10 Ch Analog Spectrum Analyzer

Analog Analyzer with digital Visualization

10 Channel
PIXEL LEDS
40Hz - 16Khz
Line in
Microphone in
Different modes
Webserver live

Building Manual

M. Donners 01-06-2021

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Table of Contents

1. Disclaimer and safety 3
2. About this project 3
3. Operation 4
4. Tools needed. 5
5. Hardware 6
   5.1. Main PCB 6
      5.1.1. Assembly 7
      5.1.2. Schematic 9
      5.1.3. PCB Part list main PCB 10
   5.2. Electronics explained. 12
   5.3. Visualisation 13
   5.4. Wiring 14
   5.5. Wiring tables 15

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1. Disclaimer and safety

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Disclaimer short version:

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2. About this project

This document is related to the 10 channel Analog Spectrum analyser. The analogue back end uses 10 band pass filters to divide the input signal into 10 frequency bands.

A ESP32 controllers reads the amplitude of each band and visualizes it using a Pixel LED Matrix. On top of that, the ESP32 runs a webserver to display a live graph of the current analysis. This enables you to visualize your spectrum analyser on any mobile device or PC within your network.

You can connect your audio signal by using the audio input or you can use the microphone input to connect a small condenser microphone. Although using the microphone will limit the frequency response because of its limitations.

The input sensitivity can by adjusted just like brightness and peak hold time. When it does not receive any input signal, after a while, it will go to fire mode in which some leds/display will light up like a fire.

The PCB can be purchased at my Tindie web shop. The firmware (Arduino Sketch) is open source and you can modify it to your needs.

3. Operation

You can use the microphone in to connect a small condenser microphone or you can connect your audio device to the line input connectors. Although the signal from the microphone is amplified on the PCB, it might not be strong enough. Depending on your microphone, you can adjust resistor R52; decreasing it's value will amplify the signal more. In my prototype I replaced it with a resistor of 0 Ohm (I shorted it). However, when using a different mic, I had to increase it again to 20K. So it all depends on your mic.

Mode button

The mode button has 3 functions:

Short press: change pattern(mode), there are 12 available patterns from which the last one is a fire screensaver.

Fast triple press: The VU meter that is displayed on the top row can be disabled/enabled

Pressed/ hold while booting: This will reset your stored WIFI settings. In case you need to change your WIFI settings or in case your system keeps rebooting, this is where to start!

Select Button

The select button has 3 functions:

Short press: Toggle between line-in and microphone input.

Long press: Press for 3 seconds to toggle "the auto change patterns" mode. When enabled, the pattern that is shown changes every few seconds. Also, when the button is pressed long enough, the Dutch national Flag will be shown. That's how you know you've pressed long enough!

Double press: The direction of the falling peak will change.

Brightness Potmeter

You can use this to adjust the overall brightness of all leds / display. WARNING:Make sure you use a power supply to match the current for the brightness that you set. For sure, the ESP32 onboard regulator cannot handle all leds at full brightness. It is best to use an external powersupply that can handle 4 to 6 A. If you are using the USB cable that is connected to the ESP32, you might end up with a burning sensation coming from the ESP32 Board.

Peak Delay Potmeter

You can use this to adjust the time it takes for a peak to fall down to / rise up from the stack

Serial Monitor

The serial monitor is your friend, it displays all info on booting, including your web server IP address.

Webserver

After uploading your sketch and booting for the first time, the ESP32 will serve as an access point. Use your labtop, cellphone etc, to connect to this wifi access point. You will be directed to the webpage of the WIFI manager to setup your WIFI access. It will be remembered on your next boot. If you need to change it, see text 'Mode button'.

When set up properly, you can access the webpage with a live view of your spectrum analyzer. You can use the Serial monitor to find the ip-address, it is shown in the boot log.

4. Tools needed.

You will be working with low voltage and you should know your way around basic electronics. Using the wrong voltage or polarity might not kill you but it will destroy your project in an instance!

Being successful in building this device requires some adequate skills and tools. You should be able to solder small components on a PCB which will require a soldering station with a small tip as you will be handling components like 0805 sized although small, if you have a steady hand, you should be able to solder them onto the board. If this is beyond your possibilities, then you should buy the pcb version that has all SMD components pre-installed.

Furthermore, you will be programming the microcontroller by using the Arduino IDE environment. Although the steps to do so will be described in this document, it is advisable for you to get to know this Arduino software.

And yes, you will need some basic tools like a screwdriver 😉

5. Hardware

5.1. Main PCB

The pcb is available at my Tindie store here:

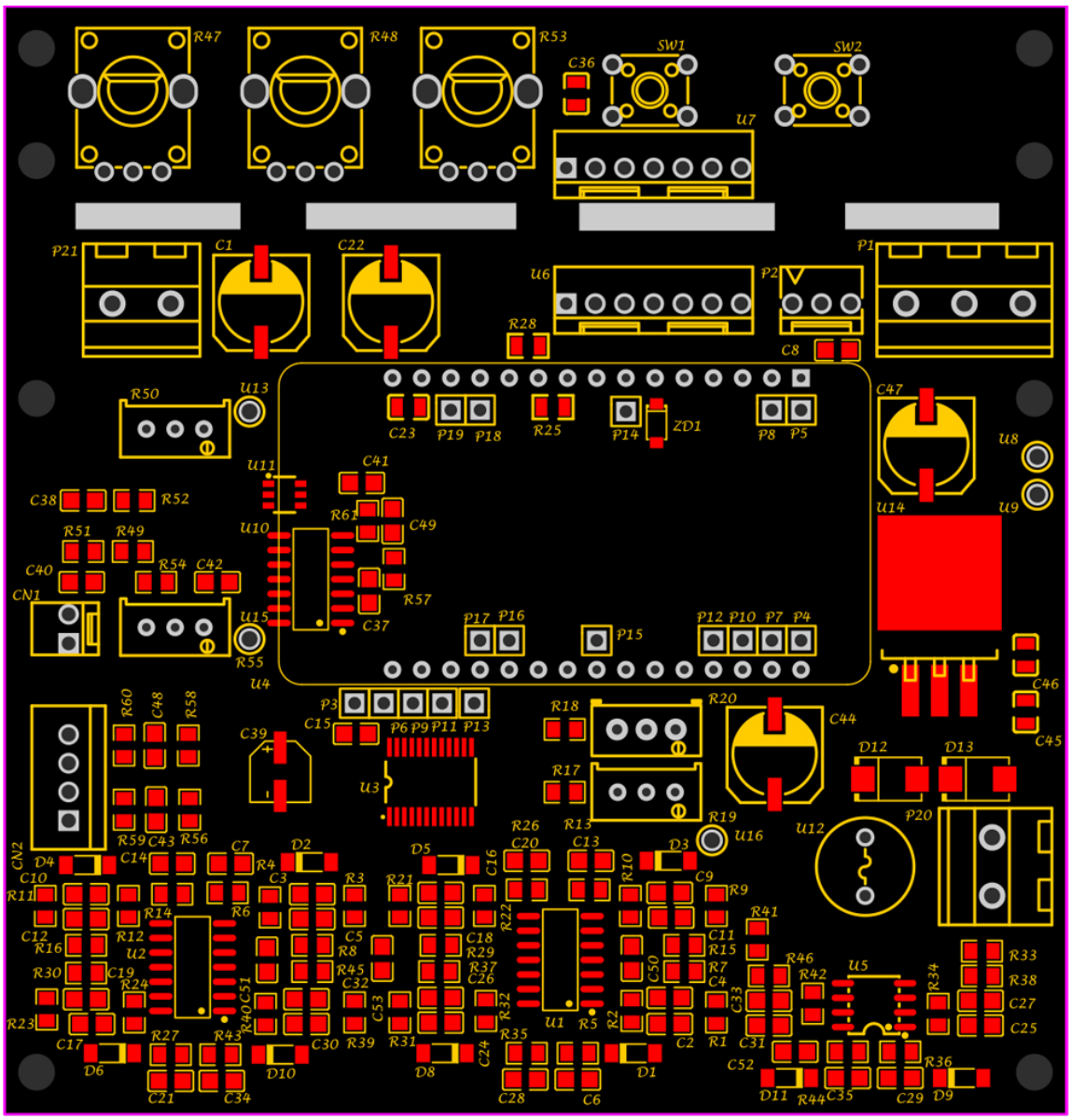
https://www.tindie.com/products/markdonners/pcb-8-64-channel-fft-spectrum-analyzer/

The PCB has all SMD components pre-installed and all you need to add is the ESP32 board and a hand full of through hole components.

Shipping is possible within the EU and some other global destinations. Take note that shipping outside the EU involves import Tax, declarations of conformity and other complicated stuff. If you are a resident of a country that I don't ship to, you can always order a pcb directly from a PCB supplier near you and assemble one yourself. The Gerber productions files you need for that are available for download, although it might be more expensive than what you are hoping for. If you need 1 or 2 PCB's, a Tindie order is the cheapest way to go. You can always file a "Ship to my country" request on Tindie and I'll see what I can do.

My shipping policy might change over time so always check the Tindie store to see if I am shipping to your country. ADDITION: I have successfully shipped to UK, USA and other non-EU countries but handling the tax, import fee and so on is on you! Check out the Tindie store to see what is possible for your country.

5.1.1. Assembly



Assembly notes:

If you didn't buy the PCB with pre-assembled SMD components then you'll have to solder those on yourself. It's possible when you use the right tools but let me remind you that soldering SMD components in this scale is not for beginners

Here are some links for some of the used components. A more detailed list of components is available on one of the following pages of this document.

Microphone
A used a simple electret microphone like this one:

https://nl.aliexpress.com/item/32961327636.html?spm=a2g0o.productlist.0.0.40156749GH0jMh&algo_pvid=b3873d4e-2d66-4844-b423-45a81e07bc15&algo_expid=b3873d4e-2d66-4844-b423-45a81e07bc15-0&btsid=2100bdd516132465203027466e5419&ws_ab_test=searchweb0_0,searchweb201602_,searchweb201603_

Power Supply
You will be needing a power supply of DC 12V that can handle 4 to 6A. (Current depends on the number of panels or leds you are planning to connect. Make sure your power supply is stable and doesn't have noise on the output.

You'll also need some connectors for audio and power and some wire to connect all. Regarding the power to the leds, use a wire that can handle a current of 4A Depending on what you planning, thinner wire can do the job as well.

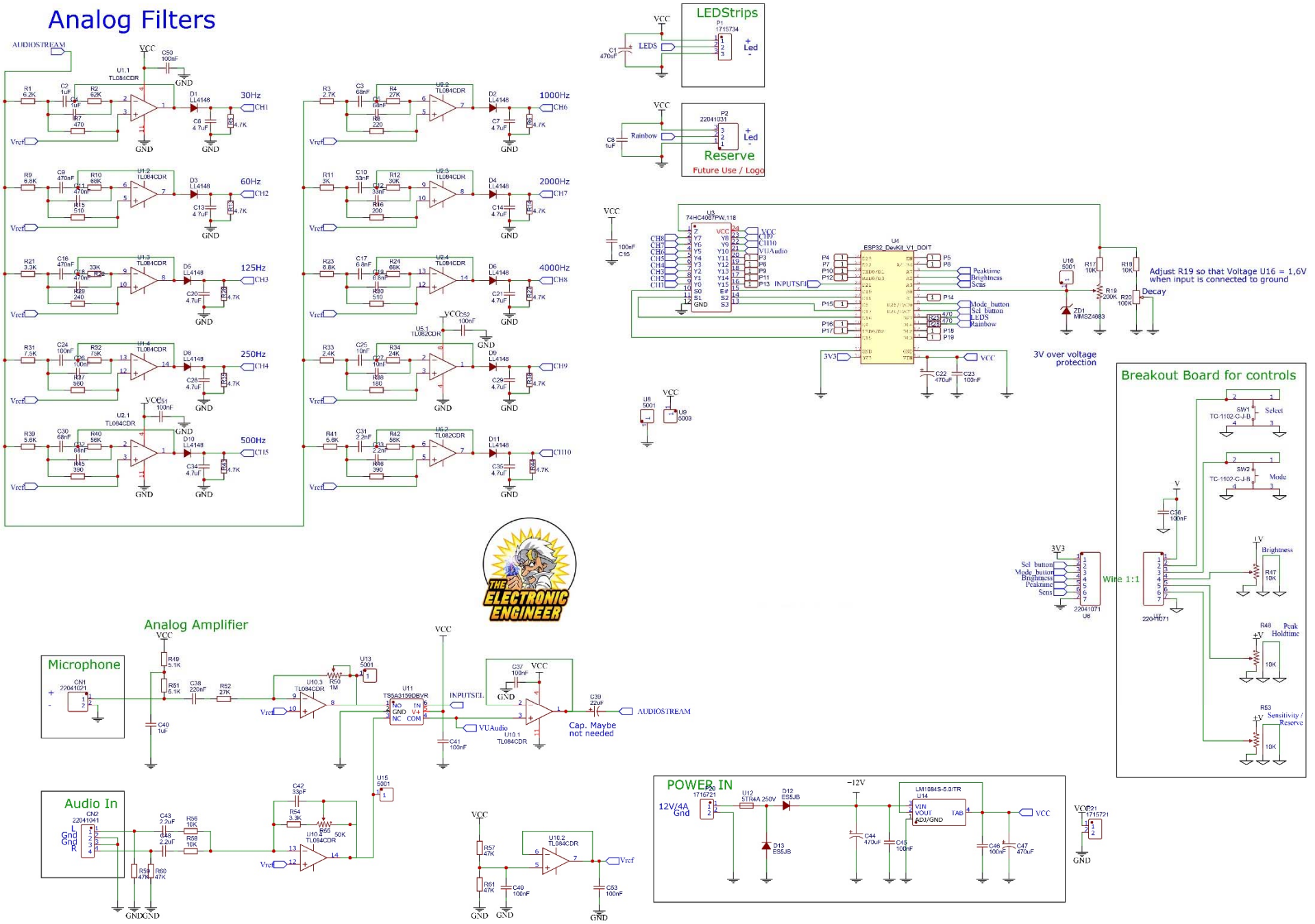
Pixel LEDS / LEDstrip
Also, you'll need to order a few meters of Pixel Ledstrip WS2812. Make sure you order the one that works with your design. (number of pixels per meter varies) I used 74Leds/meter version.

You could use Pixelled matrix as well but depending on how it is wired (zig zag or not) you might have to change the code in LEDDRIVER.h:

```
FastLED_NeoMatrix *matrix = new FastLED_NeoMatrix(leds, kMatrixWidth, kMatrixHeight,
  NEO_MATRIX_BOTTOM      + NEO_MATRIX_RIGHT +
  NEO_MATRIX_COLUMNS     + NEO_MATRIX_ZIGZAG +
  NEO_TILE_TOP + NEO_TILE_LEFT + NEO_TILE_ROWS);
```

To whatever works for your setup!

5.1.2. Schematic



5.1.3. PCB Part list main PCB

The complete part list for the main PCB is here:

ID	Name	Designator	Footprint	Quantity	Manufacturer Part	Manufacturer	Supplier	Supplier Part
1	5001	U16,U13,U15,U8	TEST-TH_BD2.54-P1.39	4	5001	Keystone	LCSC	C238122
2	470	R25,R28,R7	R0805	3	0805W8F4700T5E	UniOhm	LCSC	C17710
3	22041071	U7,U6	CONN-TH_22041071	2	22041071	MOLEX	LCSC	C293439
4	100nF	C53,C37,C26,C24,C49,C41,C15,C50,C51,C52,C46,C45,C36,C23	C0805	14	CC0805KRX7R9BB104	YAGEO	LCSC	C49678
5	1715734	P1	CONN-TH_3P-P5.08_1715734	1	1715734	Phoenix Contact	LCSC	C480520
6	1715721	P20,P21	CONN-TH_P5.08_1715721	2	1715721	Phoenix Contact	LCSC	C480516
7	TL084CDR	U10,U2,U1	SOIC-14_L8.7-W3.9-P1.27-LS6.0-BL	3	TL084CDR	TI	LCSC	C8956
8	TL082CDR	U5	SOIC-8_L5.0-W4.0-P1.27-LS6.0-BL	1	TL082CDR	TI	LCSC	C9385
9	5TR4A 250V	U12	FUSE-TH_BD8.5-P5.08-D1.0	1	5TR4A 250V	XC Elec(Shenzhen)	LCSC	C140489
10	TS5A3159DBVR	U11	SOT-23-6_L2.9-W1.6-P0.95-LS2.8-BR	1	TS5A3159DBVR	TI(Tex as Instruments)	LCSC	C92485
11	5003	U9	TEST-TH_BD2.54-P1.39	1	5003	Keystone	LCSC	C238124
12	74HC4067PW,118	U3	TSSOP-24_L7.8-W4.4-P0.65-LS6.4-BL	1	74HC4067PW,118	Nexperia	LCSC	C179326
13	TC-1102-C-J-B	SW2,SW1	KEY-TH_4P-L6.0-W6.0-P4.50-LS6.5	2	TC-1102-C-J-B	XKB Enterprise	LCSC	C381016
14	1M	R50	RES-ADJ-TH_3P-L10.0-W10.0-P2.50-BL-BS	1	3296W-1-105	Chengdu Guosheng Tech	LCSC	C118944
15	27K	R52,R4 (R52 might need to be changed, see text)	R0805	2	0805W8F2702T5E	UniOhm	LCSC	C17593
16	5.1K	R51,R49	R0805	2	0805W8F5101T5E	UniOhm	LCSC	C27834
17	10K	R48,R47,R53	RES-TH_RK09D1130C2P	3	RK09D1130C2P	ALPS Electric	LCSC	C361173
18	100K	R20	RES-ADJ-TH_3P-L9.5-W4.9-P2.50-L_3296W	1	3296W-1-104	Chengdu Guosheng Tech	LCSC	C118963
19	50K	R55	RES-ADJ-TH_3P-L9.5-W4.85-P2.50-BL-BS	1	3296W-1-503	Chengdu Guosheng Tech	LCSC	C118911
20	200K	R19	RES-ADJ-TH_3P-L9.5-W4.85-P2.50-BL-BS	1	3296W-1-204	Chengdu Guosheng Tech	LCSC	C118942
21	47K	R61,R60,R59,R57	R0805	4	0805W8F4702T5E	UniOhm	LCSC	C17713
22	10K	R58,R56,R18,R17	R0805	4	0805W8F1002T5E	UniOhm	LCSC	C17414
23	3.3K	R54,R21	R0805	2	0805W8F3301T5E	UniOhm	LCSC	C26010
24	390	R46,R45	R0805	2	0805W8F3900T5E	UniOhm	LCSC	C17655
25	4.7K	R44,R43,R36,R35,R27,R26,R14,R13,R6,R5	R0805	10	0805W8F4701T5E	UniOhm	LCSC	C17673
26	56K	R42,R40	R0805	2	0805W8F5602T5E	UniOhm	LCSC	C17756
27	5.6K	R41,R39	R0805	2	0805W8F5601T5E	UniOhm	LCSC	C4382
28	180	R38	R0805	1	0805W8F1800T5E	UniOhm	LCSC	C25270
29	560	R37	R0805	1	0805W8F5600T5E	UniOhm	LCSC	C28636
30	24K	R34	R0805	1	0805W8F2402T5E	UniOhm	LCSC	C17575
31	2.4K	R33	R0805	1	0805W8F2401T5E	UniOhm	LCSC	C17526
32	75K	R32	R0805	1	0805W8F7502T5E	UniOhm	LCSC	C17819
33	7.5K	R31	R0805	1	0805W8F7501T5E	UniOhm	LCSC	C17807
34	510	R30,R15	R0805	2	0805W8F5100T5E	UniOhm	LCSC	C17734

35	240	R29	R0805	1	0805W8F2400T5E	UniOhm	LCSC	C17572
36	68K	R24,R10	R0805	2	0805W8F6802T5E	UniOhm	LCSC	C17801
37	6.8K	R23,R9	R0805	2	0805W8F6801T5E	UniOhm	LCSC	C17772
38	33K	R22	R0805	1	0805W8F3302T5E	UniOhm	LCSC	C17633
39	200	R16	R0805	1	0805W8F2000T5E	UniOhm	LCSC	C17540
40	30K	R12	R0805	1	0805W8F3002T5E	UniOhm	LCSC	C17621
41	3K	R11	R0805	1	0805W8F3001T5E	UniOhm	LCSC	C17661
42	220	R8	R0805	1	0805W8F2200T5E	UniOhm	LCSC	C17557
43	2.7K	R3	R0805	1	0805W8F2701T5E	UniOhm	LCSC	C17530
44	62K	R2	R0805	1	0805W8F6202T5E	UniOhm	LCSC	C17783
45	6.2K	R1	R0805	1	0805W8F6201T5E	UniOhm	LCSC	C17767
46	Header-Male-2.54_1x1	P19,P18,P17,P16,P15,P14,P13,P12,P11,P10,P9,P8,P7,P6,P5,P4,P3	HDR-TH_1P-P2.54-V-M	17	Header-Male-2.54_1x1	ReliaPro	LCSC	C81276
47	22041031	P2	CONN-TH_3P-P2.54_22041031	1	22041031	MOLEX	LCSC	C293437
48	ES5JB	D13,D12	SMB_L4.6-W3.6-LS5.3-RD	2	ES5JB	Shandong Jingdao Microelectronics	LCSC	C123908
49	LL4148	D11,D10,D9,D8,D6,D5,D4,D3,D2,D1	LL-34_L3.5-W1.5-RD-1	10	LL4148	SEMTECH	LCSC	C9808
50	22041041	CN2	CONN-TH_22041041	1	22041041	MOLEX	LCSC	C185196
51	22041021	CN1	CONN-TH_22041021	1	22041021	MOLEX	LCSC	C185215
52	22uF	C39	CAP-SMD_BD5.0-L5.3-W5.3-FD	1	RVT1E220M0505	HONOR	LCSC	C15848
53	1uF	C40,C8,C4,C2	C0805	4	CL21B105KBFNNNE	SAMSUNG	LCSC	C28323
54	220nF	C38	C0805	1	CL21B224KBFNNNE	SAMSUNG	LCSC	C5378
55	2.2uF	C48,C43	C0805	2	0805F225M500NT	FH	LCSC	C49217
56	33pF	C42	C0805	1	CL21C330JBANNNC	SAMSUNG	LCSC	C1814
57	4.7uF	C35,C34,C29,C28,C21,C20,C14,C13,C7,C6	C0805	10	CL21A475KAQNNNE	SAMSUNG	LCSC	C1779
58	2.2nF	C33,C31	C0805	2	CL21C222JBFNNNE	SAMSUNG	LCSC	C28260
59	68nF	C32,C5,C3,C30	C0805	4	0805B683K500NT	FH	LCSC	C1756
60	10nF	C27,C25	C0805	2	CL21B103KBANNNC	SAMSUNG	LCSC	C1710
61	6.8nF	C19,C17	C0805	2	0805B682K500NT	FH	LCSC	C1755
62	470nF	C18,C16,C11,C9	C0805	4	CL21B474KBFNNNE	SAMSUNG	LCSC	C13967
63	33nF	C12,C10	C0805	2	0805B333K500NT	FH	LCSC	C1739
64	470uF	C47,C1,C44,C22	CAP-SMD_BD8.0-L8.3-W8.3-RD	4	VZH471M1CTR-0810	LELON	LCSC	C164069
65	MMSZ4683	ZD1	SOD-123_L2.8-W1.8-LS3.7-RD	1	MMSZ4683	CJ	LCSC	C21512
66	LM1084S-5.0/TR	U14	TO-263-3_L8.6-W10.2-P2.54-LS14.4-TL	1	LM1084S-5.0/TR	HGSEMI	LCSC	C259973
67	ESP32_DevKit_V1_DOIT	U4	ESP32_DEVKIT_V1_DOIT	1				

REMEMBER: MOST COMPONENTS ARE STANDARD COMPONENTS AND CAN BE REPLACED BY OTHER TYPE/ BRAND ETC. USE THIS LIST AS A GUIDE NOT AS AN ABSOLUTE MUST!

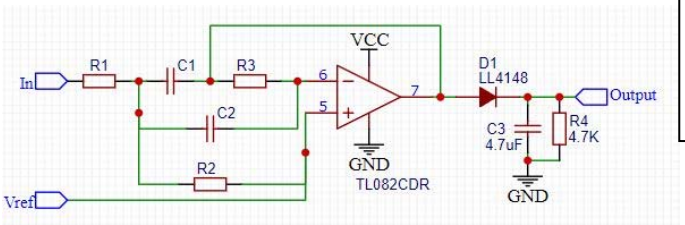
5.2. Electronics explained.

The Electronics can be divided into several sections. Of course, there is a power supply and some standard connectors for audio input and power and there are a few standard switches. Nothing scary about that at all.

Connector P20 is used to connect a 12V power supply. The circuit is protected by a fuse and two power diodes. If the power is connected reversed, D13 will conduct so that the current will rise beyond the capabilities of the fuse. While D12 will protect the circuit from this reversed voltage, the fuse will blow. However, under normal circumstances, the power source is connected correctly and while passing a few capacitors to smooth out any power supply noise or instabilities, the 12V is offered to the onboard regulator U14. U14 converts the 12V power to 5V and feeds the ESP32 board and some of our onboard features like the pre-amplifier, the bandfilters and the led strip.

The user interface consists of 3 potentiometers and two switches. The potmeters control Sensitivity, brightness and Peak time delay while the switches are used to set mode, input and auto-change mod and more.

The PCB has room for a dual pre-amplifier. One can be used to connect a microphone and the other can be used for the line in. You can adjust the output of each pre-amplifier by adjusting the potmeter R50 (for microphone) or R55 for Line-in. The output of both amplifier goes to an analog switch U11. You can use the select button to toggle between the inputs. The output of the Analog switch is buffered by U10.1. It's the output (AUDIOSTREAM) of this buffer that feeds all the bandfilters. Each bandfilter has a specific band frequency. The output signal of each bandfilter is rectified by a diode and smoothened by a capacitor.



To calculate, I used this tool:

http://sim.okawa-denshi.jp/en/OPtazyuLowkeisan.htm

R1	R2	R3	C1 [uF]	C2 [uF]		Gain		Fcentre [Hz]	Optimum [Hz]	Deviation [Hz]	Deviation %	Q
6200	470	62000	1	1		-5		31	30	1	1,93	5,96
6800	510	68000	0,47	0,47		-5		60	60	0	-0,63	5,99
3300	240	33000	0,47	0,47		-5		125	125	0	-0,30	6,07
7500	560	75000	0,1	0,1		-5		255	250	5	1,83	6,00
5600	390	56000	0,068	0,068		-5		518	500	18	3,59	6,20
2700	220	27000	0,068	0,068		-5		999	1000	-1	-0,13	5,76
3000	200	30000	0,033	0,033		-5		2034	2000	34	1,68	6,32
6800	510	68000	0,0068	0,0068		-5		4121	4000	121	3,02	5,99
2400	180	24000	0,01	0,01		-5		7939	8000	-61	-0,76	5,99
5600	390	56000	0,0022	0,0022		-5		16010	16000	10	0,06	6,20

All the output signals of the bandfilters are connected to a analog multiplexor U3. In the software you can select what channel you want to connect to the the resistor network R17/R19 R18/R20. The diode ZD1 is there to protect the ESP32 from over voltage. R19 is used to adjust the amplitude of the signal offered to the ESP32 while R20 can be used to delay the decay of the output signal, resulting in a slower/faster response.

The multiplexor is also connected to the output of the analog switch. This can be used to measure the audio level of the input signal or to do a FFT analysis of the input signal.

Last but not least, there is U10.2. This is used to create the Vref signal. The amplitude of Vref is VCC/2 so that should be around 2,5V

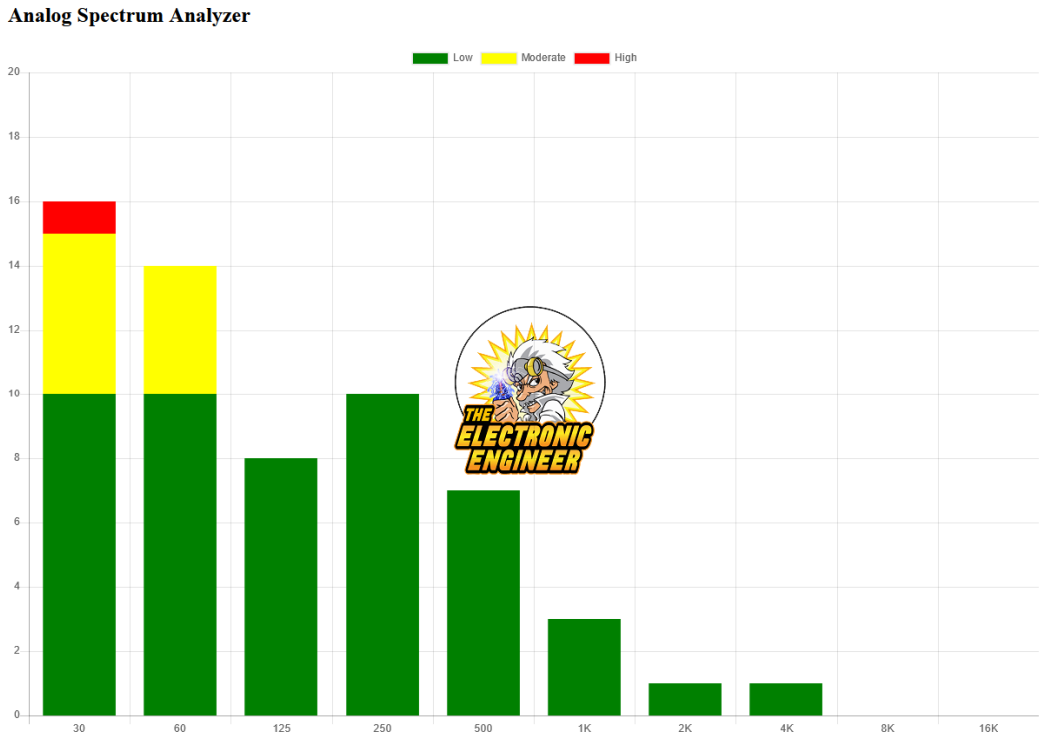
5.3. Visualisation

The visualization of the bandfilters is done by the ESP32, driving a string of LEDS. I used WS2812 based Ledstrip that I wired in ZIG ZAG. You can also use a ready made led matrix but you'll have to adjust the directions of the led accordingly .

LEDDRIVER.H

```
FastLED_NeoMatrix *matrix = new FastLED_NeoMatrix(leds, kMatrixWidth, kMatrixHeight,
NEO_MATRIX_BOTTOM     + NEO_MATRIX_LEFT +
NEO_MATRIX_COLUMNS     + NEO_MATRIX_PROGRESSIVE +
NEO_TILE_TOP + NEO_TILE_LEFT + NEO_TILE_ROWS);
```

The ESP32 also runs a webinterface that shows a live display of the analysis. In short, you can use any webbrowser as a display.



5.4. Wiring

The wiring is not that difficult. The wiring diagram is shown on the next page.

I used shielded wire to connect the microphone and the audio input and I used some general wire for everything else.

Give some extra attention to the power lines that feed the LED Strips. You must wire the data lines in series, meaning that the data out of one strip will be connected to the data in of the next. Etc. You can also do that with the power lines. It is better to feed each strip with its own power if you are connecting more then 200 leds. This would keep the current through the power line limited for each wire and it will better distribute the power to all leds.

5.5. Wiring tables

The wiring is not that spectacular.