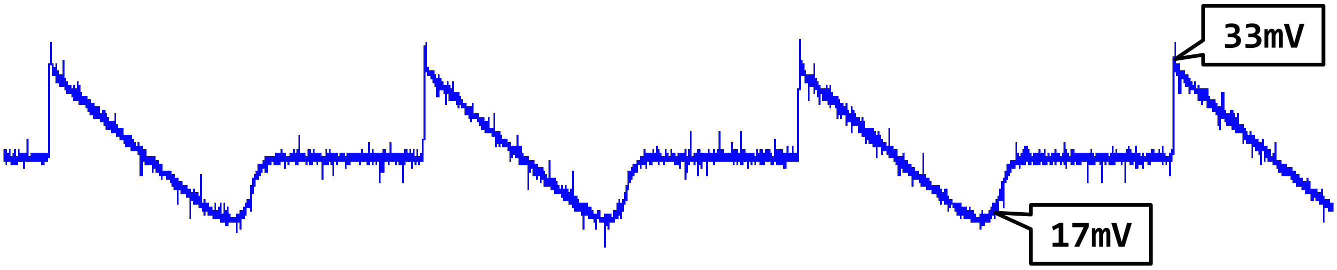
The previous stage has normalized the waveform amplitudes such that they're all about 0.4v peak to peak. The DC offset is still very different among them. For example the sin wave oscillates between 2.8v and 3.2v while the triangle oscillates between 0.1v and 0.5v. This stage uses AC coupling to bring all waveforms to a similar DC offset.

This stage also significantly attenuates the waveforms. This is because the next stage is AM. The AM stage multiples the input amplitude, so its input needs to be low amplitude to make low amplitude outputs possible.

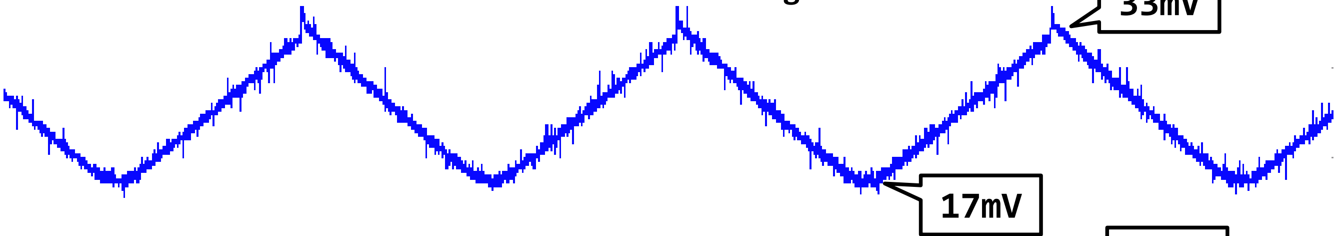


The following table shows each of the waveforms after the DC offset normalization and attenuation stage.

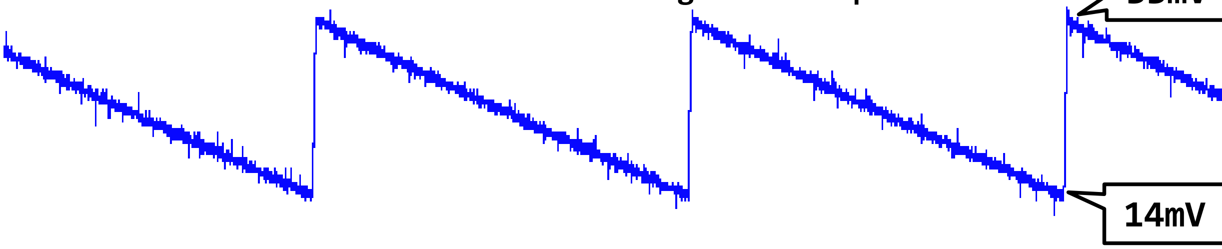
Position 1. Heartbeat.



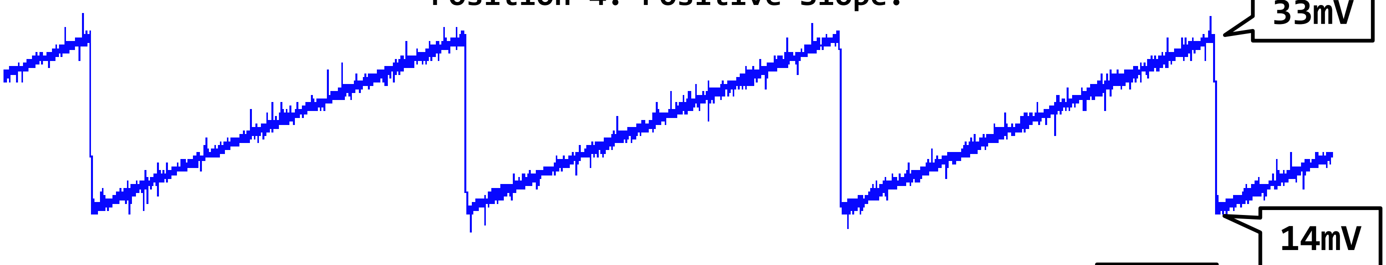
Position 2. Triangle.



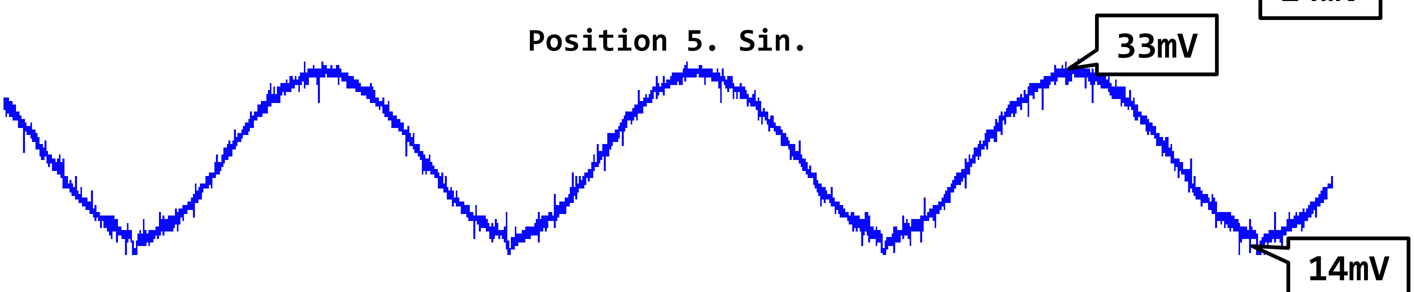
Position 3. Negative Slope.



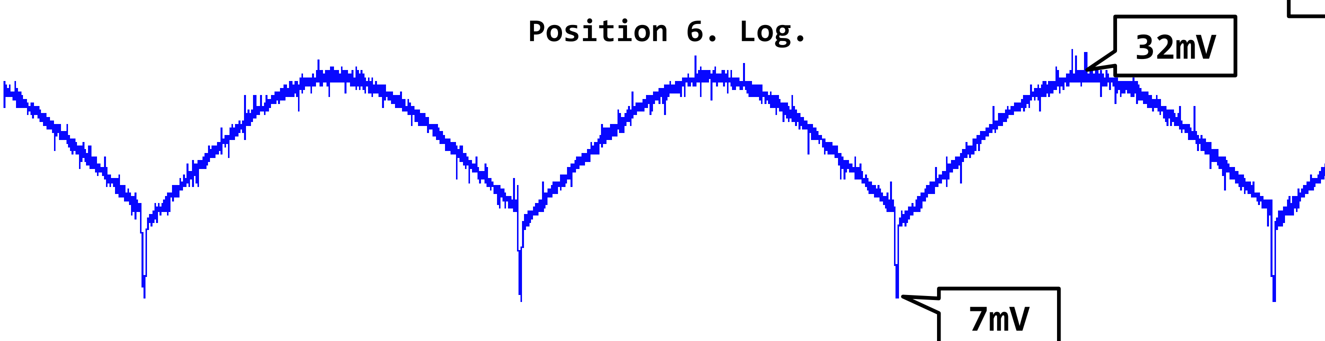
Position 4. Positive Slope.



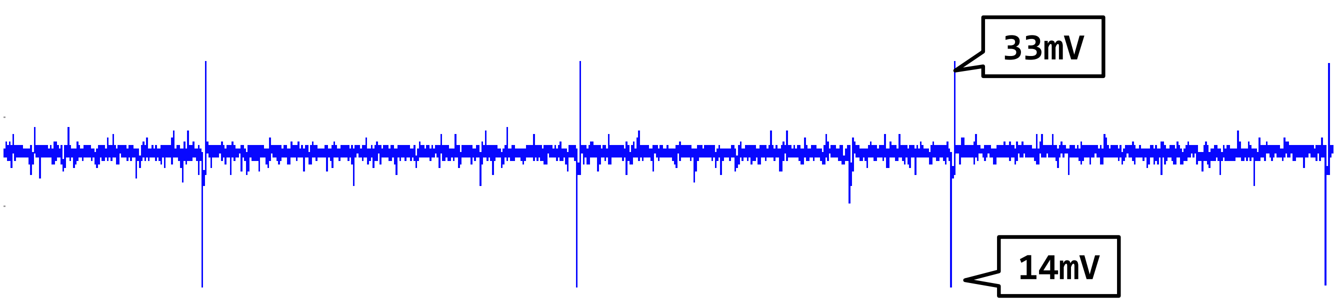
Position 5. Sin.



Position 6. Log.

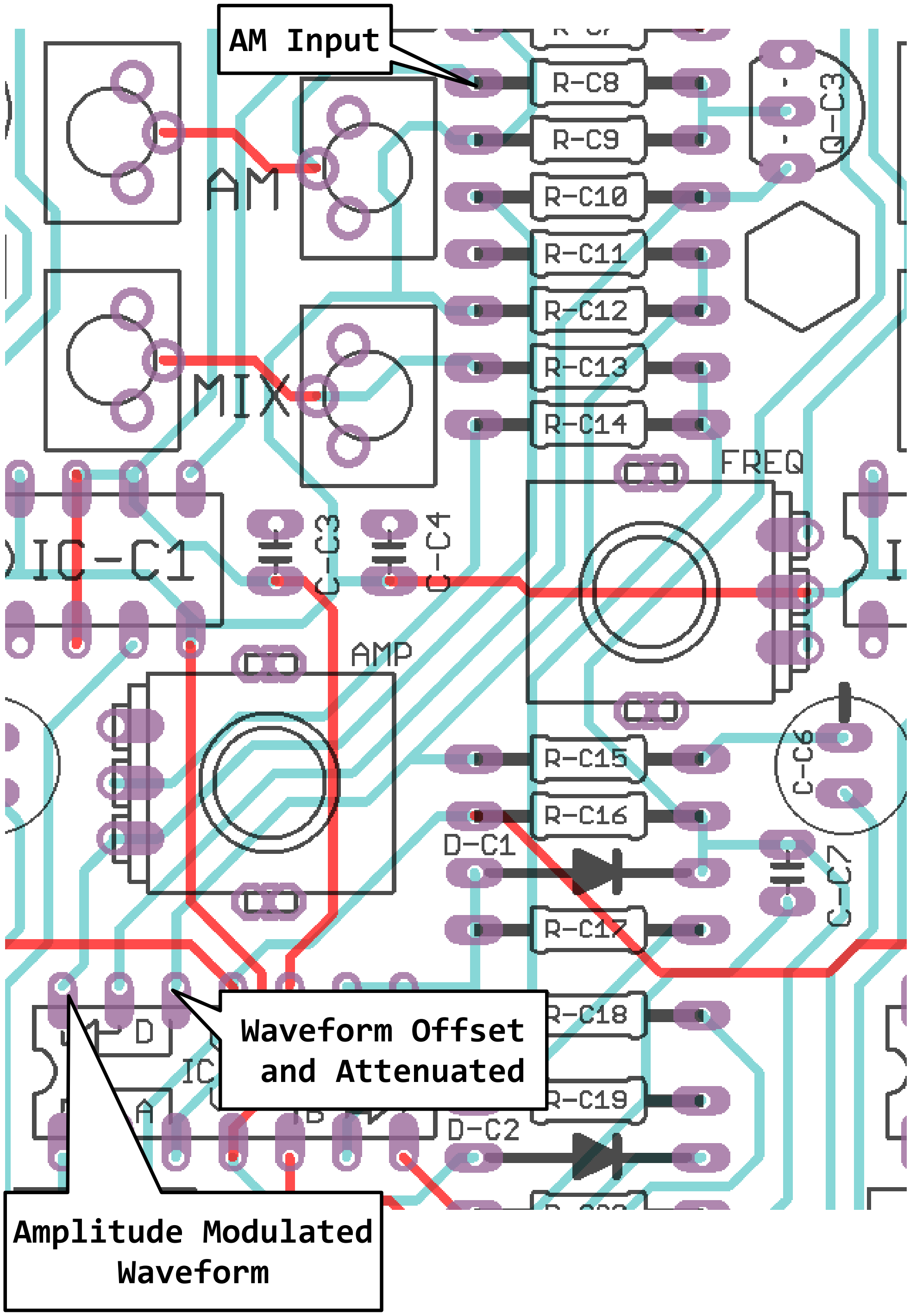


Position 7. Short Pulse.



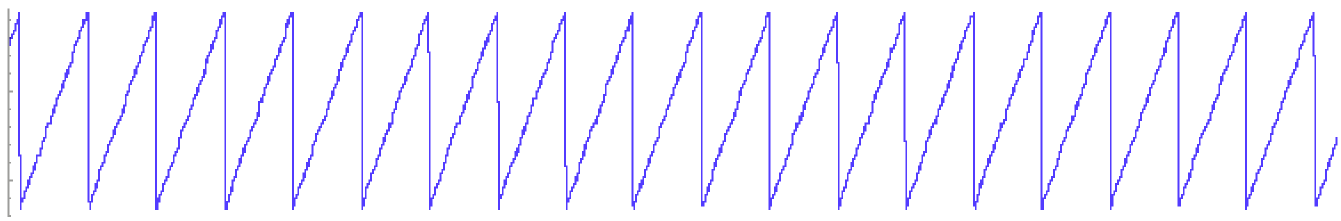
Amplitude Modulation Output.

This stage of the function generator multiplies the amplitude of the waveform by the amplitude modulation input. The circuit works by using a 2N3904 transistor in the feedback path of a non-inverting op-amp amplifier. Resistors R-C8 and R-C9 adjust the AM input to an appropriate level to drive transistor Q-C3.

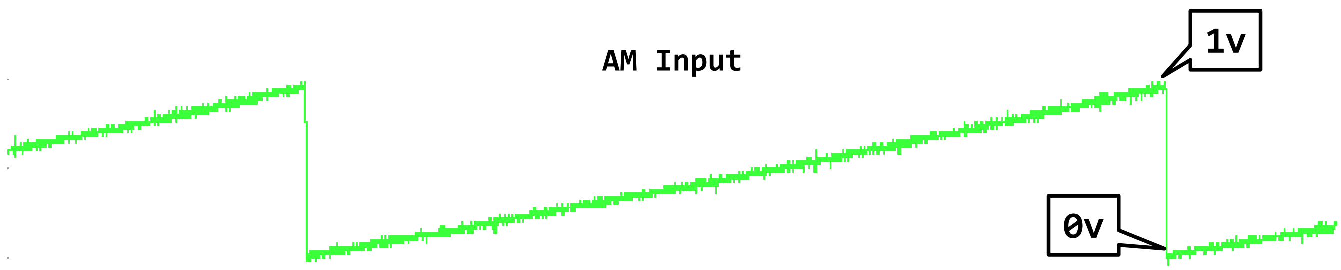


Amplitude Modulation Example

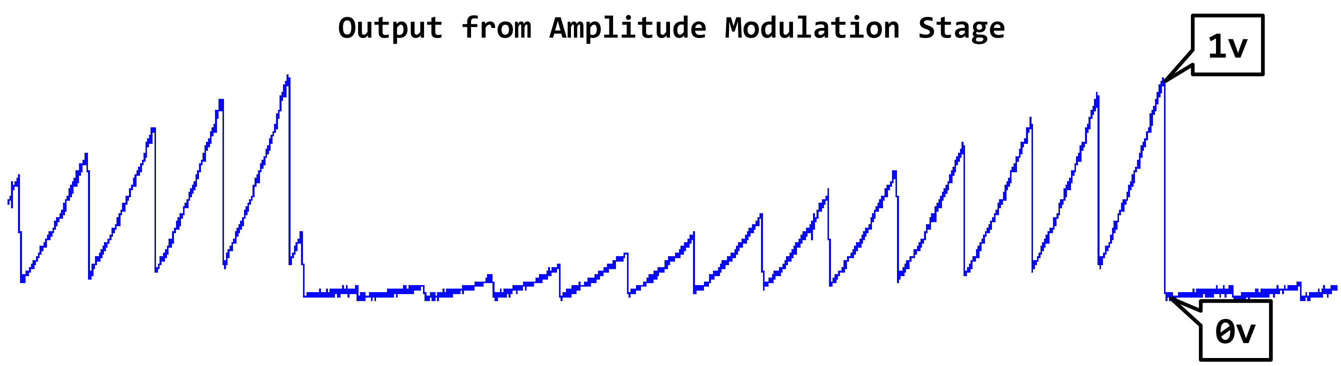
Original Waveform.



AM Input

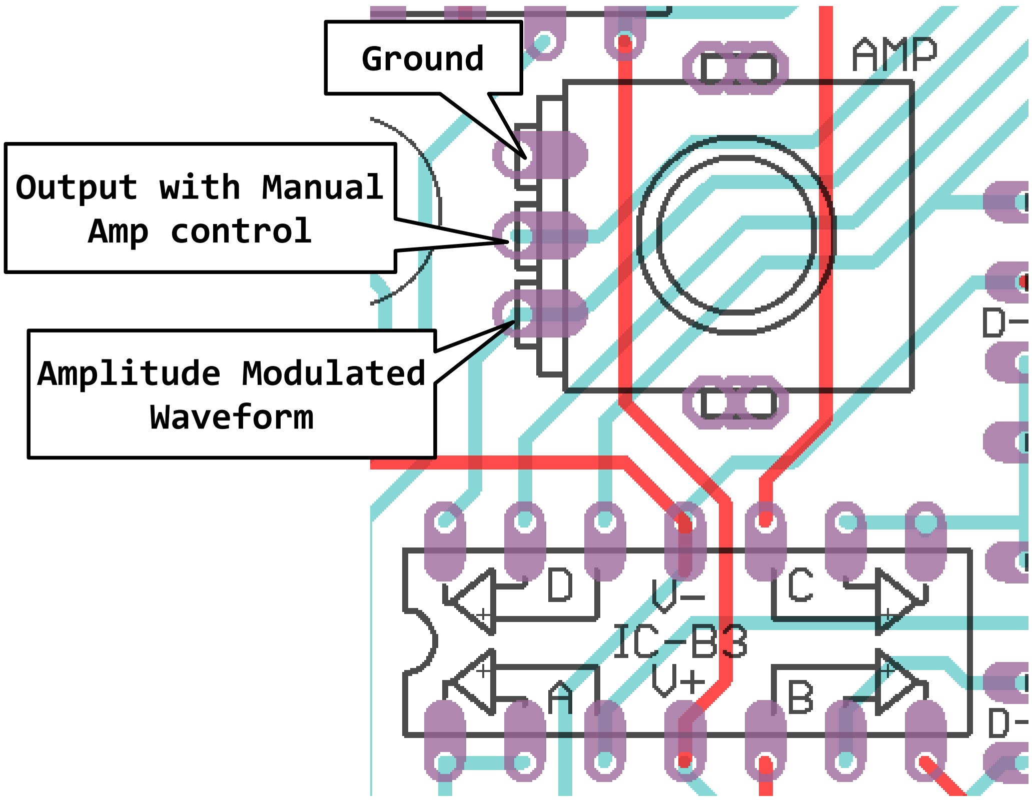


Output from Amplitude Modulation Stage



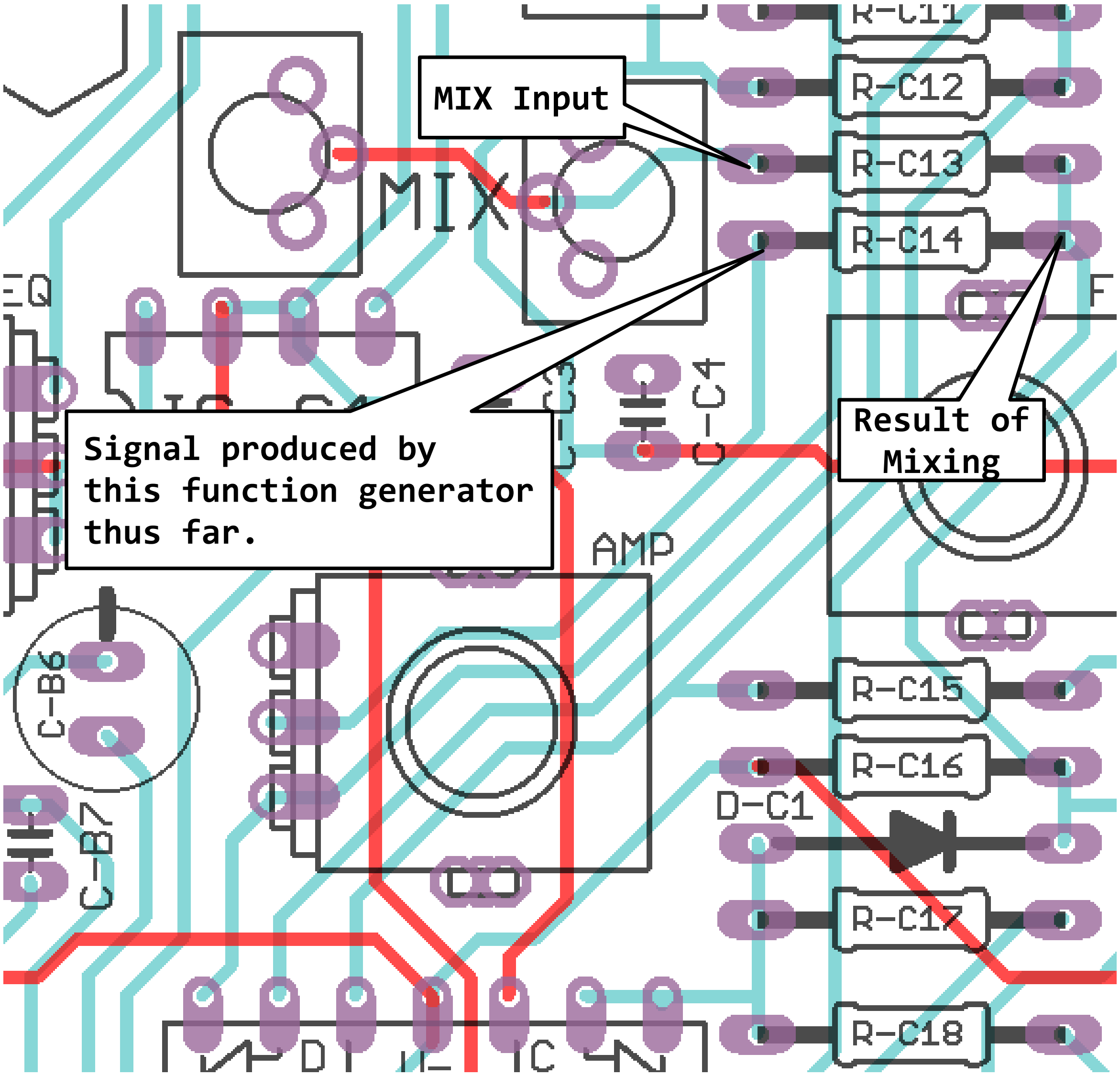
Amplitude Potentiometer

This stage divides the amplitude modulated waveform through a potentiometer voltage divider. It gives manual control over the output amplitude.



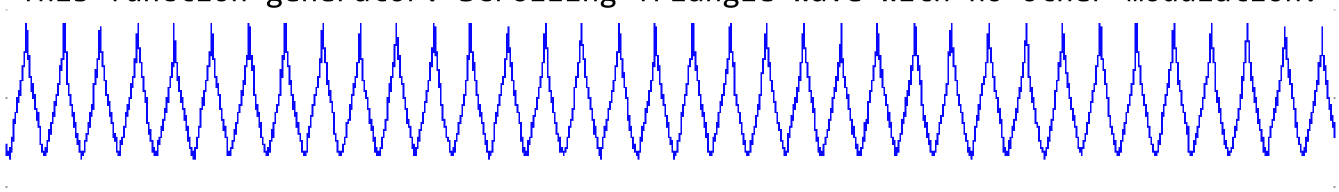
Mixing Input

This stage uses a resistor voltage mixer to add an external signal to this function generator's output. The resulting signal is roughly 50% the product of this function generator and 50% the external signal. When no cable is connected to the MIX jacks the output is 100% the product of this function generator.

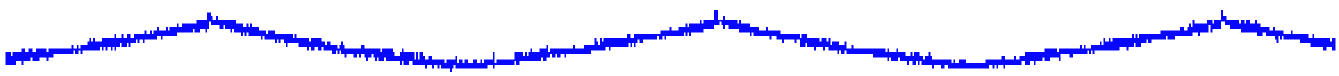


Mix Example

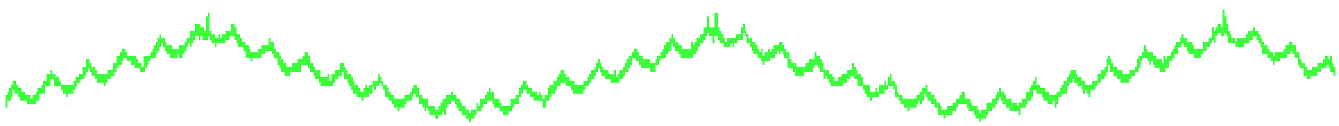
This function generator. Scrolling Triangle wave with no other modulation.



Mix Input

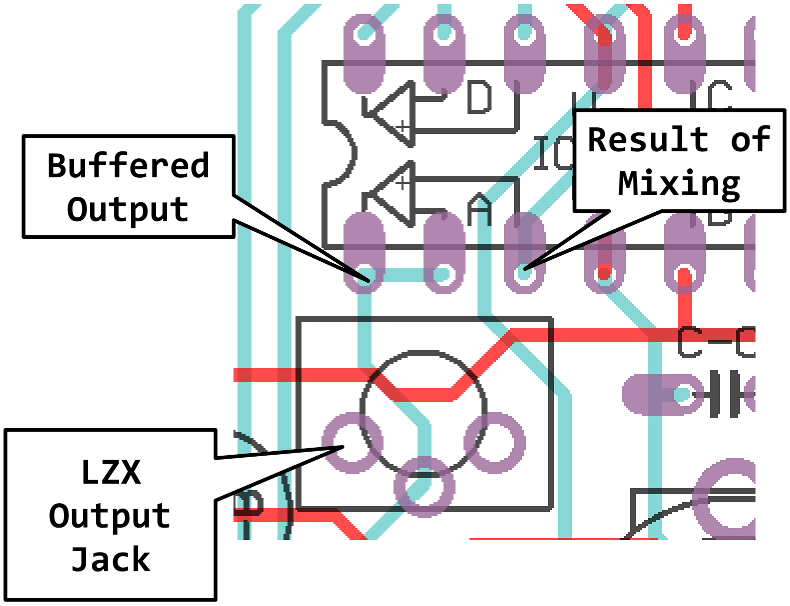


Resulting mixed waveform. Sent to the output buffer.



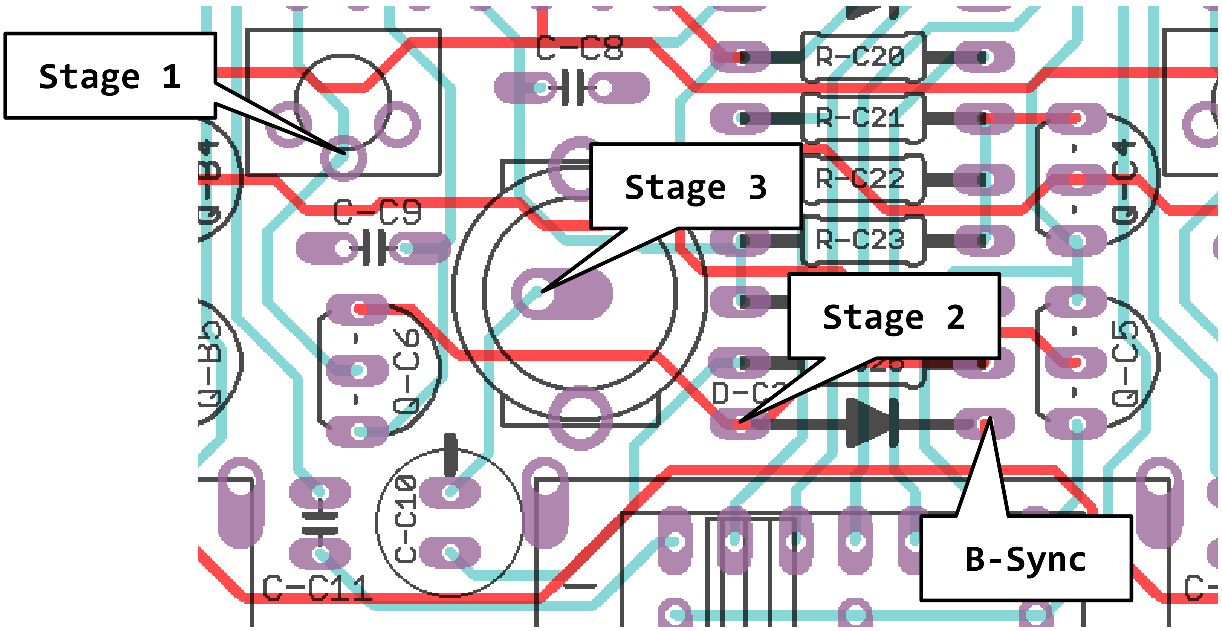
Output Buffer

This final stage uses an op-amp to buffer the function generator's signal before it goes to the output jack. The resulting buffered signal should look just like the input (output of mixing stage).



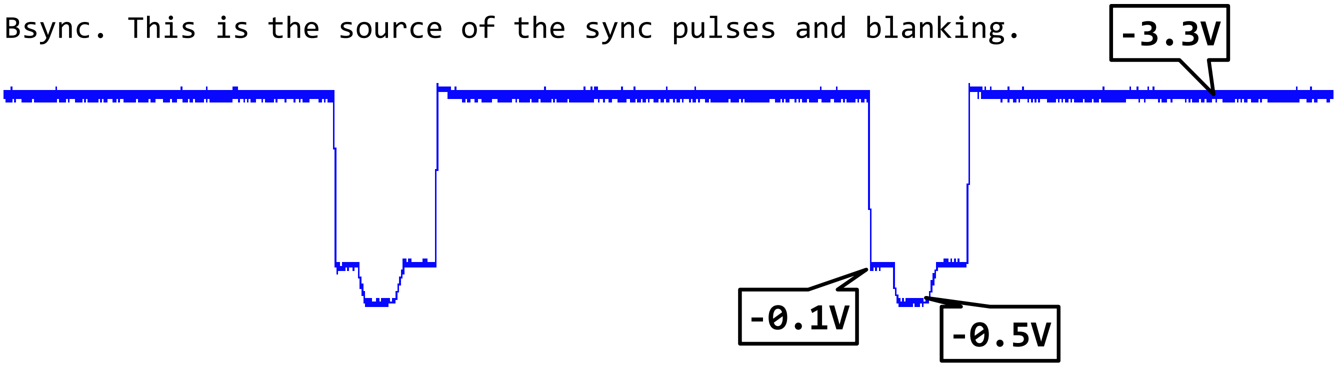
Monochrome video output

This stage allows a function generator to be connected directly to a TV through an RCA Jack. It takes the LZX 0v/1v signal present at the 3.5mm output jack and uses a diode chopper to insert blanking intervals and sync pulses into it. The resulting signal is buffered through a 2N3906 and AC coupled before reaching the RCA Jack.

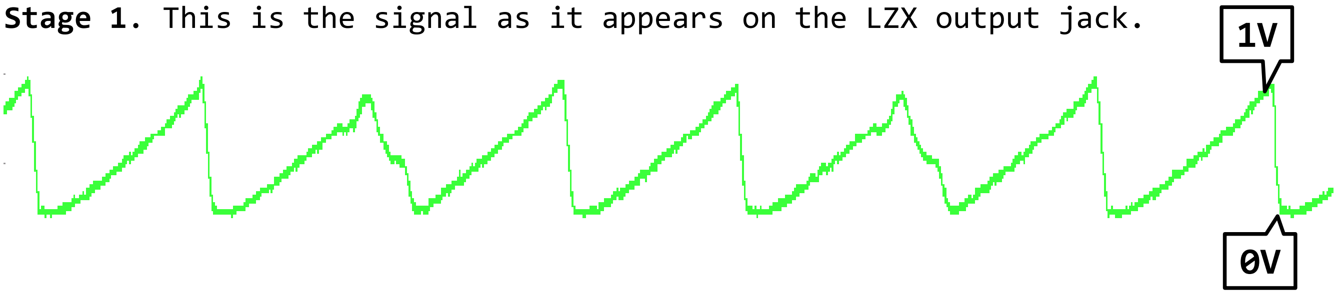


Monochrome Video Out Example Waveforms

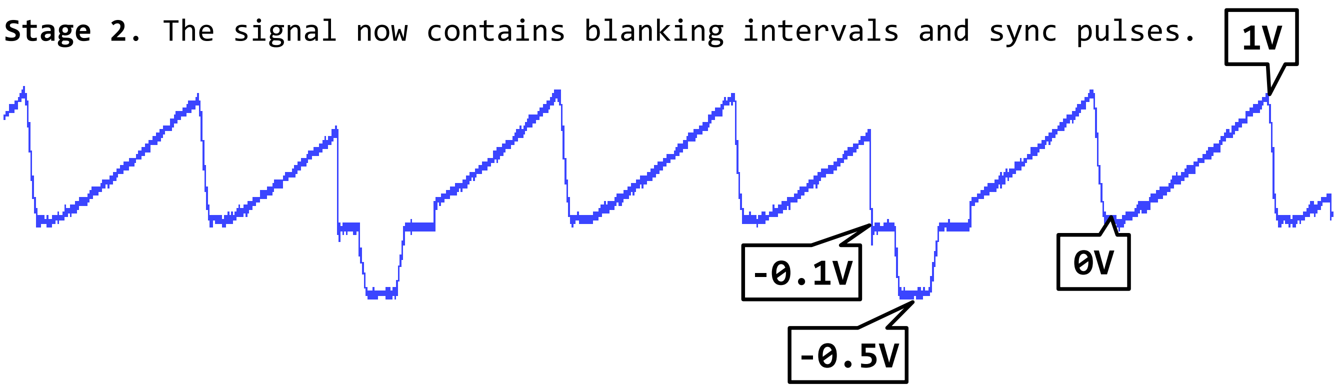
Bsync. This is the source of the sync pulses and blanking.



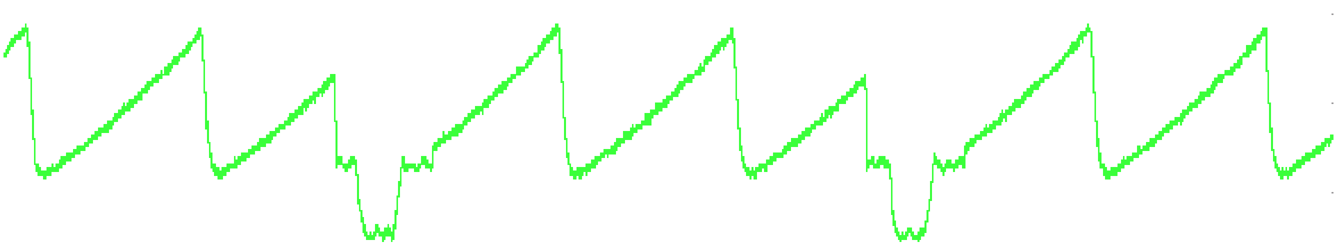
Stage 1. This is the signal as it appears on the LZX output jack.



Stage 2. The signal now contains blanking intervals and sync pulses.



Stage 3. The signal is now AC coupled. This is the signal as it appears on the RCA output jack with no TV connected. Connecting a TV will reduce signal amplitude.



Monochrome output as seen on TV.