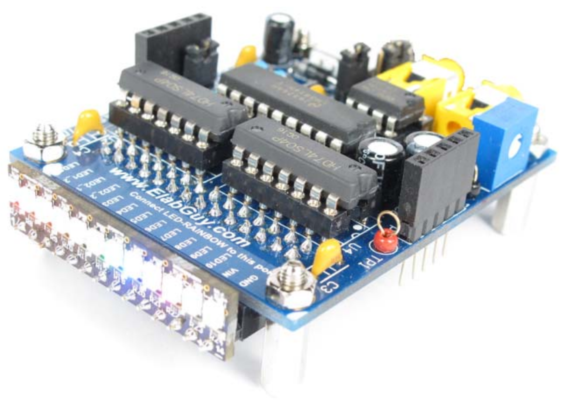
Audio Spectrum Display ASD-V1D



1.0 DESCRIPTION

The ASD-V1D is a simple DIY kit for audio level display. You can cascade a few pieces together to make an audio spectrum display. The circuit is based on the LM3914 Dot/Bar Display Driver and uses the LED-RAINBOW bar graph as the display. 10-step Dot or Bar display mode is selectable by the user. External audio signals can be connected by 3.5mm audio jacks. Audio signal gain can be adjusted by the operational amplifier with a single potentiometer.

This module can be powered by a single 5V USB power supply - this can be from any PC USB port or any USB power transformer. It works perfectly with most computers, mp3 players, mobile phones or any audio devices with a 3.5mm audio plug

2.0 CIRCUIT DESCRIPTION

Power

The input voltage required is simply a single 5V positive power supply. A USB Type A male connector is used as a power jack where power can be drawn directly from computer or from any AC-to-USB transformer. C5 is a bypass capacitor for the 5V input source. The maximum power consumption is around 90mA when all the LEDs are on. Diode D1 is for reverse power protection and it drops around 0.3V with maximum power consumption. C2, C3, C4, C6 are placed on the cathode side of D1 as bypass capacitors.

Audio Input

The audio input is designed for standard audio line voltage and has a maximum input voltage of 1.5V. Stereo signal can be transmitted through the 3.5mm audio jacks. Note that the two audio jacks are pin to pin connected to each others, either one can be input or output. Header P1 selects the left or right stereo channel for the input signal. Placing a jumper on header P6 can bypass the frequency filters, directly connect the audio input to the amplifiers (see Figure 2.1).

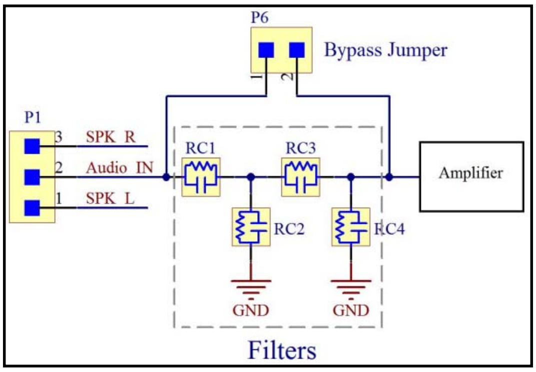


Figure 2.1 – Bypass jumper

Filters

The ASD-V1D can be attached together to form an audio spectrum display by inserting different frequency band filters. In this design, we have 5 frequency bands with a Low Pass Filter on the lowest frequency spectrum, three Band Pass Filters and one High Pass Filter on the highest frequency spectrum.

The 1st band is a Second Order Low Pass Filter with a cut-off frequency *fc* of 100 Hz.

The 2nd, 3rd, 4th bands are basic RC Second Order Band Pass Filters with cut-off frequency 300 Hz, 1 KHz and 4 KHz respectively and the 5th band is a Second Order High Pass Filter with cut-off frequency of 8 KHz. Figure 2.2 shows a 2nd order RC Low-Pass Filter and Figure 2.3 shows a 2nd order RC High-Pass Filter. The High Pass and Low Pass cut-off frequency *fc* can be found by equation 2.1.

Equation 2.1: $$fc = \frac{1}{2\pi RC} \text{ (Hz)}$$

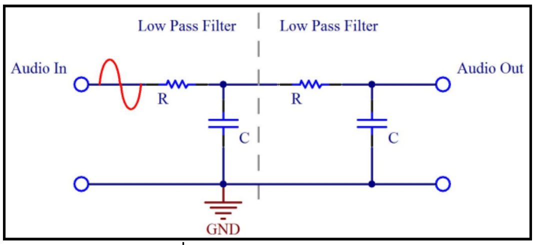


Figure 2.2 – 2nd order RC Low-Pass Filter

Example calculation for a Low-Pass Filter:
In the design, RC1 = RC3 =33KΩ, RC2 = RC4 = 47nF

$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi(33\text{K}\Omega)(47\text{nF})} \approx 100Hz$$

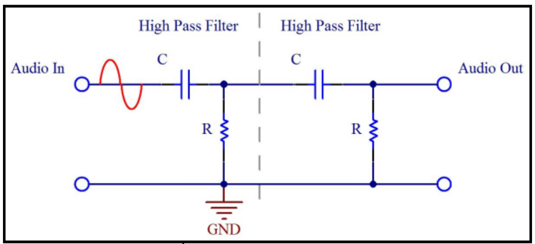


Figure 2.3 – 2nd order RC High-Pass Filter

Example calculation for a High-Pass Filter:
In the design, RC1 = RC3 =20KΩ,
RC2 = RC4 = 1nF

$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi(20\text{K}\Omega)(1\text{nF})} \approx 8KHz$$

The Band-Pass Filter simply connects a High-Pass and a Low-Pass Filter together as shown in Figure 2.4. The cut-off frequency is set to 300 Hz, 1 KHz and 4 KHz respectively and the resistors value can be calculated by equation 2.1 as well. Table 2.1 shows the standard components value for the Band-Pass Filters. Users can always design their own filters with different cut-off frequencies.

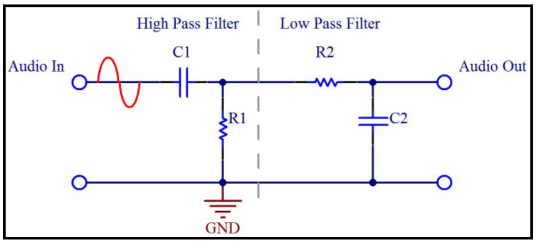


Figure 2.4 – Simple RC Band-Pass Filter

	2nd band	3rd band	4th band
High Pass *fc*	300 Hz	1 KHz	4 KHz
C1	0.1uF	47nF	2.2nF
R2	5.1KΩ	3.3KΩ	18KΩ
Low Pass *fc*	300 Hz	1 KHz	4 KHz
R3	0.1uF	47nF	2.2nF
C4	5.1KΩ	3.3KΩ	18KΩ

Table 2.1 – Band Pass Filters with standard components value

Note that the filters are only basic RC filter with low quality Q factor. The display spectrum may intercept each other.

Amplification

Before any amplification is done, the negative side of the audio signal needs to be filtered off since the LM3914 driver is only interested in the positive peak value, also there is only one positive power supply in this project. If we insert a negative signal into the Op-Amp, the Op-Amp will enter to a funny stage where the negative signal will transform to the maximum amplitude. D1 is used to eliminate the negative input signal and C1 rectifies the signal in order to make the peak period longer. R1 is a bleeder resistor for discharging the energy stored in C1. The Op-Amps are configured as Non-inverting amplifiers where it only requires a positive input power and the negative power input can connect to ground (see figure 2.5). The first Op-Amp U1A amplifies the input signal with a fixed gain of 2 and the second Op-Amp U1B provides an adjustable amplification. The amplified signal can be measured through test point TP1.

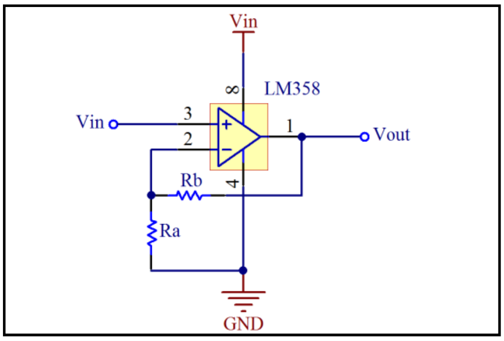


Figure 2.5 – Single Supply Non-Inverting Amplifier

Equation 2.2: $Vout = Vin(1 + \frac{Rb}{Ra})$ (V)

Example calculation:

In the design, R2 = R3 = 10KΩ

Gain = $\frac{Vout}{Vin} = 1 + \frac{10K\Omega}{10K\Omega}$ = **2**

LM3914

The LM3914 (U3) is a linear bar-graph driver that senses analog voltage levels and drives 10 LEDs. In this design, the peak detect voltage is set to approximate 3.2V. Figure 2.6 shows the relationship between REFOUT and REF ADU. Since the LM3914 is a linear device, the step size is around 0.32V per step with total 10 steps.

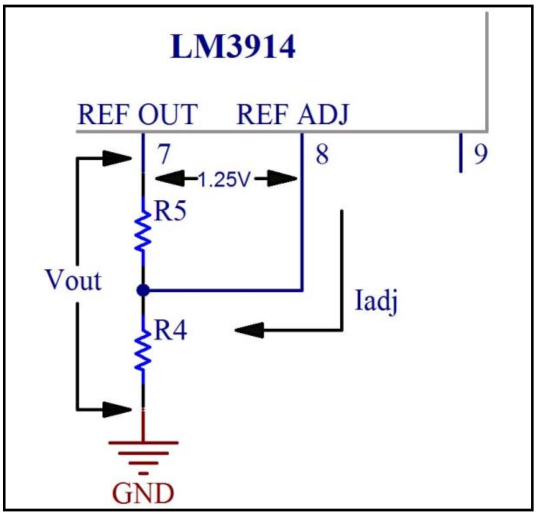


Figure 2.6 – Reference Out Adjust

Equation 2.3:

$$Vout = 1.25\left(1 + \frac{R4}{R5}\right) + I_{adj}R4 \quad (V)$$

Example calculation:

In the design, R4 = 3.3KΩ, R5 = 2.4KΩ, $I_{adj} \approx$ 60μA

$$Vout = 1.25\left(1 + \frac{3.3K\Omega}{2.4K\Omega}\right) + (60\mu A \text{ X } 3.3K\Omega)$$

$$Vout \approx \mathbf{3.20\ V}$$

Dot Mode or bar mode is selected by placing a jumper on header P5 (Bar mode) or leaving the header open (Dot mode). Note that dot mode is not suitable for this sample project since the audio signals rise and drop so quickly that you won't be able to see the change in dot mode.

(Please read the LM3914 datasheet on National semiconductor's website for more details)

Inverter logic

The LM3914 turns on LED by sinking the LED power to ground and turns off the LED by pulling positive on the output. Using the 74LS04 (U1, U4) inverter can invert the LED output signal where turning the LED on becomes "High" and turning off the LED becomes "Low".

LED-Rainbow

The LED-RAINBOW-V1B is a LED bar graph. It has 12 LEDs with different colors (red, orange, yellow, green, yellow green, blue, violet, pink, warm white, white) and 12 NPN transistors drive each single LED separately. The NPN transistors act as an on/off switch where a "high" signal applied to the control lines will turn on the LED and "low" will turn it off. One nice thing about the LED-RAINBOW is it doesn't draw too much power from the 74LS04 since the LEDs are driven by transistors switches. Note that LED1&LED2, LED3&LED4 are connected to each other.

(Please read the LED-RAINBOW-V1B datasheet for more details)

Cascading the display

The ASD-V1D can be cascaded with maximum 5 pieces together. The maximum current drawn by each module is around 90mA, connecting 5 together needs to draw 450mA from a USB power supply where standard USB port only provide 500mA max. If you desperately want to cascade more than 5 pieces, you need to connect a separate USB power source. Connecting the modules together is simple, you just need to stack the 5pin socket on port P2 and P3 on top of another module and mount the metal stand to make it more stable. Note that the 5pin socket shares the common ground, 5V power, stereo left and stereo right channel, therefore only one USB power and one stereo signal connection is needed to the cascaded modules.

Examples of cascading formations:

- Connect five together with different filters (low, high, band pass) to make a 5 band spectrum display.
- Connect two together and set one of the channels to be Left and another one to be Right for stereo level display.

3.0 ASSEMBLY INSTRUCTIONS

Few things keep in mind before you assemble the ASD-V1D.

- Do not cut off the pins of the 5pin sockets (P2, P3), these pins are for connecting to another modules. Also, don't put too much solder on these pins. You do not need to solder the 5pin socket if you are not planning to cascade with others.

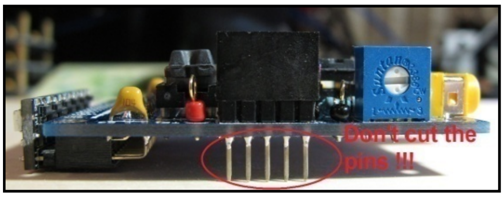


Figure 3.1 – 5pin Socket

- For beginners, soldering the 14X2pin socket (P4) first can make the assembling process easier since the IC sockets (U2, U4) are very close to P4. Make sure the socket is placed on the bottom side of the PCB.

Figure 3.2 – 14X2pin Socket placed on bottom side

- Make sure the polarity of the electrolytic capacitors and diodes are in the correct position, the polarity should be indicated on the PCB.
- Do not place the IC on the sockets before soldering.
- Make sure the LED-RAINBOW is connected in the correct position.

The components can be soldered to the PCB in any orders, please look at Figure A1 & A2 for assembly reference.

A simple RC Low-Pass, High-Pass or Band-Pass filter can be added on the circuit and four footprints (RC1-RC4) are reserved for it. Figure 3.3 shows the placement of different filters. Remove jumper P6 if filters are in use.

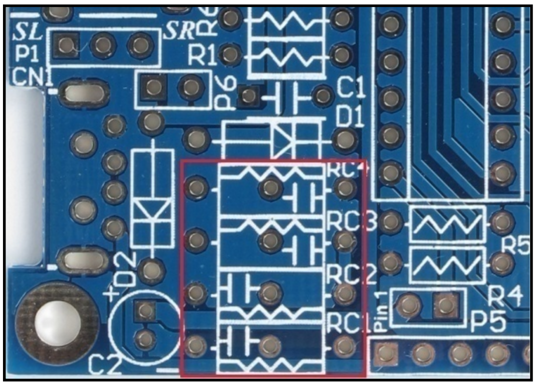


Figure 3.2 – Filters Footprint on PCB

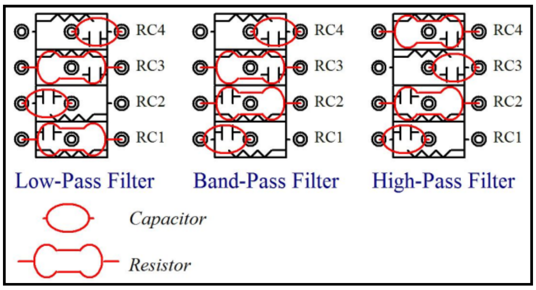


Figure 3.3 – Filters Placement

4.0 CIRCUIT CALIBRATION

Audio level meter calibration

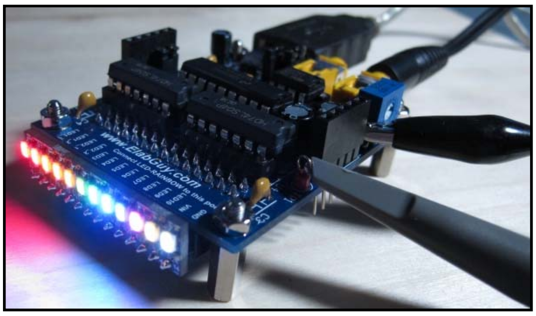


Figure 4.1 – Audio Level Meter

Calibration is simple and fast, it can be done with the following steps:

1. Apply a continuous signal to the audio input, for example a 1KHz sin wave with positive peak value of 1.4V. If you don't have a function generator, you can apply a DC 1.4V for calibration.

2. Turn the potentiometer counterclockwise to the end.
3. Slowly adjust the potentiometer until you see all the LEDs are on. Do not continue to turn up the potentiometer if you see that the last LED is on.

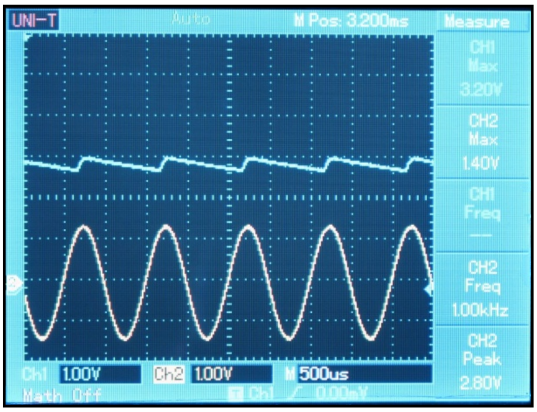


Figure 4.2 – Adjusting the audio level meter

Figure 4.2 shows the input signal and the output amplified signal. Note that the input signal is rectified before amplification.

Audio spectrum display calibration

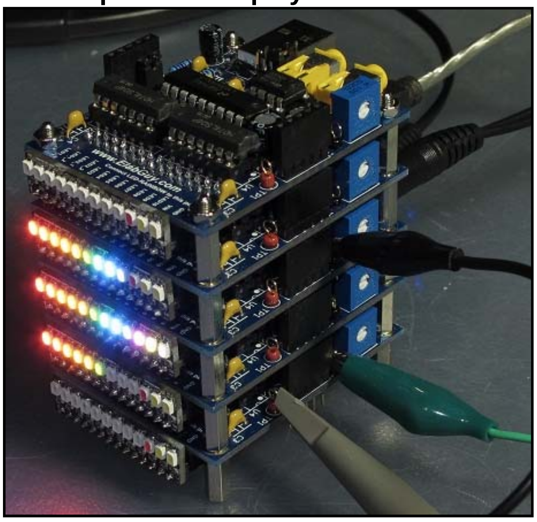


Figure 4.3 – Audio spectrum display

Calibrating the audio spectrum display is same as the audio level meter. The only difference is that a specific frequency is needed for each band. For example you need to apply a 100Hz signal with a positive peak voltage of 1.4V to calibrate the 1st band display which contains the 100Hz Low-Pass Filter. A 300Hz, 1KHz, 4KHz and 8KHz signal should be used to calibrating the 2nd, 3rd, 4th and 5th band display respectively.

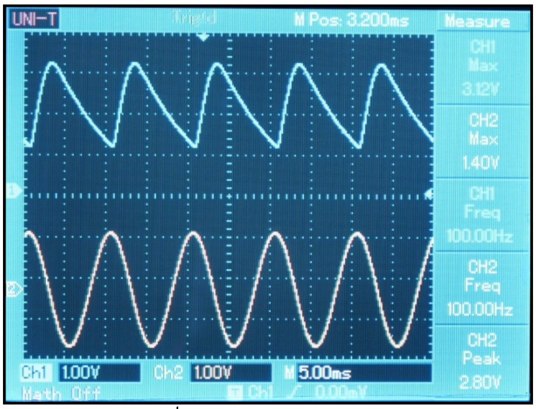


Figure 4.4 – 1st band output waveform (100Hz)

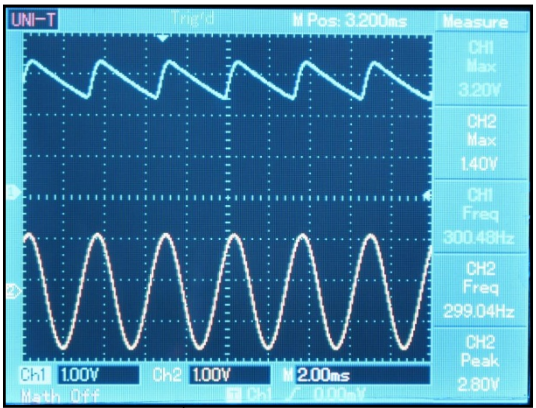


Figure 4.5 – 2nd band output waveform (300Hz)

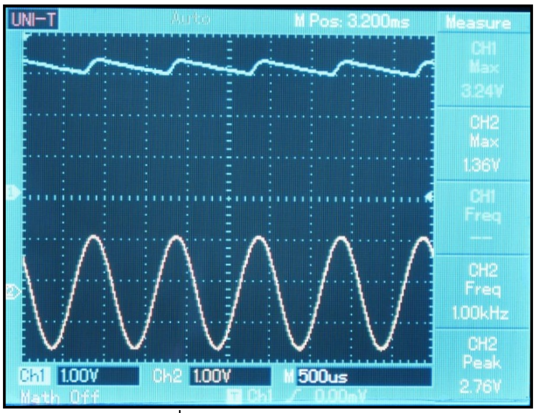


Figure 4.6 – 3rd band output waveform (1KHz)

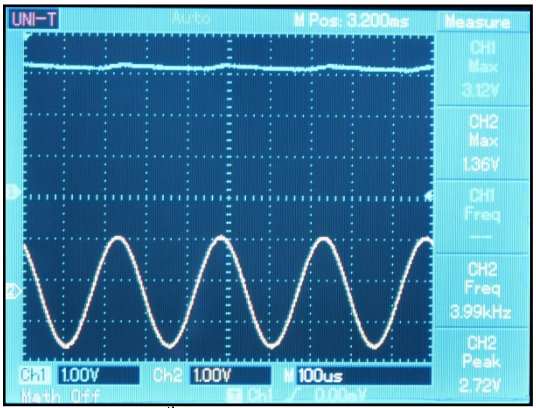


Figure 4.7 – 4th band output waveform (4KHz)

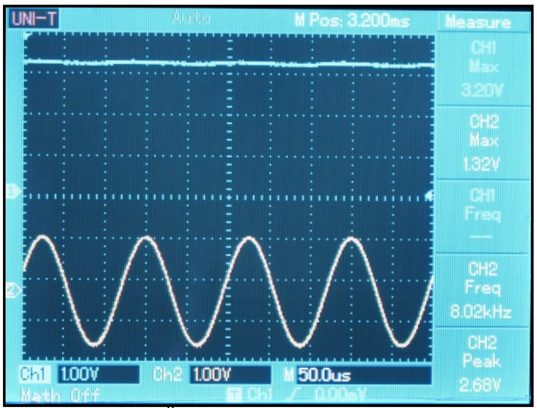


Figure 4.8 – 5th band output waveform (10KHz)

5.0 TROUBLESHOOTING

Poor soldering is the most likely cause for the circuit not working properly. Check all the solder joints and follow the track with a multi-meter to check for any short circuits. Placing a component with wrong value is also a common mistake, carefully check all the components to match the circuit.

Check list for troubleshooting

- Check the polarity of the electrolytic capacitors and diodes.
- Check if the LED-RAINBOW is placed in the right direction.
- Make sure the jumpers are placed correctly with the desired function.
- Check if the IC is placed in the right orientation
- Check that the following voltages on the LM3914 are presents; approximate 3.2V on Pin6 & Pin7, 1.9V on Pin8 respect to ground.
- Check if any component is touching the metal stand.
- When stacking another module on top, check if the extra legs are shorted to the bottom modules.
- The input audio signal amplitude maybe too low.

If you want to measure the total current consumption, the USB-AF-BO-V1A breakout board can help you to expose the pins of the USB connector for measuring. The USB-AF-BO-V1A can be purchased from www.elabguy.com


Figure5.1 - ASD-V1D with USB-AF-BO-V1A

6.0 COMPONENTS

Major components checklist

Part Type	Designator	Quantity
2.4K	R5	1
3.3K	R4	1
10K	R2, R3	2
100K	R1	1
10K Pot	POT1	1
3.5mm Audio Jack	AJ1, AJ2	2
USB Type A Male Plug	CN1	1
7pin header (2.54mm)	P1, P5, P6	1
Socket 5X1_2.54mm	P2, P3	2
Socket 14X2_2.54mm	P4	1
0.1uF ceramic capacitor	C1, C3, C4	3
100uF electrolytic capacitor	C2	1
220uF electrolytic capacitor	C5,C6	2
1N5817 diode	D1, D2	2
8pin DIP socket	U1	1
14pin DIP socket	U2, U4	2
18pin DIP socket	U3	1
Red test point	TP1	1
Black test point		1
LM358		1
74LS04		2
LM3914		1
ASD-V1D PCB		1
Jumper		3
Nuts		4
12mm Metal Stand		4
LED-RAINBOW-V1B		1

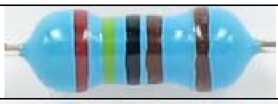
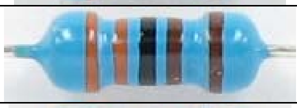
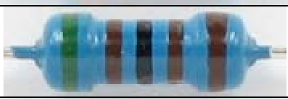
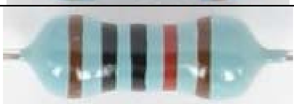
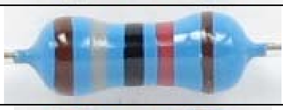
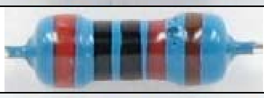
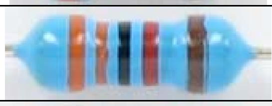
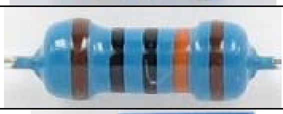
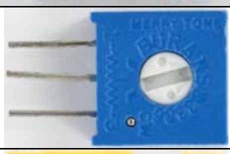
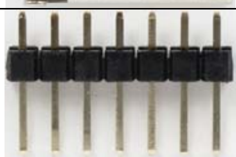
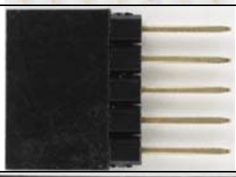
Filter components checklist

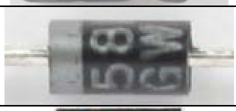
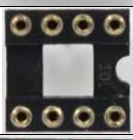
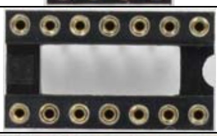
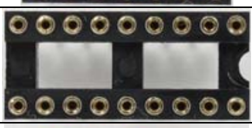
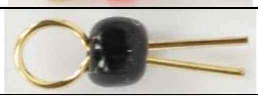
Part Type	Designator	Quantity
1st Band – second order Low Pass Filter		
33K	RC1	1
47nF	RC2	1
33K	RC3	1
47nF	RC4	1
2nd Band – second order Band Pass Filter		
0.1uF	RC1	1
5.1K	RC2	1
5.1K	RC3	1
0.1uF	RC4	1
3rd Band – second order Band Pass Filter		
47nF	RC1	1
3.3K	RC2	1
3.3K	RC3	1
47nF	RC4	1
4th Band – second order Band Pass Filter		
2.2nF	RC1	1
18K	RC2	1
18K	RC3	1
2.2nF	RC4	1
5th Band – second order High Pass Filter		
1nF	RC1	1
20K	RC2	1
1nF	RC3	1
20K	RC4	1

(All resistors are metal film, 0.25W, 1%)

Please look at Table A1 for visual components checklist.

Appendix

Diagram	Part Type	Designator	Quantity
	2.4K (red, yellow, black brown, brown)	R5	1
	3.3K (orange, orange, black, brown, brown)	R4, Filters	3
	5.1K (green, brown, black, brown, brown)	Filters	2
	10K (brown, black, black, red, brown)	R2, R3	2
	18K(brown, grey, black, red, brown)	Filters	2
	20K (red, black, black, red, brown)	Filters	2
	33K (orange, orange, black, red. brown)	Filters	2
	100K(brown, black, black, orange, brown)	R1	1
	10K Pot	POT1	1
	3.5mm Audio Jack	AJ1, AJ2	2
	USB Type A Male Plug	CN1	1
	7pin header pin (2.54mm)	P1, P5, P6	1
	Socket 5X1_2.54mm	P2, P3	2
	Socket 14X2_2.54mm	P4	1

	1nF (102)	Filters	2
	2.2nF (222)	Filters	2
	47nF (473)	Filters	2
	0.1uF ceramic capacitor	C1, C3, C4, Filters	5
	100uF electrolytic capacitor	C2	1
	220uF electrolytic capacitor	C5,C6	2
	1N5817 diode	D1, D2	2
	8pin DIP socket	U1	1
	14pin DIP socket	U2, U4	2
	18pin DIP socket	U3	1
	Red test point	TP1	1
	Black test point		1
	LM358		1
	74LS04		2
	LM3914		1

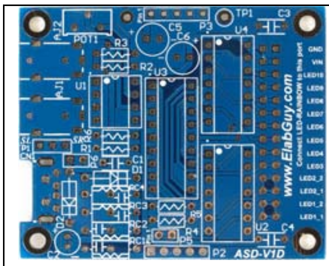
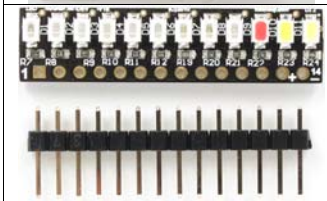
	ASD-V1D PCB		1
	Jumper		3
	Nuts		4
	12mm Metal Stand		4
	LED-RAINBOW-V1B		1

Table A1 - Visual components checklist

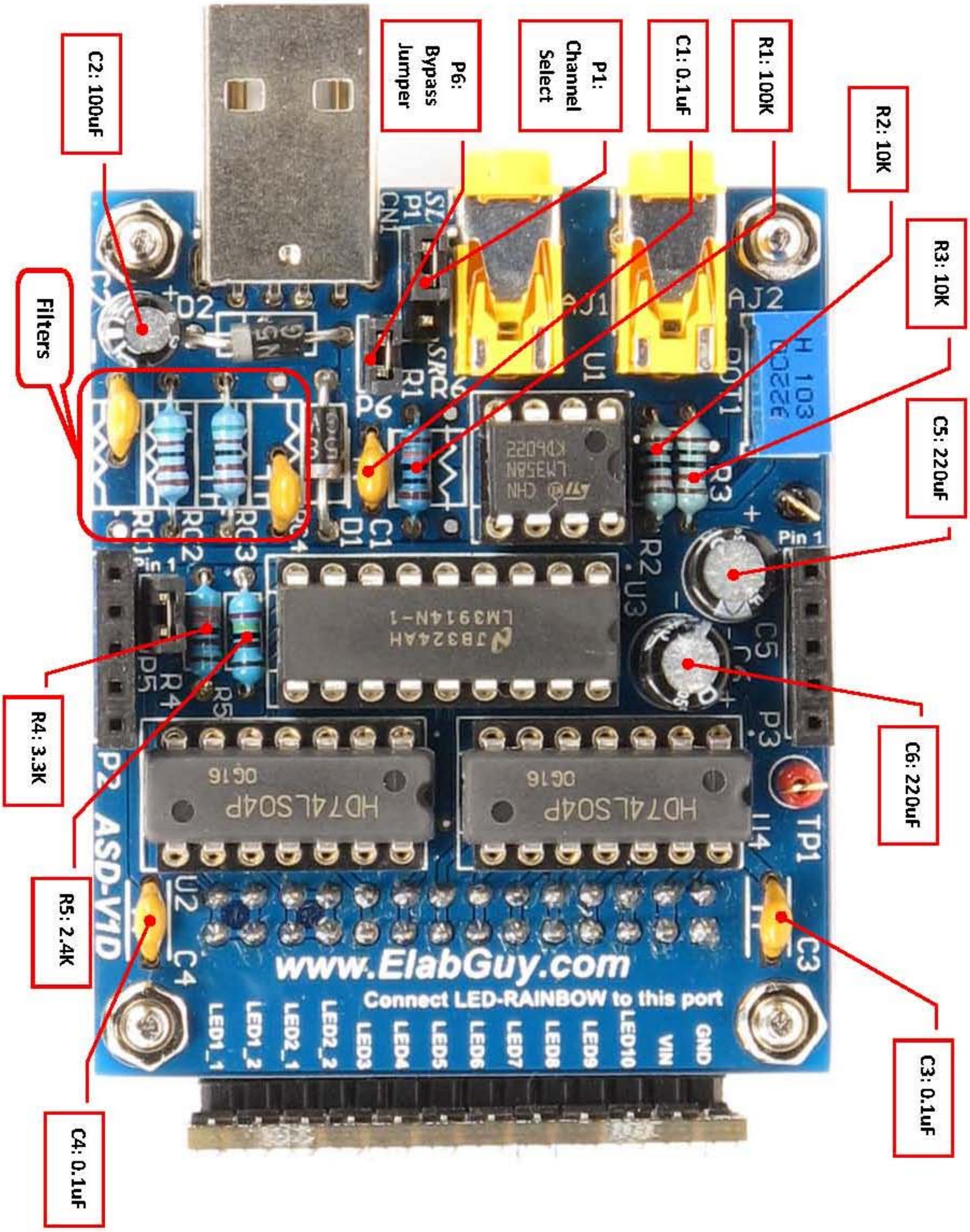
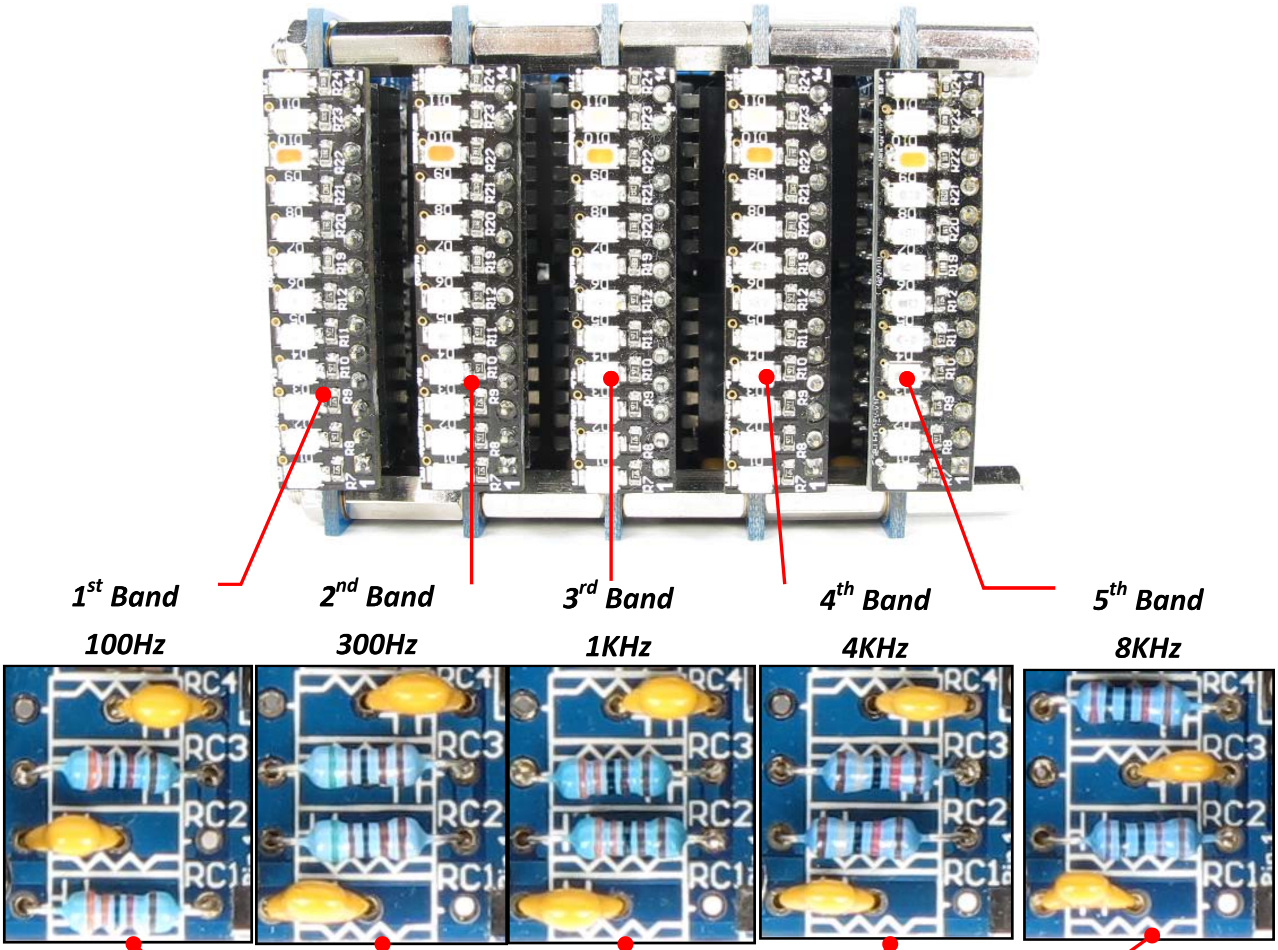


Figure A1 - Components placement



Designator	1^{st} Band	2^{nd} Band	3^{rd} Band	4^{th} Band	5^{th} Band
RC4	47nF	0.1uF	47nF	2.2nF	20K
RC3	33K	5.1K	3.3K	18K	1nF
RC2	47nF	5.1K	3.3K	18K	20K
RC1	33K	0.1uF	47nF	2.2nF	1nF

Figure A2 – Audio Spectrum Display filters

Figure A4 – Connecting iPhone to ASD-V1D

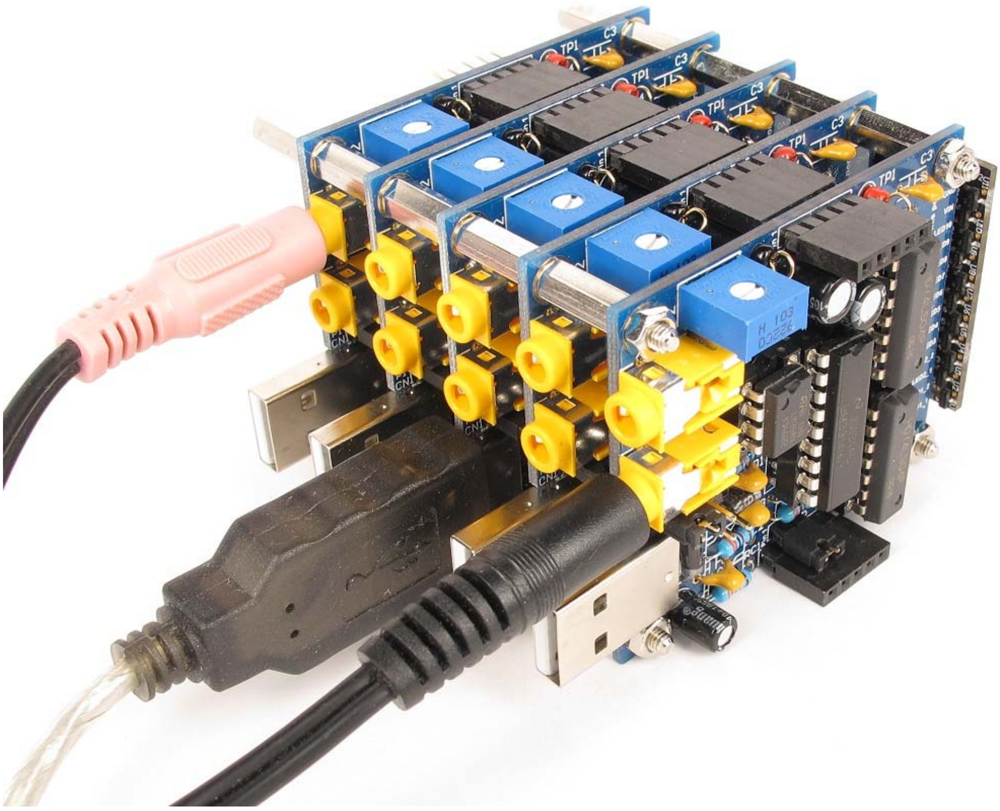


Figure A5 – Sample connection for Audio Spectrum Display

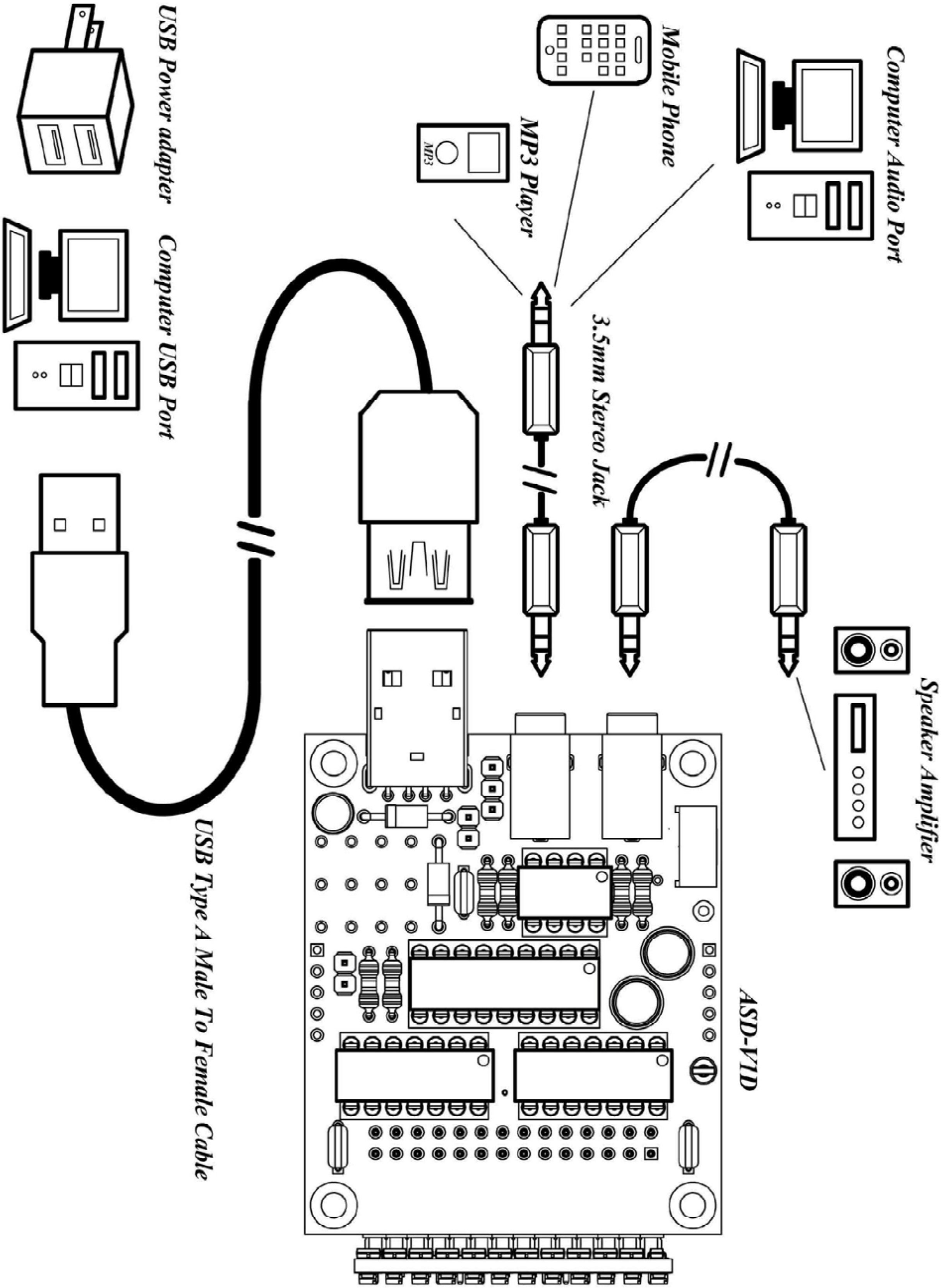


Figure A6 – Wiring up the ASD-V1D