Tone Stack With Graphic Spectrum Analyzer

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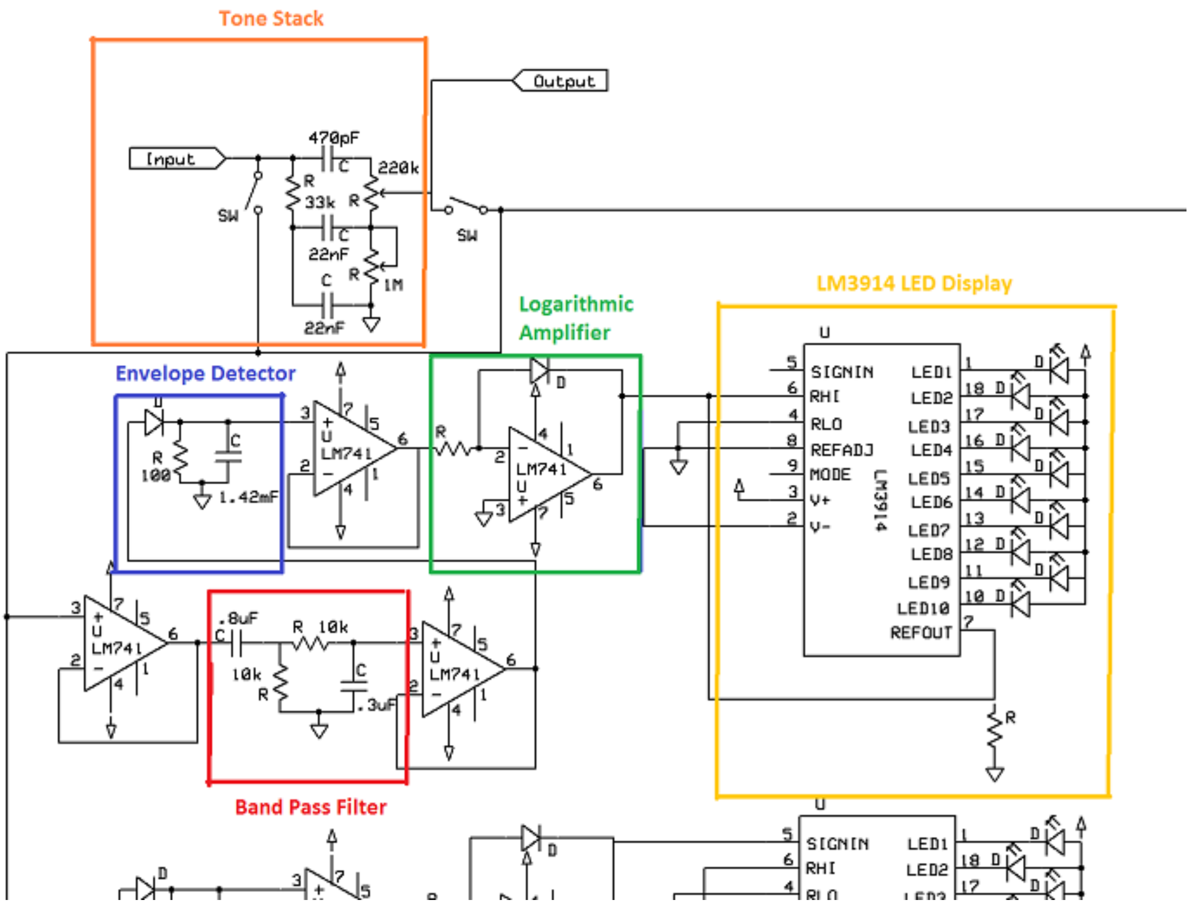

Fig. 1. Circuit for one of the bands of the LEDs. There are eight total of these circuits with different component values.

This project is designed for use with a guitar amp or other audio device such as a computer or cell phone. It is made up of two components: a tone stack and a graphical spectrum analyzer. The input signal is split and processed through the tone stack, and also sent in parallel to the crossovers, which split the signal into 8 different bands to display on 8 different LED Light Column Voltmeters. However, before the signal is sent to the Voltmeter, it must be smoothed with an envelope detector so the lights don't turn on and off rapidly. The input to the spectrum analyzer will have a switch, so that the spectrum can be viewed pre or post-EQ.

Keywords—tone stack, filter, logarithmic amplifier, envelope detection, integrated circuit, crossover, LED

I. Introduction

Our project's schematic essentially involves 3 parts: The EQ section, a section that splits the signal into 8 frequency bands and smooths them with an envelope follower, and the LM3914 integrated circuit that drive the 8 LEDs per band. The tone stack is based on the Marshall Tone Stack, commonly found in guitar amplifiers. The band pass splits the audible spectrum by starting at 20 Hz and creating bands in multiples of 2.5 The component values of the envelope detector are set to be optimized for each band. Gain for the LEDs takes place during the logarithmic amplification block. Each section is separated by unity gain buffers to prevent loading

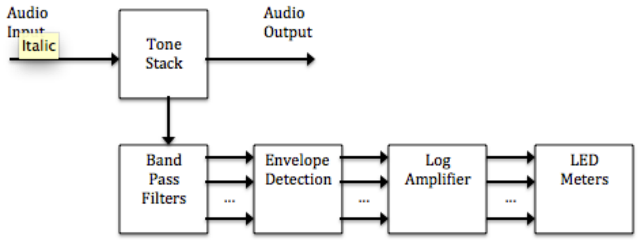

Fig. 2 Block diagram of circuit

II. Marshall Tone Stack

Our EQ section is based off of the guitar amplifier company Marshall's tone stack circuit (which is based off Fender's). There are three user-controllable knobs: bass, mid and treble. Changing one knob in the EQ section will change the response of the other two bands as well. Although the interaction of the controls and elements make the tone stack seem quite complicated, the function of each knob can be simplified.

The treble control is mainly a high pass filter formed by the 33k resistor and 470pF capacitor. The bass control is essentially a band pass filter where the pot sets the lower cutoff frequency with the first 22nF capacitor. The pot that controls the mids is an attenuator that controls the output of the band pass filter formed by the 33k resistor, the second 22nF capacitor and the pot. The schematic for the tone stack can be seen in the orange box in Fig. 1.

III. Preprocessing For LEDs

A. Band Pass Filter

After the tone stack, we split the signal into eight different bands. Each goes through a unity gain buffer and a passive RC band pass filter comprised of a low pass and high pass in series. Equations for cap values on page. We chose the crossover frequencies of the bands by starting with 20 Hz and multiplying by 2.5 so that they were logarithmically related and 20-20k could fit nicely into 8 bands. Frequency perception is logarithmic and not linear so bands get bigger in higher frequencies.

$$f_c = \frac{1}{2\pi RC} Hz \qquad (1)$$

By solving for the capacitor and plugging in each cutoff frequency:

$$C = \frac{1}{2\pi R f_c} Hz \qquad (2)$$

Since the cutoff frequencies are based on the relation of R and C, all resistors were set to 10K ohms for the calculations.

B. Envelope Detection

The envelope detector is included so that the LEDs don't flash on and off too quickly. We want the light strip for each band to follow the perceived loudness, not flicker. Our envelope detector circuit is similar to a circuit used in rectifiers. The component values will vary from band to band based on frequencies being processed. If the capacitor discharges too slow, charge will build up, and if it discharges too fast, ripple will be too high. Our envelope detectors follow the envelop of the center frequency of each band. The maximum V_r we want to see is 0.1V. The capacitor values were set using the equation for ripple voltage in an envelope detector:

$$V_r = \frac{V_p}{fRC} \qquad (3)$$

V_p is set to .5, based on the output voltage of the typical audio jack of a mobile device. V_r was set to .1, being the chosen tolerance for ripple voltage. f_H and f_L are the high and low cutoff frequencies of the frequency band that the envelope detector is being used on. Since V_r is based on the relation between R and C, R is set to 100 ohms.

$$C = \frac{5}{100 * .5(f_H + f_L)} \qquad (4)$$

C. Logarithmic Amplifier

Sound intensity is perceived logarithmically so values on LEDs should be logarithmic. To design the log amp, we will adjust the pot until the values fit the LEDs properly. The log amplifier also drives the comparators in the IC that controls the LEDs.

IV. LEDs

We decided to use a LM3914 integrated circuit used for driving LEDs. This Integrated Circuit has outputs at different ratios of the source voltage and LEDs are connected to each pin. We did this rather than use 8 comparators, resistors and diodes per frequency band to save on money and more importantly space. Below is a picture of the inside of the Integrated Circuit:

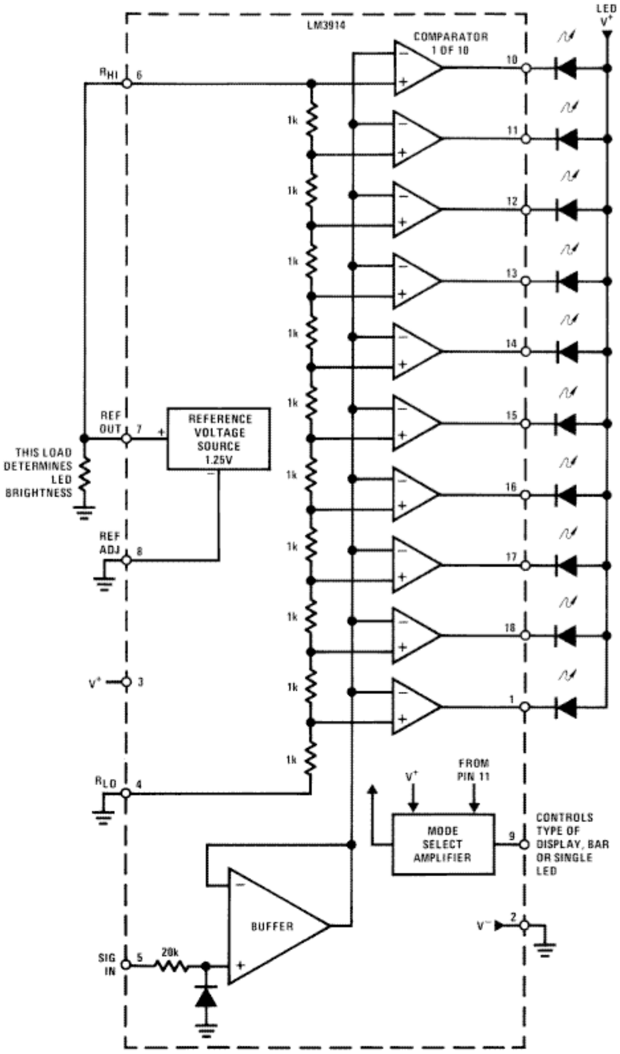

Fig. 3 Block Diagram of interior circuitry of LM3914

IV. Implementation

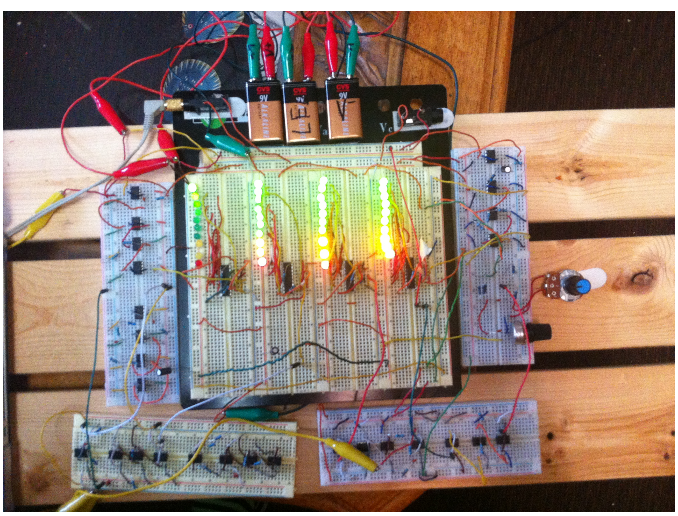
Fig. 4 Implementation of Circuit on Prototyping Boards

Practical implementation of the circuit brought forth many issues not apparent in the original design. The first step was purchasing all the necessary components including resistors of various values, capacitors, potentiometers, LEDs, integrated circuits, wiring, batteries, and audio jacks. Organizing all of the components into sorted containers was necessary to keep the project organized. Another issue was that purchased components have standard values, so obtaining exact values had to be done through putting resistors in series or parallel. In some cases, entire parts of the circuit had to be redesigned, for example choosing different resistor values for filters when certain capacitor values were not available.

One of the other issues of the project was size and the limited number of nodes on each prototyping board. While a large number of physical components can be fit on the prototyping board, organization can be limited by the configuration of each board, which cannot be changed. The circuit ended up taking far more space than expected. For this reason we reduced the number of bands from eight to four. Another amplifier was also required for each band to put the music's amplitude in a useable range for the LEDs. This replaced the envelope detector, which for frequencies over around 40 Hz, was not necessary. While there is some flashing for frequencies below 40, the flashing is not perceivable to the human eye above this level.

Grounding was also an issue throughout the project. We focused on using the ground pin of the audio jack. The ground pin of each battery was then attached to this reference point. An issue with this was that the ground is then dependent on what is connected to it. With a cellular device, whether the device is being held by a person, placed on a table, or has the case on or not affected the reference point. When the speaker output was added, this would sometimes trigger LEDs to turn on falsely, as the two ground pins were at different relative voltages. This would be fixed if the input was a guitar, as a guitar has proper mechanisms for grounding. Also, if a power supply was used instead of batteries, the power ground could be referenced, with the input and output grounds connected to power ground.

One other issue that was present in the project was due to powering multiple bands of LEDs with the same voltage source. Having signals that were too large on multiple LED bands would cause the LEDs to stay on even after audio stopped. In order to prevent any sort of AC signals on the battery path, a large capacitor of 10uF was added from the battery to ground, which would low pass filter everything except the DC voltage from the battery. This allowed all bands of LEDs to operate at any level without freezing the display.

V. Conclusion

Seeing this project through to completion helped us gain additional knowledge beyond conventional theory and analysis. Most circuit analysis assumes ideal conditions and models components linearly. Because of this, many calculations done on paper had different results in the context of the circuit. Instead of basing the project completely on theory, the building process involved intelligently tweaking values until the results were correct, and then analyzing what had caused our original design to be incorrect.

Some improvements that could be made on this project in the future include using higher order filters to split bands (only first order were used in this project), including the envelope detector to eliminate visible flashing at low frequencies, and using a power supply to avoid issues with batteries such as grounding and losing charge. Overall, this project was a valuable learning experience on practical implementation of circuits that both allowed us to see the design project all the way through, and gain greater insight into the workings of electronics.

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