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**: $37\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$ 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$35V) on input

Component Selection Justification (Cont.)

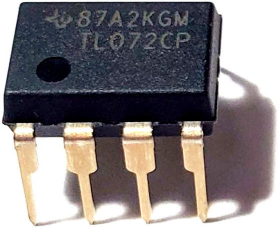
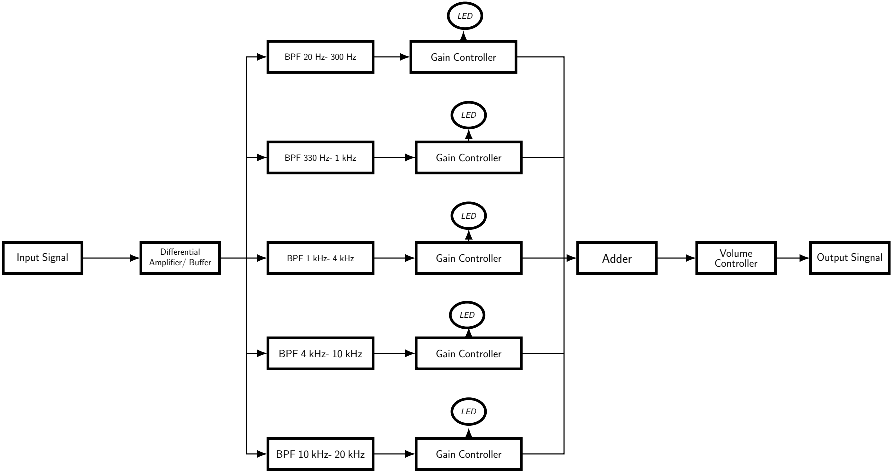


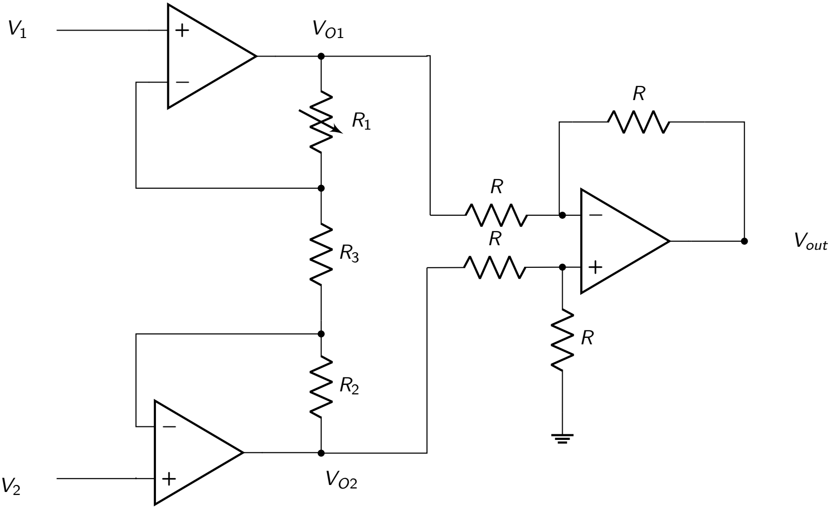
Figure: TL072CP Operational Amplifier

Figure: LM3915 Dot/Bar Display Driver

System Architecture



Differential Amplifier



Differential Amplifier (Cont.)

$$\frac{V_1 - V_2}{R_3} = \frac{V_{O1} - V_{O2}}{R_1 + R_2 + R_3}$$

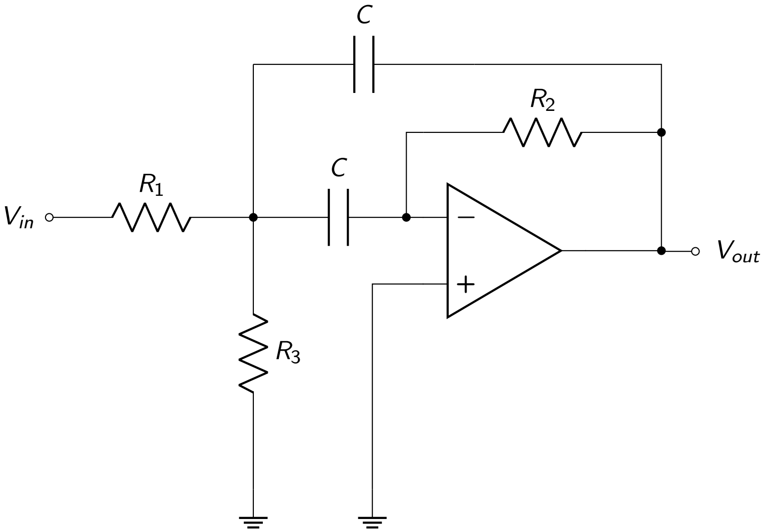
$$\text{Then, } \left(1 + \frac{R_1 + R_2}{R_3}\right)(V_1 - V_2) = (V_{O1} - V_{O2})$$

$$\text{Also, } V_{\text{out}} = (V_{O2} - V_{O1})$$

$$V_{\text{out}} = \left(1 + \frac{R_1 + R_2}{R_3}\right)(V_2 - V_1)$$

By changing the resistance of the R_1 resistor we can vary the amplitude of input signal.

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:

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

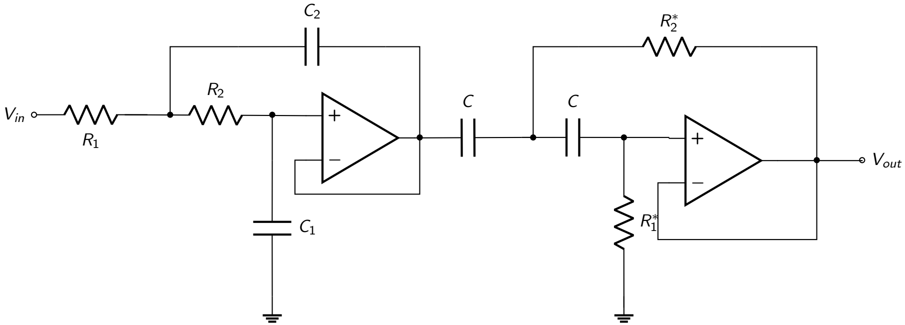
the mid frequency of filter 2 is:

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

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:

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

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)

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

Resistor & Capacitor values for 1st MFB Filter

- Frequency Range: 300 Hz - 1 kHz
  $R_1 = 3.3\ \mathrm{k\Omega}, R_2 = 10\ \mathrm{k\Omega}, R_3 = 3.9\ \mathrm{k\Omega}, C = 100\ \mathrm{nF}$
- Frequency Range: 1 kHz - 4 kHz
  $R_1 = 2.7\ \mathrm{k\Omega}, R_2 = 8.2\ \mathrm{k\Omega}, R_3 = 6.8\ \mathrm{k\Omega}, C = 33\ \mathrm{nF}$
- Frequency Range: 4 kHz - 10 kHz
  $R_1 = 2.2\ \mathrm{k\Omega}, R_2 = 6.8\ \mathrm{k\Omega}, R_3 = 1\ \mathrm{k\Omega}, C = 15\ \mathrm{nF}$

Resistor & Capacitor Values (Cont.)

Resistor & Capacitor values for 1st MFB Filter(Cont.)

- Frequency Range: 10 kHz - 20 kHz
  $R_1 = 2.2$ kΩ, $R_2 = 5.6$ kΩ, $R_3 = 390$ Ω, $C = 10$ nF

Resistor & Capacitor values for 2nd MFB Filter

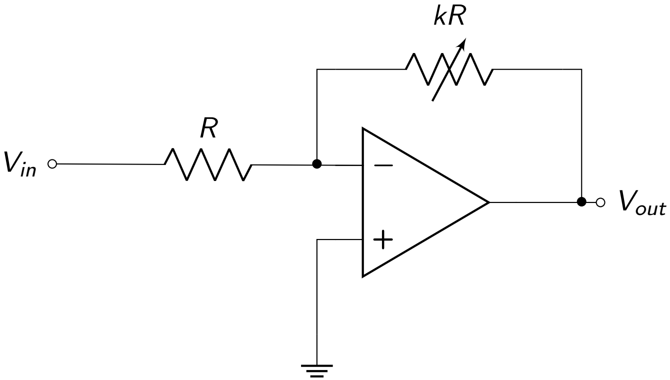
- Frequency Range: 300 Hz - 1 kHz
  $R_1 = 15$ kΩ, $R_2 = 47$ kΩ, $R_3 = 15$ kΩ, $C = 10$ nF
- Frequency Range: 1 kHz - 4 kHz
  $R_1 = 3.3$ kΩ, $R_2 = 10$ kΩ, $R_3 = 6.8$ kΩ, $C = 10$ nF
- Frequency Range: 4 kHz - 10 kHz
  $R_1 = 2.7$ kΩ, $R_2 = 8.2$ kΩ, $R_3 = 1$ kΩ, $C = 6.8$ nF

Resistor & Capacitor Values (Cont.)

Resistor & Capacitor values for 2nd MFB Filter (Cont.)

- Frequency Range: 10 kHz - 20 kHz
  $R_1 = 1.8\ \mathrm{k\Omega}$, $R_2 = 5.6\ \mathrm{k\Omega}$, $R_3 = 330\ \Omega$, $C = 6.8\ \mathrm{nF}$

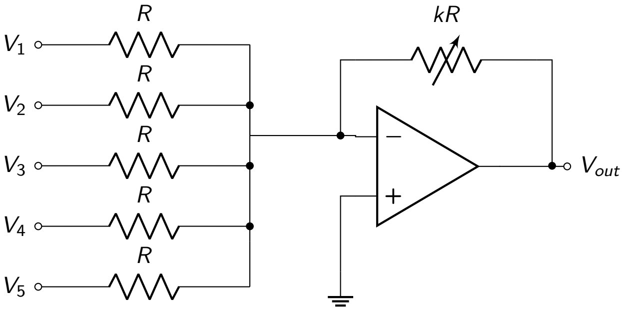
Gain Controller



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

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

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

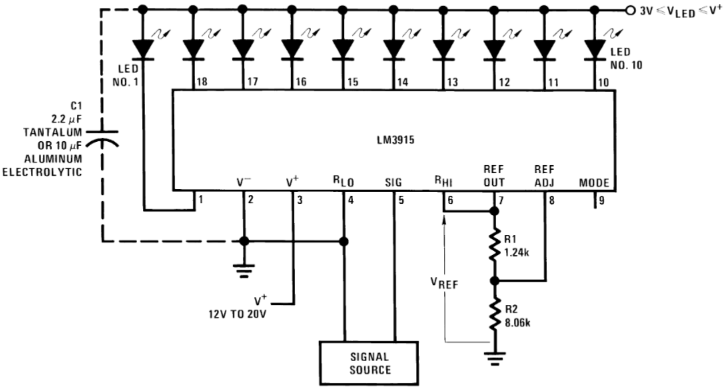
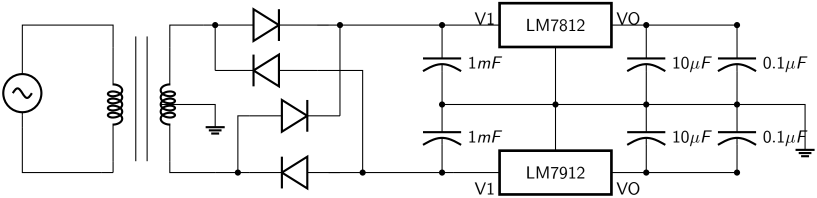


Figure: Circuit connection for LED display[2]

Power Supply Circuit



For the transformer, we used 12 V×2 center tapped transformer.

References

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- 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!