

# Five Band Audio Equalizer

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# Presentation Structure

① Introduction

② Filter Design

③ Other Circuits

# Component Selection Justification

## ① TL072CP Operational Amplifier

- **Low Noise:**  $37 \text{ nV}/\sqrt{\text{Hz}}$  ideal for audio signal processing
- **FET Input:** High impedance ( $10^{12} \Omega$ ) prevents filter loading
- **Dual Channel:** 2 op-amps per IC reduces component count
- **Adequate BW:** 3 MHz sufficient for audio bands (20 Hz–20 kHz)
- **Low Power:** 1.4 mA per channel enables multi-stage design
- **Wide Supply:** 7 V to 30 V allows flexible power options

## ② LM3915 Dot/Bar Display Driver

- Logarithmic 3 dB/step response for audio
- Direct LED drive without current-limiting resistors
- Simple setup with minimal external components
- Over-voltage protection ( $\pm 35\text{V}$ ) on input

## Component Selection Justification (Cont.)

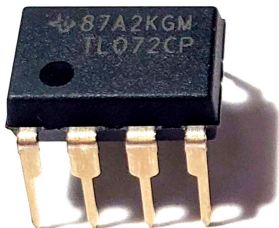
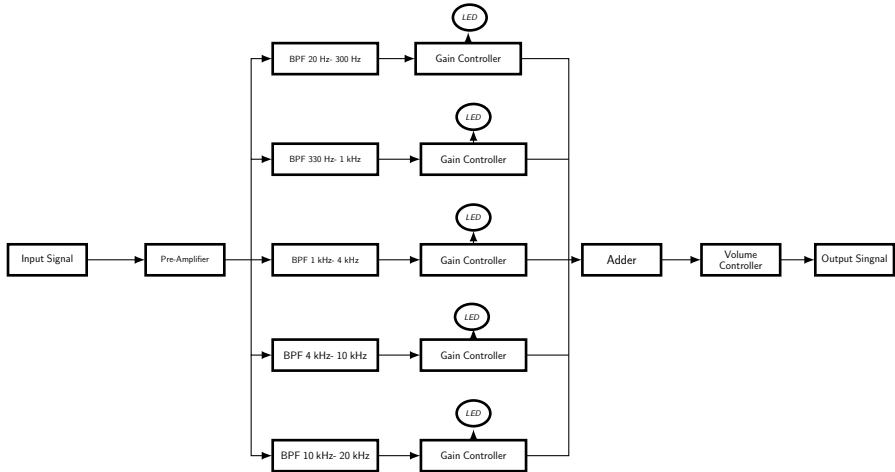


Figure: TL072CP Operational Amplifier



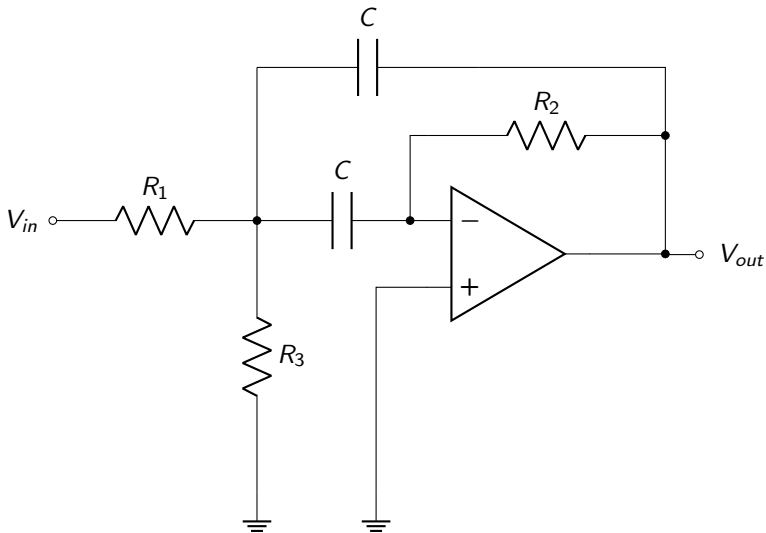
Figure: LM3915 Dot/Bar Display Driver

# System Architecture



# Filter Design

# MFB Band-Pass Filter



## MFB Band-Pass Filter (Cont.)

- mid-frequency:  $f_m = \frac{1}{2\pi C} \sqrt{\frac{R_1 + R_3}{R_1 R_2 R_3}}$
- gain at  $f_m$ :  $-A_m = \frac{R_2}{2R_1}$
- filter quality:  $Q = \pi f_m R_2 C$
- bandwidth:  $B = \frac{1}{\pi R_2 C}$

The MFB band-pass allows to adjust  $Q$ ,  $A_m$ , and  $f_m$  independently. Bandwidth and gain factor do not depend on  $R_3$ . Therefore,  $R_3$  can be used to modify the mid frequency without affecting bandwidth,  $B$ , or gain,  $A_m$ . Furthermore,

$$R_1 = \frac{R_2}{-2A_m}, R_2 = \frac{Q}{\pi f_m C}, R_3 = \frac{-A_m R_1}{2Q^2 + A_m}$$



## Fourth-Order Band-Pass Filter (Staggered Tuning)

In order to make Fourth-Order Band-Pass filter, we cascaded two MFB Band-Pass filters.

The mid frequency of filter 1 is:

$$f_{m1} = \frac{f_m}{\alpha}$$

the mid frequency of filter 2 is:

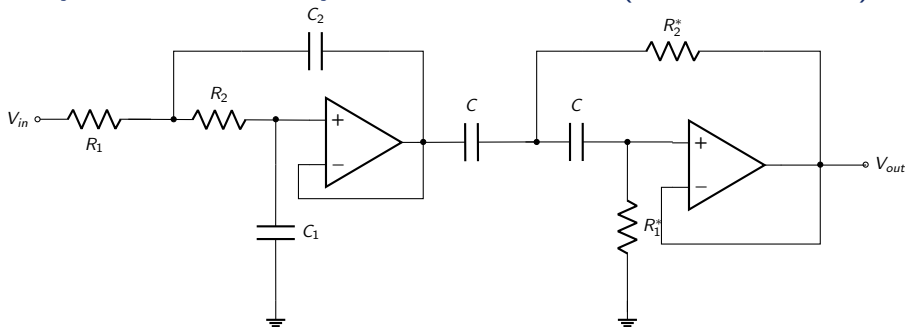
$$f_{m2} = f_m \cdot \alpha$$

with  $Q$  being the quality factor of the overall filter.

The individual gain ( $A_{mi}$ ) at the partial mid frequencies,  $f_{m1}$  and  $f_{m2}$ , is the same for both filters:

$$A_{mi} = \frac{Q_i}{Q} \sqrt{\frac{A_m}{B_1}}$$

## Unity-Gain Sallen-Key Band-Pass Filter (For 20-300 Hz)



For given  $C_1$  and  $C_2$ , the resistor values for  $R_1$  and  $R_2$  are calculated through:

$$R_{1,2} = \frac{a_1 C_2 \mp \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

For given  $C$ , the resistor values for  $R_1^*$  and  $R_2^*$  are calculated through:

$$R_1^* = \frac{1}{\pi f_c C a_1}, R_2^* = \frac{a_1}{4\pi f_c C b_1}$$

## Resistor & Capacitor Values

Resistor & Capacitor values (For Frequency Range: 20 Hz – 300 Hz)

$$R_1 = 1.2 \text{ k}\Omega, R_2 = 2.2 \text{ k}\Omega, C_1 = 220 \text{ nF}, C_2 = 470 \text{ nF}, \\ R_1^* = 47 \text{ k}\Omega, R_2^* = 27 \text{ k}\Omega, C = 220 \text{ nF}$$

Resistor & Capacitor values for 1st MFB Filter

Frequency Range	$R_1$	$R_2$	$R_3$	$C$
300 Hz – 1 kHz	2.7 k $\Omega$	10 k $\Omega$	10 k $\Omega$	100 nF
1 kHz – 4 kHz	2.7 k $\Omega$	8.2 k $\Omega$	15 k $\Omega$	33 nF
4 kHz – 10 kHz	2.2 k $\Omega$	6.8 k $\Omega$	1.2 k $\Omega$	15 nF
10 kHz – 20 kHz	1.8 k $\Omega$	5.6 k $\Omega$	470 $\Omega$	10 nF

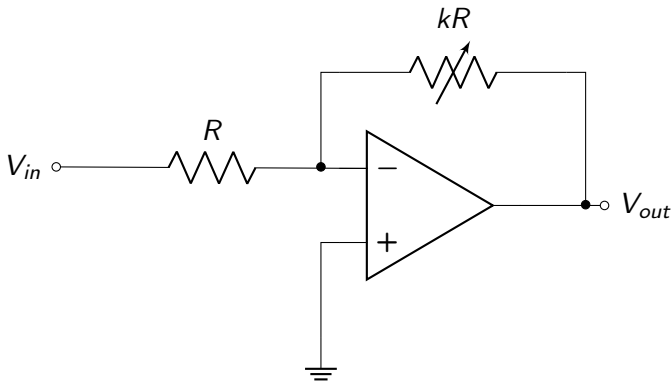
## Resistor & Capacitor Values (Cont.)

### Resistor & Capacitor values for 2nd MFB Filter

Frequency Range	$R_1$	$R_2$	$R_3$	$C$
300 Hz – 1 kHz	8.2 k $\Omega$	27 k $\Omega$	27 k $\Omega$	10 nF
1 kHz – 4 kHz	2.2 k $\Omega$	8.2 k $\Omega$	15 k $\Omega$	10 nF
4 kHz – 10 kHz	2.2 k $\Omega$	6.8 k $\Omega$	1.2 k $\Omega$	6.8 nF
10 kHz – 20 kHz	1.5 k $\Omega$	3.9 k $\Omega$	390 $\Omega$	6.8 nF

# Other Circuits

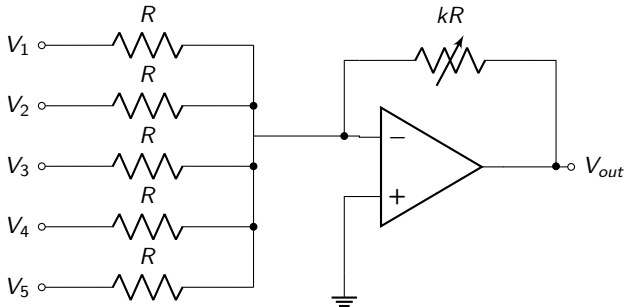
# Gain Controller



$$\frac{V_{in} - 0}{R} = \frac{0 - V_{out}}{kR}$$

$$V_{out} = -kV_{in}$$

## Adder & Volume Controller



$$\sum_{i=1}^5 \frac{V_i - 0}{R} = \frac{0 - V_{out}}{kR}$$

Hence,

$$V_{out} = -k \sum_{i=1}^5 V_i$$

# LED Display

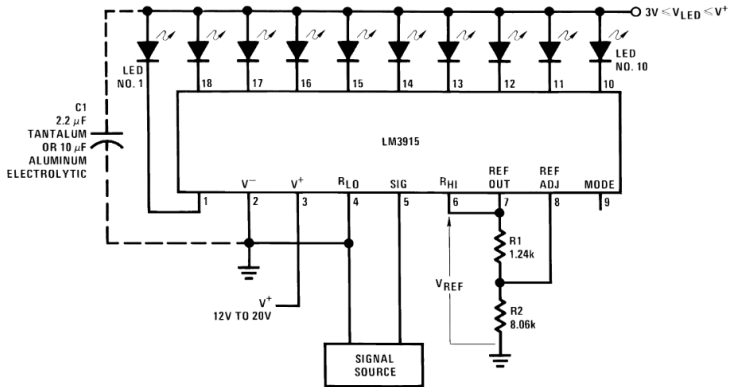
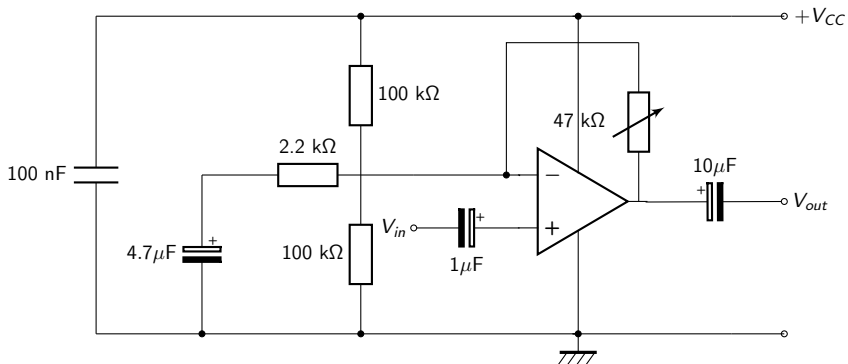


Figure: Circuit connection for LED display[2]

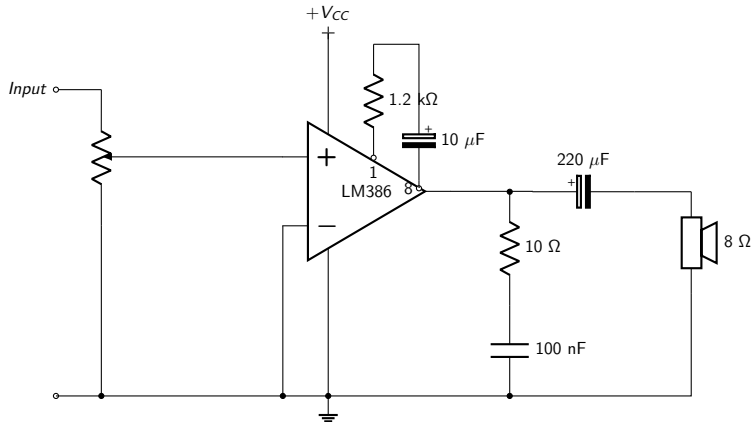


# Pre-Amplifier Circuit<sup>1</sup>



<sup>1</sup><https://www.homemade-circuits.com>

# Power Amplifier Circuit<sup>2</sup>



<sup>2</sup><https://www.eleccircuit.com/lm386-audio-amplifier-circuit/>

# References



Texas Instruments, *Top Amps for Everyone Design Guide*, Rev. 8, Advanced Analog Products, SLOD006B, Aug. 2002. [Online]. Available: [https://web.mit.edu/6.101/www/reference/op\\_amps\\_everyone.pdf](https://web.mit.edu/6.101/www/reference/op_amps_everyone.pdf)



Texas Instruments. *LM3915 Dot/Bar Display Driver Datasheet*, SNVS740C. Revised Mar. 2013. [Online]. Available: <https://www.alldatasheet.com/datasheet-pdf/view/558236/TI/LM3915.html>

# Thank You!