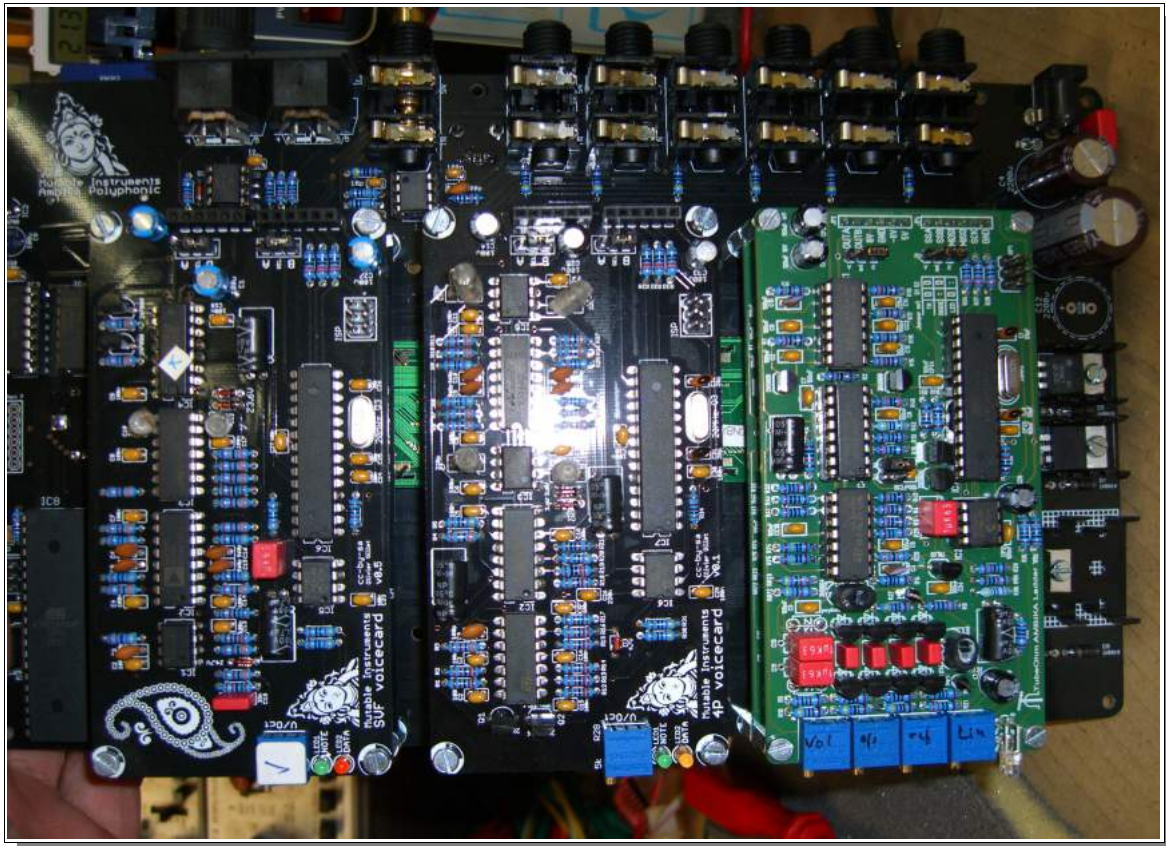


# TubeOhm Ladder Filter for Ambika from Mutable Instruments

DIY instruction, circuit diagram and BOM



DIY Kit:

All components, circuit board and parts listed in the BOM have been thoroughly tested. We suggest that you order your components in accordance to the attached BOM. The filter board has been built several times using those parts and was functional right away.

Building a filter that is functional is mostly in your hands.

Therefore you should take your time and first read through this build instruction.

It is a DIY-Kit and it might be helpful if you're able to read circuit diagrams in order to troubleshoot a malfunctioning board.

We could only warrant flawless function if we, TubeOhm, shipped the filter boards ready built, which would theoretically be possible, but not the purpose of a DIY-Kit

We do not take responsibility for faulty built filters, destroyed equipment, like for example amplifiers or speakers, damage to the AMBIKA or electric shock.

That's part of what DIY means; You build on your own responsibility.

Should your filter board still refuse to do its job after you did some troubleshooting, you're welcome to send us an e-mail and in exceptional cases you can send your faulty board back to us.

Usually it boils down to very minor mistakes which you didn't see.

If you have questions beforehand, feel free to drop us an e-mail at [Kontakt@TubeOhm.com](mailto:Kontakt@TubeOhm.com)

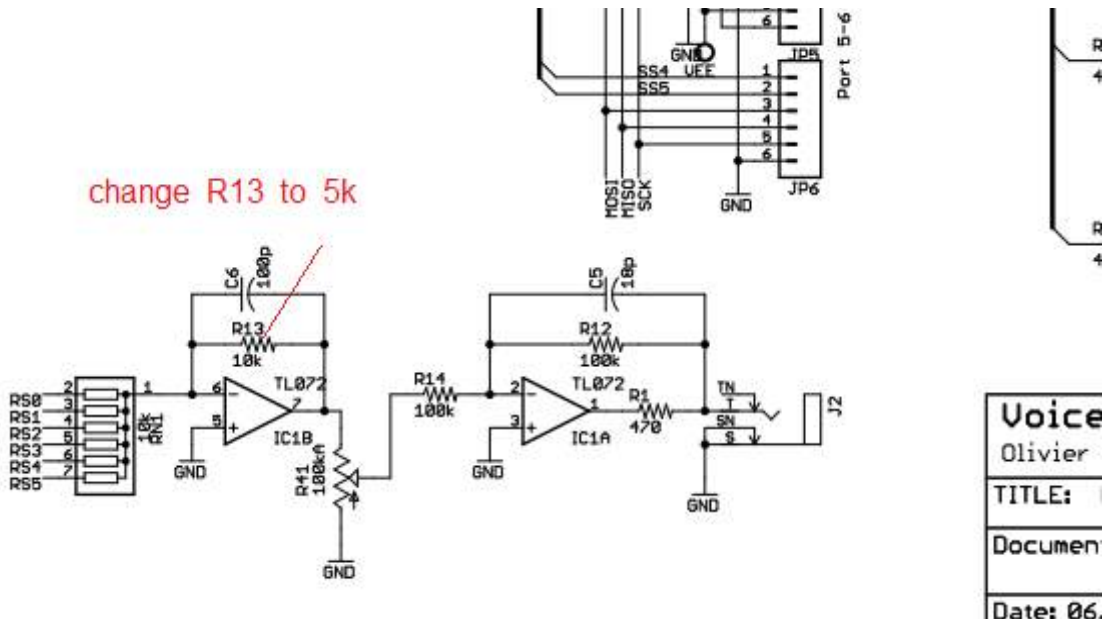
**Some info in advance:**

Building the ladder filter is not a begginer project. However, if you got some experience with soldering and handling a multimeter, the build process will be rather easy.

Furthermore you will need a frequency counter and a guitar tuner. Our Filter-Calib tool will work just fine. You can also use another software of your preference.

Be careful when you're going to test your ladder filter, as it can produce high amplitudes. Use the volume poti to adjust the volume of the ladder filter to match your other voice cards. If you decide to equip your AMBIKA with 6 ladder filters, we suggest to make a modification in the following way:

In order to keep the OpAmp on the AMBIKA from being overdriven, R13 on the motherboard should be swapped with a 5 kOhm resistor.



## **Introduction and functional info, please read !!!**

The Ambika ladder filter uses a transistor/diode-cascading (voltage multiplying) circuit to create the typical ladder-sound.

During development we kept in mind, that a ladder filter can use either transistors, diodes or even LEDs as current-driven resistors.

However, after final testing with various semiconductors, transistors, diodes/LEDs, we came to the conclusion that a transistor ladder filter provides the best sound.

The transistor ladder has a homogenous sound and with a high resonance, the signal amplitude doesn't drop as much as is the case with a diode/LED filter.

Nevertheless, if you want to get experimental, you have the option to build a diode filter with the same circuit board.

Further, we implemented 3 distinct modes in our filter, which can be set and saved inside the Ambika filter menu.

Usually you can choose between following modes on your Ambika:

- 1:) Low-pass (LP)
- 2:) Bandpass (BP)
- 3:) High-pass. (HP)

The ladder filter is designed as low-pass only, hence there is no bandpass or high-pass, but instead you can choose between „Crunch Mode“, „Normal Mode“ and „Distortion Mode“

This can be done by selecting:

- 1:) LP = crunch mode
- 2:) BP = normal Mode
- 3:) HP = distortion mode.

The „Crunch Mode“ is realized by coupling the original signal from the DAC via R50/C37 into pin 3 of IC4/1.

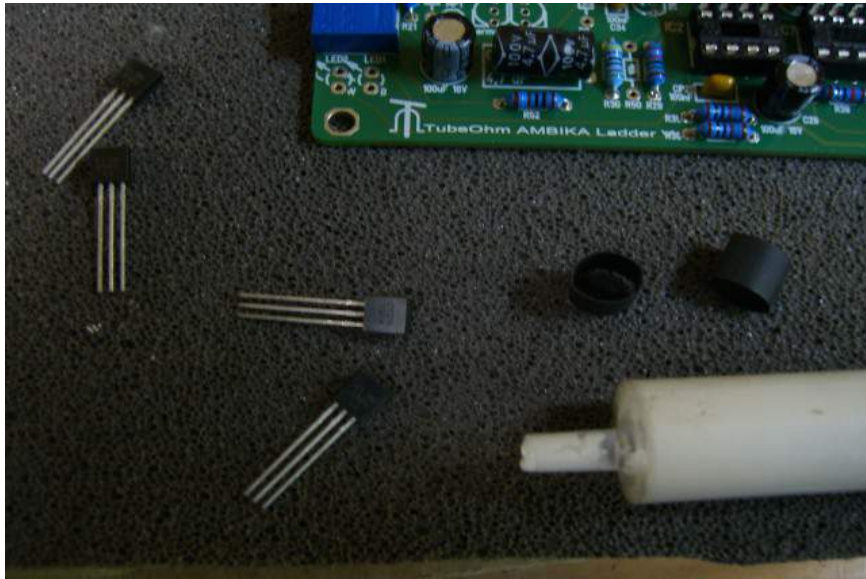
The „Normal Mode“ doesn't use this coupling.

The „Distortion Mode“ uses the coupling and also sets the differential amplifier controlling the currents within the cascade, asymmetrical. This results in the differential amp being unbalanced so that it distorts the signal. R52 gets connected to ground and thereby, via IC8C, modifies the operating point of the right transistor belonging to the differential amplifier.

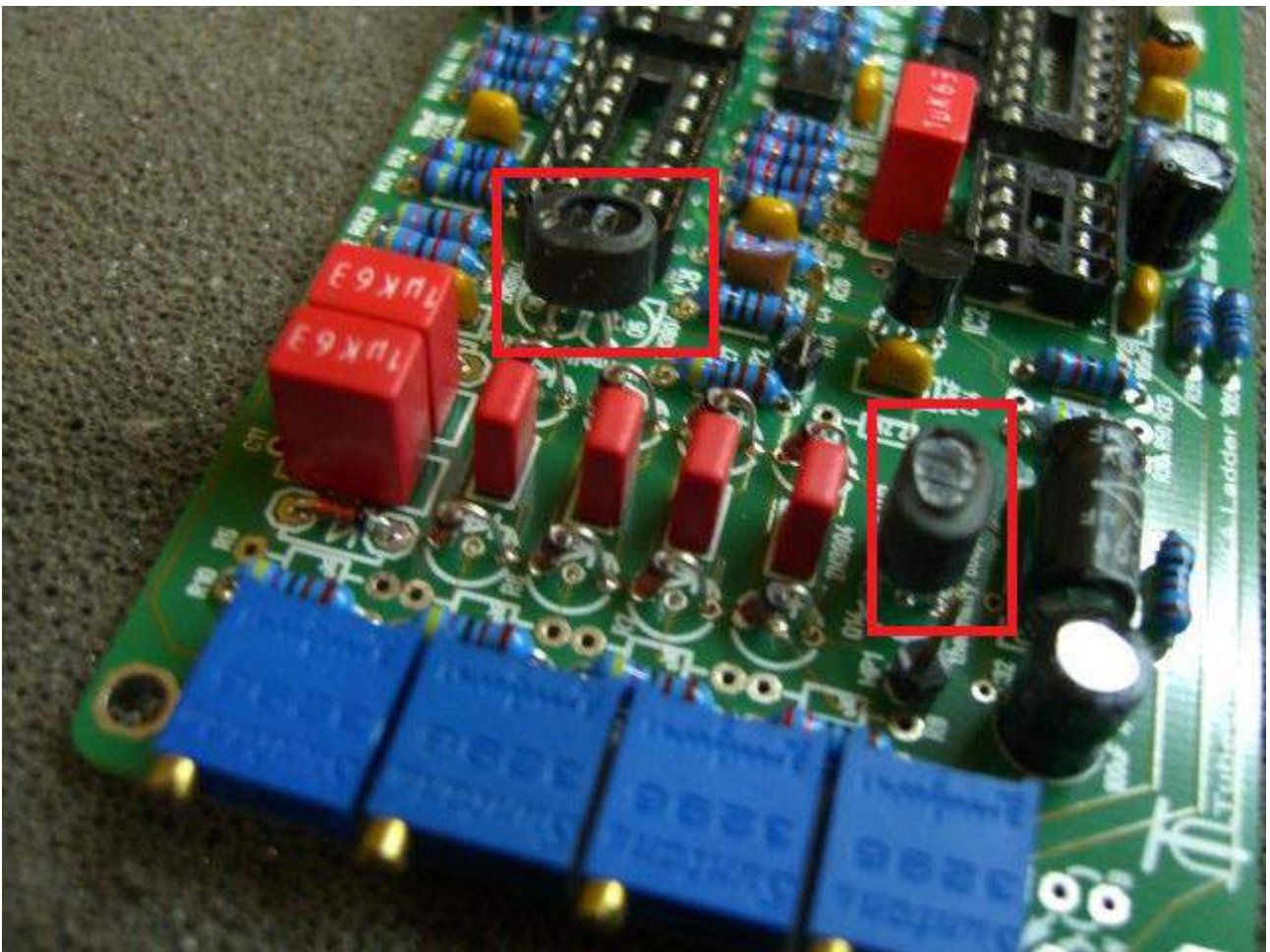
## **Temperature drift.**

The Atmels, aswell as the power supply heat up the Ambika significantly. The two transistors belonging to the differential amplifier and the two for the log converter need to be thermically coupled, otherwise the cutoff might have a significant temperature drift.

The transistor-pairs need to be coated with some thermal grease and joined within shrink tubing. In our kit this already happened.



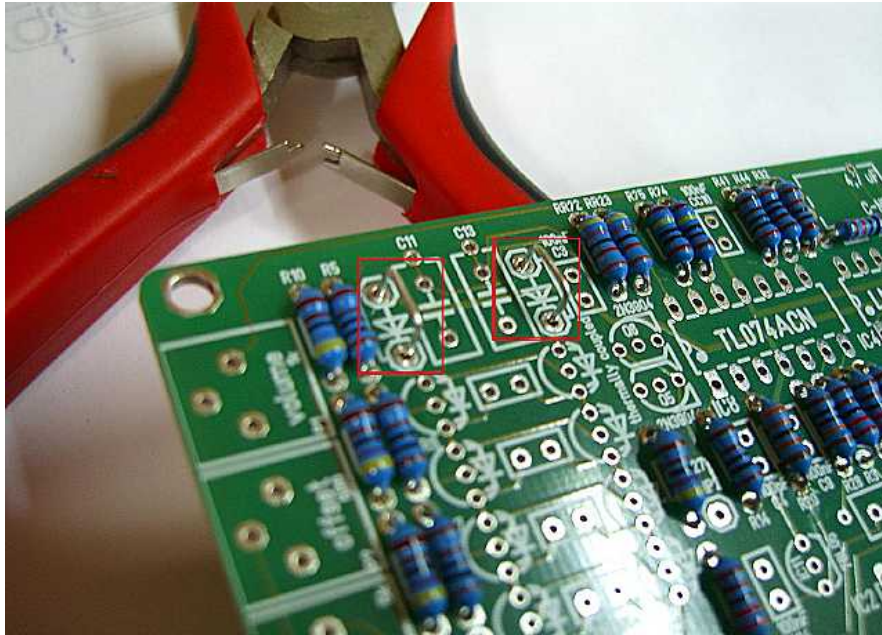
This is how it should look like after soldering the transistor pairs. The process is identical for the transistor and diode type of ladder filter.



Picture diode ladder

## Different filters – transistor, diode, LED

When building a **transistor ladder**, 2 bridges for the power supply need to be soldered as shown below



ONLY do this for the transistor ladder filter !!!!!

For the **diode filter**, 2 1N4148 diodes will go into these holes instead. There is no need to place the resistors R5, R6, R7, R8 and R9. Instead of transistors, 1N4148 diodes will go into the collector-emitter-path of the printed transistors. Also mind the 4 ladder capacitors, which will be 47nF for the diode filter.

Diode and LED filter are identical except for the capacitor values.

Conclusion:

### Transistor ladder

- 1:) Put the 2 bridges
- 2:) Solder 8 matched transistors
- 3:) Couple-capacitors C17,C15,C7 and C21 = 100nF

### Diode ladder

- 1:) 2 1N4148-diodes instead of bridges
- 2:) 8 x 1N4148 into the collector-emitter path instead of transistors
- 3:) Disregard R5,R6,R7,R8 and R9
- 4:) Couple-capacitors C17,C15,C7 and C21 = 47nF

### LED ladder, standard 3mm LEDs in red, no high current LEDs

- 1:) 2 LEDs instead of bridges or diodes
- 2:) 8 x LEDs in place of diodes/transistors. Treat them the same as diodes.
- 3:) Disregard R5,R6,R7,R8 and R9
- 4:) Couple-capacitors C17,C15,C7 and C21 = 68nF

## A couple tips before commencing the build

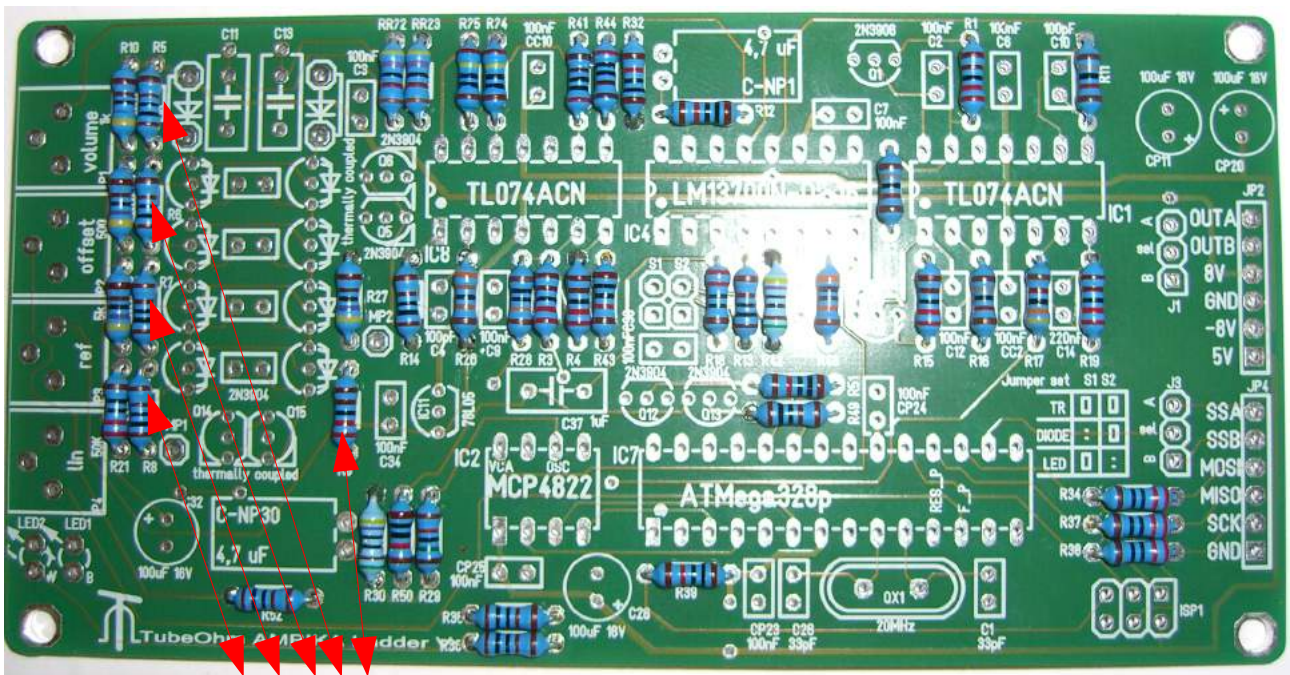
Nothing is more difficult than finding selfmade mistakes. Double-check the parts you're soldering – correct values? Positioned correctly?

Alright, grabbed a coffee, locked out the wife and the kids are gone? Mute the telephone and smoke a cigarette (or don't, because - unhealthy).

Soldering iron hot, pliers and parts ready? Lets go.

### First off are the resistors.

PLEASE, if you're unsure about the resistors' values, check them with a multimeter !!!!!



For the **diode/LED Ladder** you dont need to solder the resistors R5,R6,R7,R8,R9. Keep it free.

### Once all resistors are in place, proceed with the IC-sockets

Watch the markings !!

### After that come the capacitors/oscillator

**Careful!** C14 =220nF, C4 =100pF, C 10 =100pF. Solder these first to avoid mistakes.

The impulse-capacitors are 100nF

**Transistor:** The ladder capacitors for the transistors are **4 x 100nF film**

**Diode :** The ladder capacitors for diode 1N4148 are **4 x 47nF film**

**LED:** The ladder capacitors for diode 1N4148 are **4 x 68nF film**

### Oscillatory-capacitors - important !!

C26 and C 1 are 33pF. These depend on the used crystal oscillator !!! We are using the 20 Mhz crystal from Reichelt with a load capacity of 32pF.

Other manufacturers are using crystals with 18...22pF load capacity. Thereof, if using different crystal oscillators, the capacitors need to be adjusted.

**Please watch the polarity** on the 100µF capacitors; the 4,7 µF capacitors have no polarity.



### **2N3904 NPN:**

All capacitors placed ??? Double-check ! Now for the semiconductors.

For the transistor ladder we need 8 matched 2N3904, a pair thermally coupled for the differential amplifier, another pair for the log converter and 2x 2N3904 serving as switching transistors for the filter modes.

### **2N3906 PNP:**

2x 2N3906 are being used to drive the VCAs and the resonance (Q2/Q1)

### **78L05:**

To stabilize the reference voltage, we use a 78L05 / 100mA (IC11)

**Pay attention to the labels, as the 78L05 looks like a regular transistor !!!**

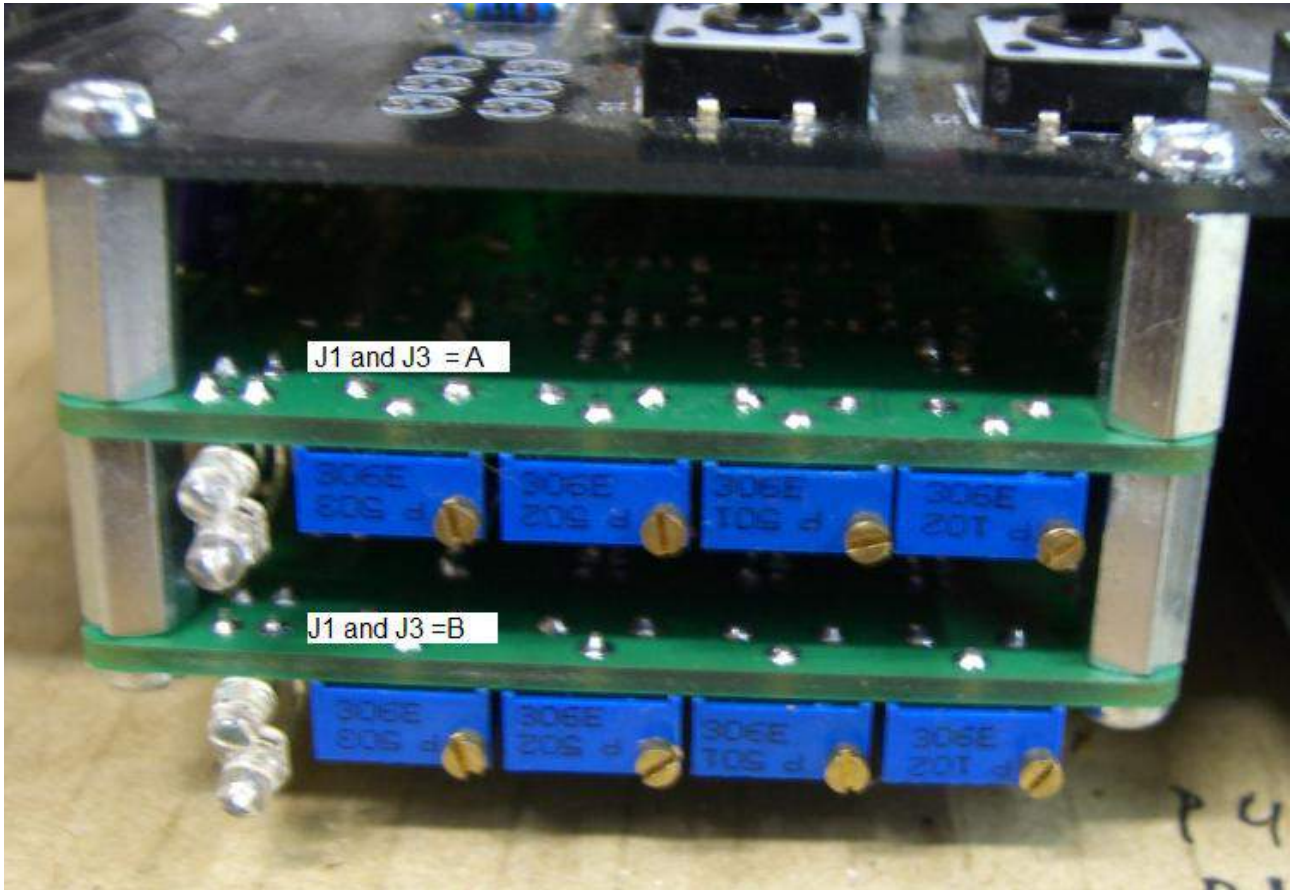
Everything soldered? Great. Now we can move on to the pots and connectors. That's all.

Don't forget:



## Jumpers !!!!

J1 aswell as J3 let you set the voice card order and the output routing. Both jumpers will have to be set up on each voice card. Set the jumpers on the first voice card, which are close to the motherboard, to „A“ and on the second card to „B“ as shown below.



Next to the output selector J1 (A/B) and the selector for the Atmel J3 (A/B) are the pins S1 and S2, which let you select between the different filter types (transistor/diode or LED) and the feedback behaviour.

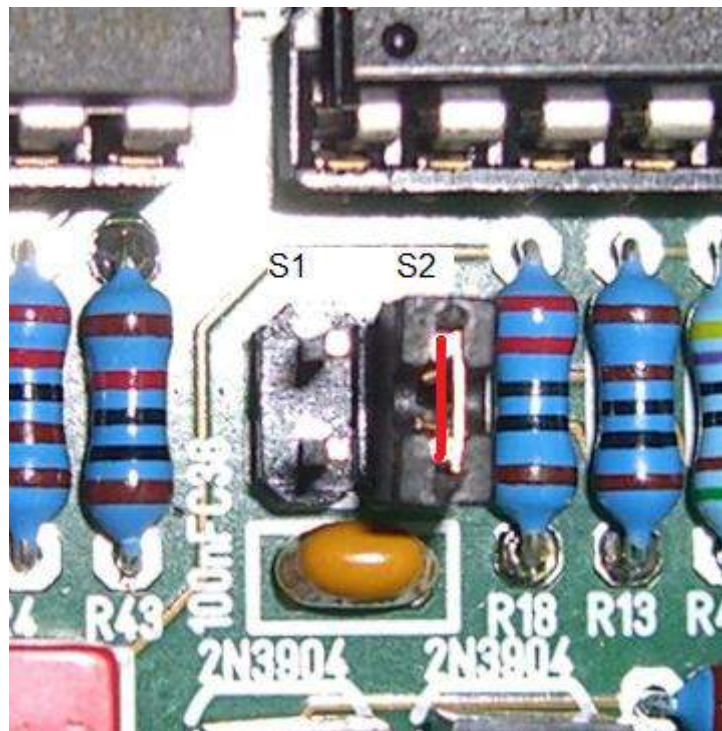
When using the transistor filter, S1 and S2 will be bridged via jumper.

Apparently the transistor filter allows for more resonance than intended. If desired, for higher resonance, only S2 may be bridged and S1 left open !!!! This will run the transistor filter with a diode kind of feedback !!

The same setting is used for the diode filter.

For a LED filter only S1 is bridged.

From a technical perspective, the signal amplitude is lowered by R13/R42. The jumpers connect either R13 or R42 or both to ground, modifying the voltage divider R43/R13/R42. The feedback signal is lowered.



## Measure the voltages before you insert ICs.

First make sure there is no short circuit between +8V/-8V and ground. Use a multimeter set to „Ohm“ to measure between these points. Please do not insert the ICs just yet.

Measure between 5V and ground to make sure there is no short circuit either.

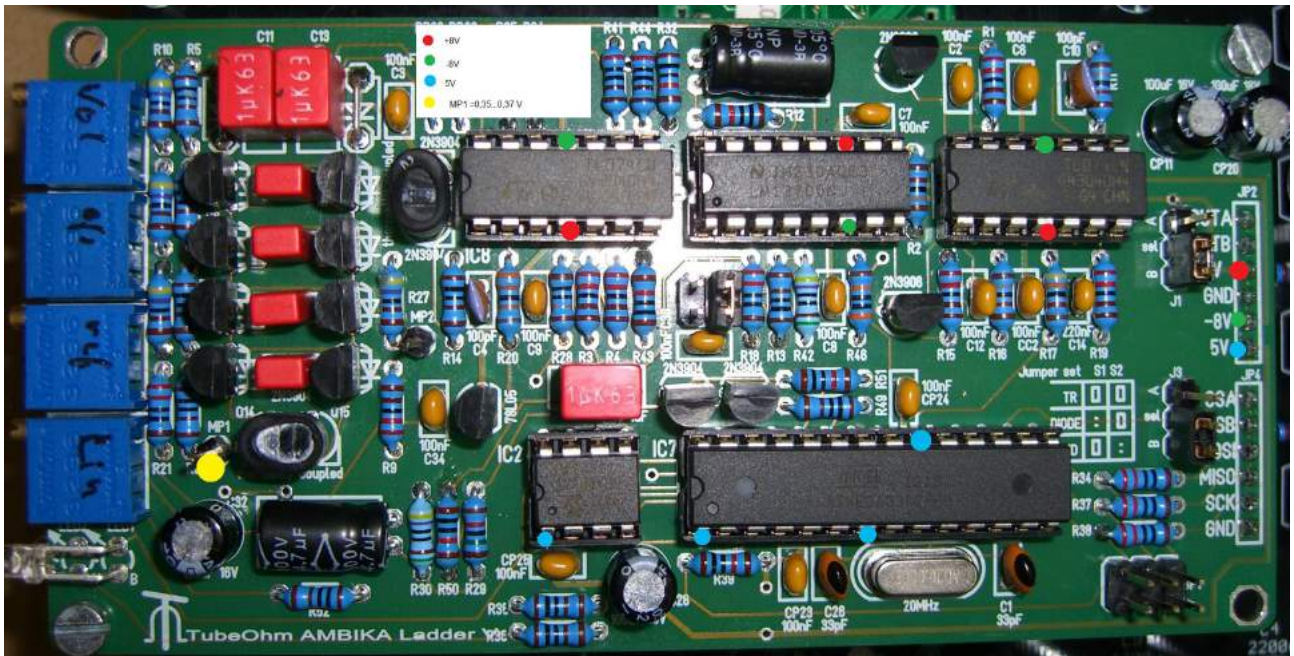
You can now plug the board without ICs into your Ambika and measure the voltages. +/-8V and 5V are where they're supposed to be?

**Red = 8V**

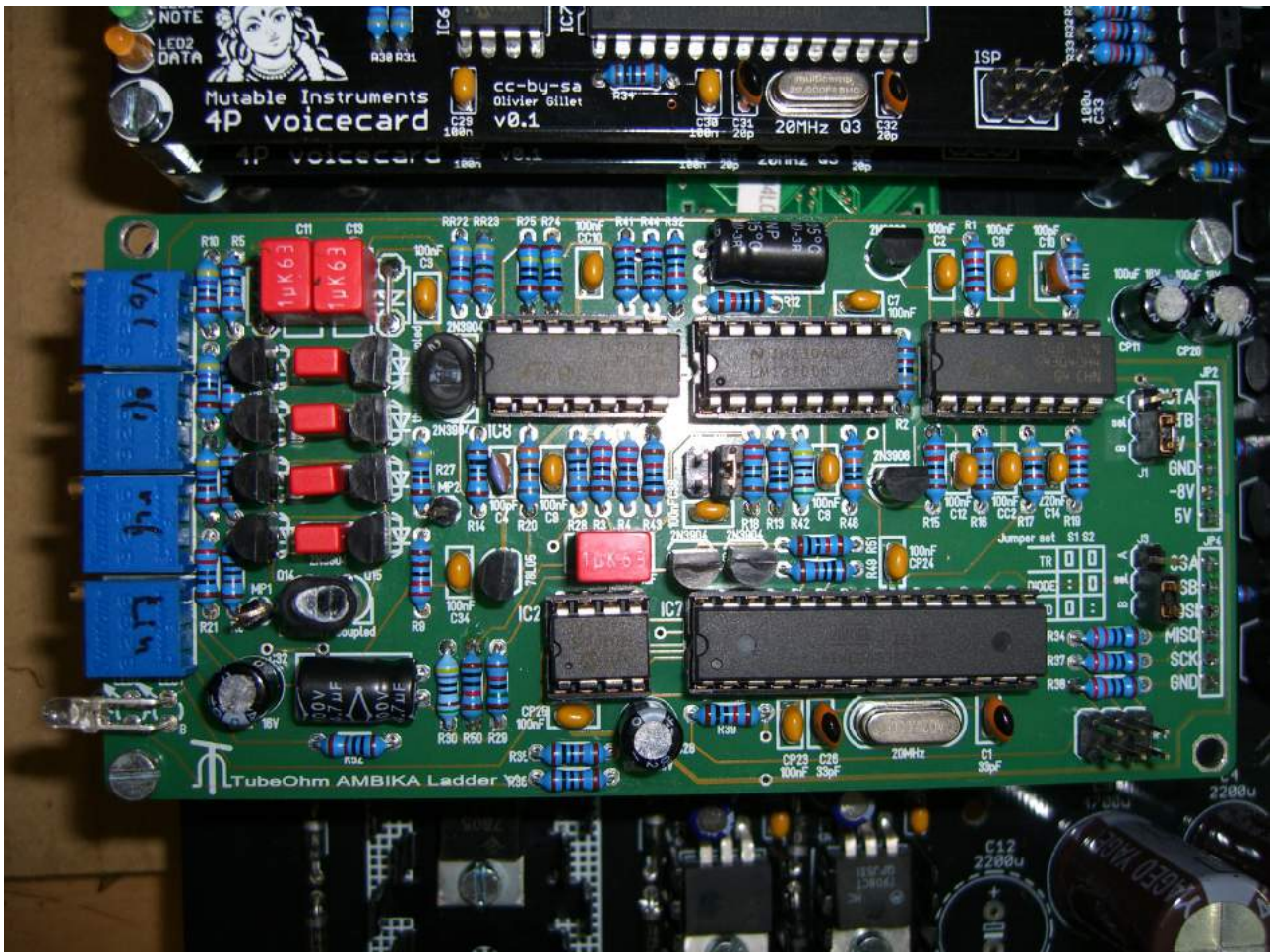
**Green = -8V**

**Blue = 5V**

**Yellow = MP1 0.35...0,37V**



The board should now look like this:



### Adjusting.

Don't panic, it's only 4 pots. One step at a time.

From left to right with the component side of the board facing downwards, we have the following settings

Linearity	Reference	Offset	Volume
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**Linearity:** Sets the amplification of V/OCT control voltage.

**Reference:** Shifts the log control voltage and is used to match the cutoff frequency between multiple filters.

**Offset:** Tunes the differential amplifier

**Volume:** Sets the volume for the whole filter.

Now comes the exciting part. All ICs are inserted, Ambika gets powered on and nothing is smoldering? Good.

Check that the filter is set active on the Ambika. The LEDs should light up when notes are played, indicating most things are functional. If you can hear something that's even better.

Let's adjust the board.

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**If you're not hearing anything, it could be that the volume poti is set to 0. Turn it to the left or right until you can hear something.**

**Step 1:** Offset first. Grab the multimeter and set it to VDC.

Measure the voltage between ground and measuring point 1 (MP1). You should get readings around 0.35-0.37V. On my filter it is at 0.356V.

**Step 2:** Now measure the voltage at measuring point 2 (MP2) and use the offset-poti to adjust the voltage to match MP1. MP1 and MP2 should now both have ~0.35-0.37V. In that case the differential amp is running synchronous.

**That's that.**

### **Calibrating Linearity.**

In order for the filter cutoff to exactly follow the control voltage V/OCT, the amplification needs to be set to a value that doubles the resonance frequency with each octave.

Start with setting ADSR and LFO to 0 in the Ambika filter menu; resonance to maximum.

Turn off both oscillators and suboscillators

Nun sollte man die Filter-Oszillation hören. You should be able to hear the filter-oscillation.

Eventually the cutoff needs to be raised a little bit.

Playing notes will create a rather crooked sound utilizing only the resonance frequency

This is where we need our frequency measurement tool.

**Step 3:** Connect the frequency measurement tool or guitar tuner. Then play a note, for example C3, and tune the cutoff frequency to 100 Hz. Play C4 next. The frequency needs to be at 200 Hz. C5 accordingly at 400 Hz.

**Step 4:** Using the linearity poti will set the amplification to a degree that accurately doubles the resonance frequency from one octave to the next higher one.

It is recommended to repeat calibration a few times, because adjusting amplification will influence low and high frequencies unequally.

When done right, playing notes while still utilizing only resonance frequency will now sound proper.

\*\*\*\* You can also try to calibrate by listening, if you've got an experienced ear for that.

**That was the linearity calibration !**

## **Equalizing reference**

Why reference? Equalizing the reference will make multiple filters share the same cutoff frequency when playing the same note. Tolerances may lead to filter 1 having 1000 Hz on a played note, whereas filter 2 is at maybe 1300 Hz, filter 3 maybe at 800 Hz... You can't help that fact with standard Ambika filters, but with these you can.

Equalizing the reference principally shifts the whole control curve up or down without affecting the log curve.

You could think of it as an additional cutoff controller for the operating point of the filter.

## **Equalizing:**

Turn the oscillators back on in the Ambika.

### **>>> Ambika with just a single ladder filter:**

**Step 5A:** Set the poti so, that the filter closes completely at a cutoff of 10.

### **>>> Ambika with multiple ladder filters.**

**Step 5B:** Turn off all oscillators again and set ADSR and LFO to 0; resonance to maximum.

Tell the Ambika to use a 4P or SVF filter for now. Play a note (C3) and set the resonance to 200 Hz. Switch back to the ladder filter and play the same note (C3). Set the resonance to 200 Hz using the reference poti.

Switch back and forth between the filters and verify the resonance frequencies do conform. If they do, you're done.

## **Setting the volume.**

I noticed that different filters on the Ambika have different volume. Das ist bei Einzelausgängen nicht das Problem, wohl aber, wenn man polyphon über den Summenausgang spielt.

Monophonically this isn't a problem but it is when playing in polyphony.

There is a volume poti to match the ladder filters' volume with the other filters.

This is easy; just tweak the poti to match the other filters. Too high volume may overdrive the output amp and you will hear clipping.

You could use the level indicator in your mixer or an oscilloscope to make a precise setting.

**That ends the whole process of adjusting the filter...for now! We're utilizing analog instrumentation, meaning that the whole thing is dependent on temperature. Thereof, you're not quite done yet.**

This will be the very last step. Put your Ambika back into its enclosure and let it sit powered up for half an hour.

**The Atmels aswell as the power supply are heating up the whole device. Once the Ambika had time to heat up, double check the reference equalization and re-calibrate. That's it. Done for good!**

**Congratulations, you have built a TubeOhm ladder filter !**

## Modes of the ladder filter

**At the beginning I mentioned that the ladder filter includes 3 distinct modes.**

- 1:) Crunch Mode in TP setting
- 2:) Normal Mode in BP setting
- 3:) Distortion Mode in HP setting

Regarding crunch mode - The filter is keeping a level signal amplitude with rising resonance. At maximum resonance the filter will start to „scream“. The resonance is mixed with the signal and not perceptible as stand-alone signal.

Regarding normal mode - The oscillator signal will become more silent with rising resonance. At some point the filter will start to oscillate and you will hear the typical filter sweep. At maximum resonance, the oscillator signal will be nearly mute.

Regarding distortion Mode – Remember the offset setting? We adjusted the differential amplifier with  $\sim 0.356\text{V}$  on the measuring points. This voltage is switched to ground via a 1 kOhm resistor and a transistor when the distortion mode is turned on. This results in the voltage dropping to about 0.3V making the differential amplifier run asymmetrically and causing it to generate a second resonance frequency and minor distortion. Especially at lower frequencies with little cutoff and some resonance the distortion becomes very noticeable.

The resonance frequency settles slower and V/OCT might not be linear anymore, since the differential amp is now asymmetrical, but that's what is making it sound nicely.

That's all.

Have fun assembling, testing and making music.

Andre'

TubeOhm



AMBIKA LADDER FILTER BOM						
	23.07.13					
Pos	name	value	unit	Farnell	Reichelt	
1	C1,C26	33pF	2		KERKO 33P	
2	C7,15,17,21	100nF	4		MKS-02 100N	
3	Peak caps	100nF	14		Z5U-2,5 100N	
4	C10	100pF	2		KERKO 100P	
5	C14	220nF	1		Z5U-2,5 220N	
6	C28	100uF 16V	4		SM 100/16RAD	
7	C37	1uF	3		MKS-2 1,0µ	
8	C-NP1	4,7 uF	2	NP35V475M5X11		
9	IC1	TL074ACN	2		<a href="#">TL074 DIL</a>	
10	IC2	MCP4822	1	<a href="#">MCP4822-E/P</a>		
11	IC4	LM13700N-DIL16	1		LM 13700 DIL	
12	IC7	ATMega328p	1		ATMEGA328P-PU	
13	IC11	78L05	1		ua 78L05	
14	ISP1	6xstift	1		MPE 087-2-006	
15	LED1	R	1		LED 3-3500 RT	
16	LED2	W	1		LED 3-04700 WS	
17	P1	1k	1		64P-1,0K	
18	P2	500	1		64P-500	
19	P3	5k	1		64P-5,0K	
20	P4	50K	1		64P-50K	
21	Q1	2N3906	2		2N3906	
22	Q5	2N3904	14		2N3904	
23	QX1	20MHz	1		<a href="#">20.0000-HC49U-S</a>	
24	R	2,2k	6		Metall 2,2K	
25	R	18k	3		Metall 18,0K	
26	R	1k	10		Metall 1,0K	
27	R	4,7k	4		Metall 4,7K	
28	R	10k	6		Metall 10K	
29	R	43k	1		Metall 43K	
30	R	220	5		Metall 220	
31	R	330k	1		Metall 330k	
32	R	1M	4		Metall 1M	
33	R	100k	1		Metall 100K	
34	R	15k	1		Metall 15 K	
35	R	470	2		Metall 470	
36	R	2k	2		Metall 2K	
37	R	300k	1		Metall 300 K	
38	R	47k	2		Metall 47 K	
39	Jumper B		3		<a href="#">JUMPER 2,54 BL</a>	
40	Jumper R		1		JUMPER 2,54 RT	
41						
42	Stiftleiste		1		<a href="#">MPE 087-1-024</a>	
43	Header	6pol	2			
44	PCB		1		TubeOhm	
45	GS 28P-S	Socket Atmel	1		GS 28P-S	
46	GS14	Socket	2		GS14	
47	GS 16	Socket	1		GS 16	
48	GS8	Socket	1		GS8	
49	<b>OPTIONAL</b>					
50	1N4148		10	DIODE LAD	1N4148	
51	47nF	Diode	4	DIODE LAD	MKS-02 47N	
52	68nF	LED	4	LED LAD	MKS-02 68N	
53	LED rot 3mm	standart rot 3mm	10	LED LAD	LED3mm rt	

Layout: positions and values

