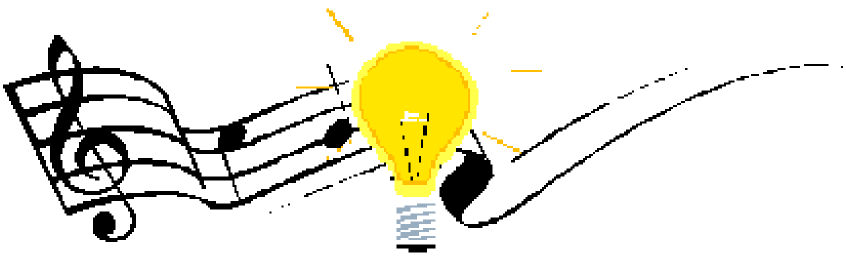
AS Electronics Project:
3-Channel Sound-to-Light Display



By
David Bull

1. Contents

2. Aim

I enjoy listening to dance and club music. I have already constructed an audio mixer and VU meter. I thought it would be interesting to look at sound controlled lighting.

The first real dedicated disco lights were invented in about 1968 when someone decided to control lighting using electronics. The idea was to flash lamps to different frequencies, originally three channels. Basically, one lamp would flash in time with the bass frequency, one in time with the middle and one in time with the treble.

Between 1968 and 1973 sound-to-light was very popular. Sound-to-light soon progressed from 3-channel to 4-channel, using bass, lower middle, upper middle and treble. However, sound-to-light had a basic problem; whilst the lights were following the music and reacting to different frequencies, the human eye had great difficulty in relating the visual effect to the music. It was just too complex.

A new idea surfaced in 1973 to overcome this problem. Instead of flashing each channel to a different frequency, the new way was to make the lights only react to the bass beat lighting each channel in turn. This gave an easy and dramatic sound-activated effect that the eye could easily follow, and the Sound Chaser was born.

I have decided to build a simple 3-channel sound-to-light display despite the problems previously encountered so as to see what the effect was like.

3. Specification

- The input impedance should be around 50kΩ so as not to load the source.
- The input sensitivity will be variable sufficient to drive the display from typical line outputs of 115mV to 775mV.
- 3 Filters:
  - Bass – Low pass filter with cut off at 300Hz
  - Middle – Band pass filter with range 300Hz > 5kHz
  - Treble – High pass filter with cut off at 5kHz
- The display will be powered by a ±12Vsplit rail power supply.
- The display will be modular allowing different lighting units to be added or changed.

4. Possible Solutions

I have been unable to find many designs of sound-to-light displays, but at the most basic level one would consist that shown in Figure 1.

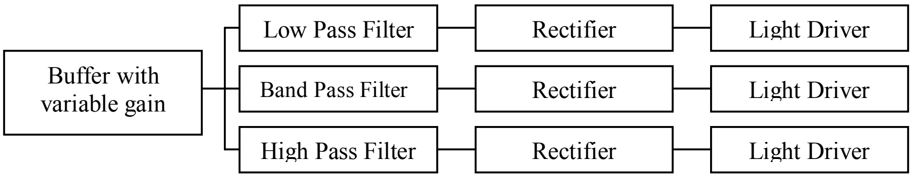


Figure 1 – Stages of a basic 3-channel sound-to-light display

4.1. Filters

There are two types of filter; active and passive. Passive filters are made using resistors and capacitors, resistors and inductors, or inductors and capacitors. Active filters consist of integrated circuitry, particularly the IC op-amp, combined with resistors and capacitors to accurately simulate the performance of traditional inductance-capacitance filters. Active filters usually have some gain and require some supply power.

Filters may be designed to have different rates of cut off outside the pass band. This is known as the "order" of the filter, e.g. first or second order. Simple RC and RL filters are first order in which the cut-of rate is relatively shallow - only 6dB per octave. As the order of the filter increases so does the complexity of the filter.

All passive filters introduce signal attenuation that may have to be compensated for by adding a gain stage.

4.2. Rectifiers

Because the use of mains powered lighting is not within the scope of this project low power, low voltage DC lamps will be used. Therefore the AC output signal from the filter will need to be rectified. The two types of rectifiers are half-wave and full-wave. Full wave rectifiers are more complex than half-wave rectifiers and therefore the component count is greater. As the output will only be driving a lamp a half-wave rectifier would be adequate for this circuit.

There is also a choice of using either a passive or active rectifier. A passive rectifier is relatively simple but has the disadvantage of the 600mV voltage drop across each of the diodes. In order to compensate for this voltage drop extra gain would be required. A better solution would be to use an active rectifier. This incorporates the diodes in the feedback loop of the op-amp thus overcoming the 600mV voltage drop.

5. Chosen Solution

Figure 2 shows a block diagram of the stages of the final display circuit.

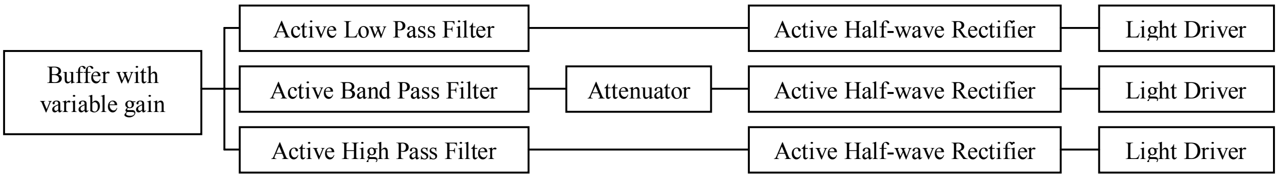


Figure 2 – Stages of the 3-channel sound-to-light display

5.1. Buffer

The buffer stage provides the required 50kΩ input impedance to prevent the source from being loaded. The buffer stage also provides variable gain to adjust the sensitivity of the display.

5.2. Filters & Attenuator

The filters used are 2nd order Equal Component Sallen-Key filters. I have chosen to use 2nd order filters as the roll-off of 1st order filters is too shallow causing a large overlap between the channels. Higher order filters are more complex to design and require more components. I have chosen to use Sallen-Key filters as they are the simplest 2nd order active filters that can be built – they are easy to use, easy to design and easy to tune. 2nd order Sallen-Key circuits generally consist of two cascaded RC sections driving a high input impedance non-inverting amplifier. The output signal, which is fed back into the filter circuitry, modifies the filter characteristic changing the roll off. In the equal component version of the Sallen-Key Filter both resistors are of identical values and both capacitors are of identical values making the circuit simple to design. This forces the gain of the circuit to a value of 3-d. Also, just by switching the capacitors and resistors to their opposite positions the circuit can be converted to an identical high-pass one. The need for an attenuator after the band-pass filter is due to the fact that the band-pass filter consists of a low-pass filter and a high-pass filter in series. Both of these filters have gain and the total gain of the filters is the gain of the low-pass filter plus the gain of the high-pass filter. To keep the total gain of all the filters equal an attenuator is required on the output of the band-pass filter.

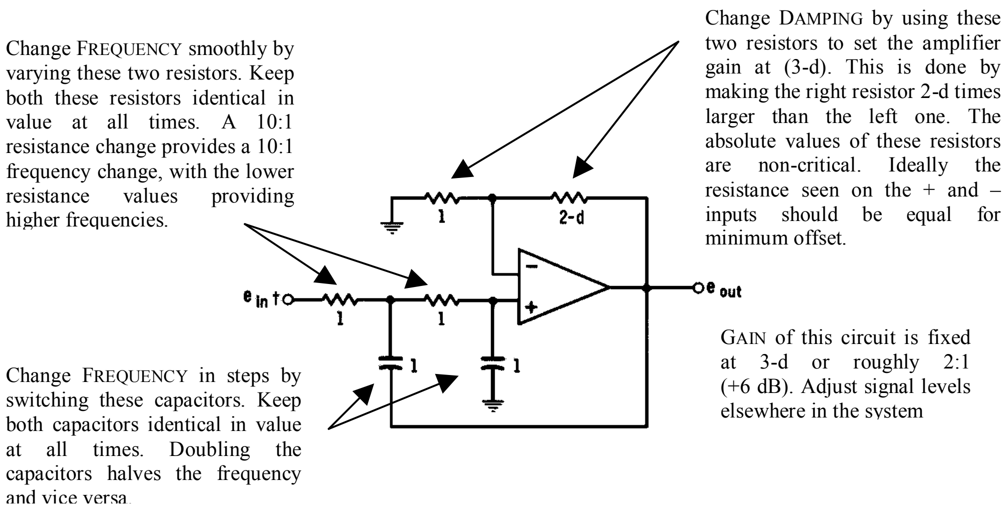


Figure 3 – The Equal Component 2nd Order Sallen-Key Low Pass Filter

5.3. Rectifier

The rectifier I have decided to use for the circuit is a half-wave active rectifier. A full-wave rectifier is more complex and a half-wave rectifier will be perfectly adequate in this situation. I have decided to use an active rectifier to overcome the 600mV voltage drop that would be incurred if I were to use a passive rectifier. Figure 4 shows the active half-wave rectifier circuit that will be used.

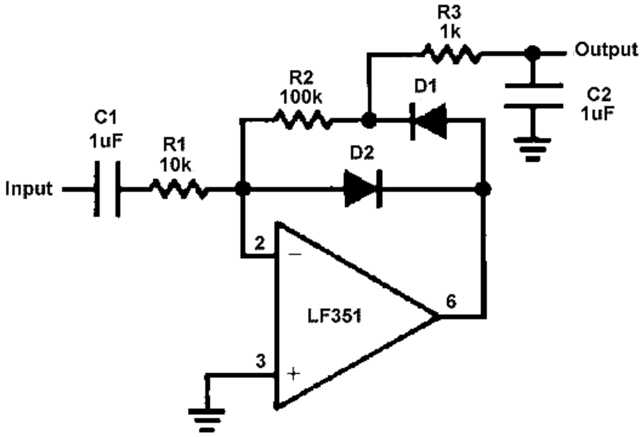


Figure 4 – Precision Half-Wave Active Rectifier

5.4. Light Driver

For this stage of the circuit a number of designs could have been used, including:

- Mains powered lighting – *This is not permissible for safety reasons, but if it were to be used an opto-isolator stage would need to be designed.*

- Low voltage, high power bulbs e.g. 12V Dichroic Bulbs – *The drawback of this solution is the large amount of current that would be required. For a 12V 60W bulb the current required would be 5 amps. For three bulbs the current required be 15 amps. This would require a substantial power supply.*

- Low voltage, low power bulbs – *This solution is far more suitable as the focus of this project was on the filter and rectifier stages. Low power bulbs draw far less current than the high power ones.*

I have decided to use 6V 4W bulbs as the maximum current required for three of these bulbs is only 2A. The current output of the op-amps in the active rectifiers is only a few tens of milli-amps. To overcome this I have used a high power transistor in emitter-follower mode to take advantage of its current gain. The bulb is connected to the emitter of the transistor and the base is fed from the output of the rectifier via a small load resistor. I decided to use a TIP3055, which is a 90W transistor, because it allowed for higher power bulbs to be used at a later date. They are also cheap and readily available.

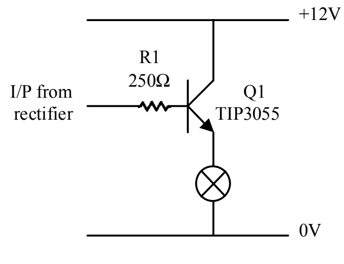


Figure 5 – Light Driver Circuit

6. Construction

6.1. Complete Circuit Diagram

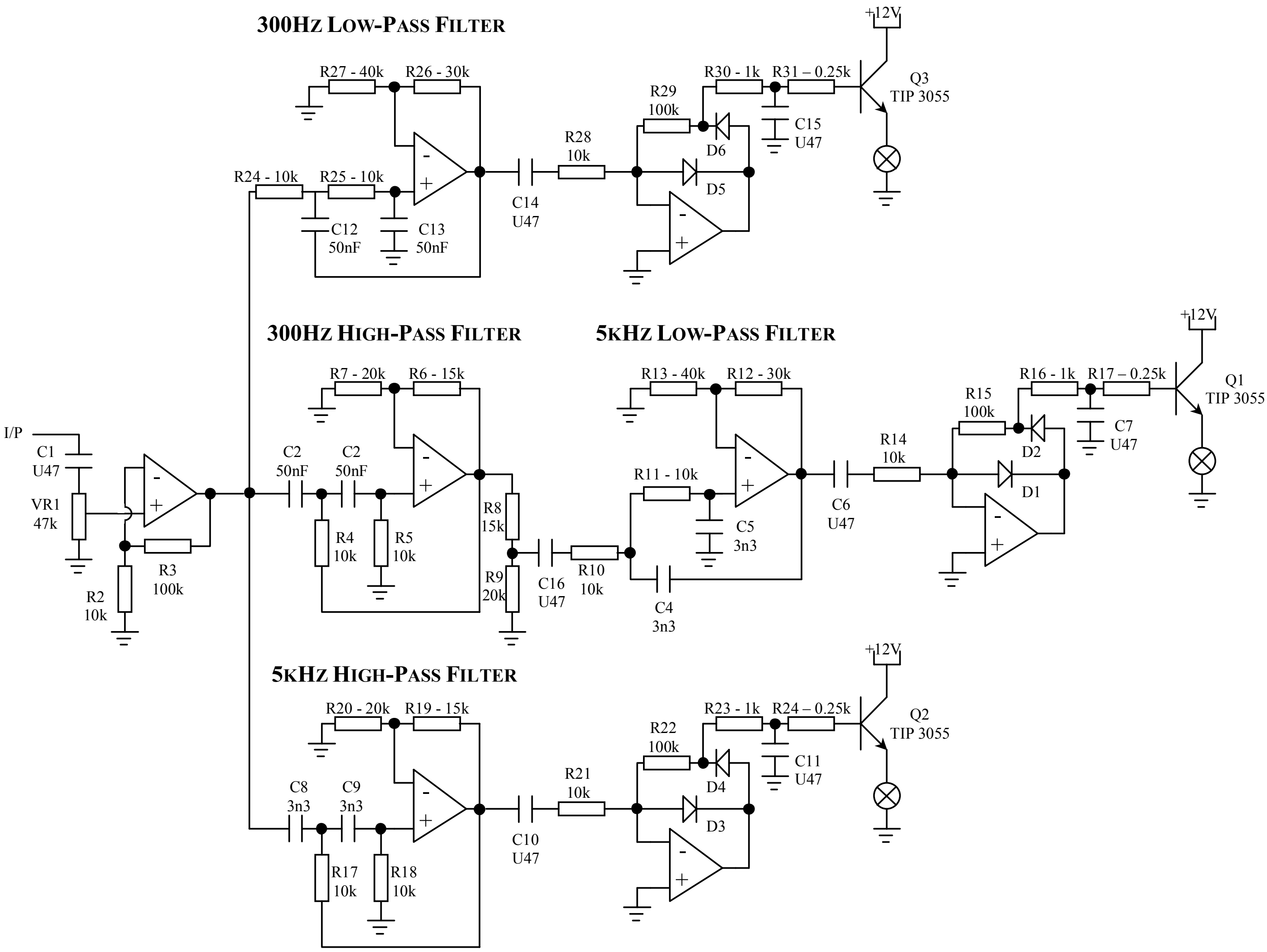


Figure 6 – Complete Circuit Diagram

6.2. Veroboard Layout

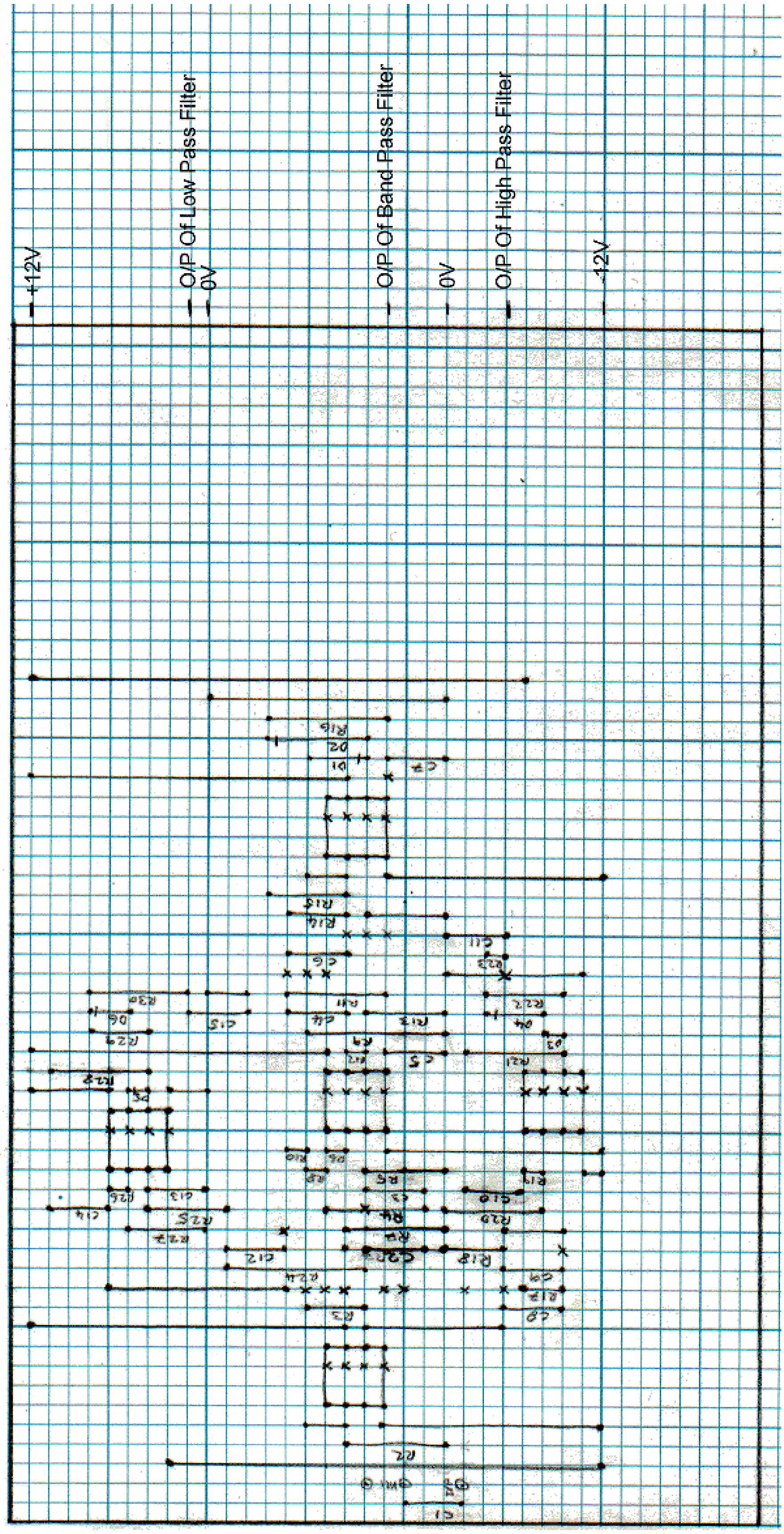


Figure 7 - Veroboard Layout

Figure 6 shows the veroboard layout for the filter and rectifier stages. The light driver stages have not been put on the board as the transistors may require heatsinks and they can be more easily mounted to a case. The maximum size of board I had was 100x160mm so I had to lay the components out to fit within this space.

6.3. Component & Price List

(Using Maplin Catalogue: April 2000 – August 2000)

The table below shows the price list for the components used to make the sound to light display.

Item	Page	Code	Price	Quantity	Total Cost
250R 0.6w Metal Film Resistor	*271*	*M250R*	*£0.07*	*3*	*£0.21*
1k 0.6w Metal Film Resistor	*271*	*M1K*	*£0.07*	*3*	*£0.21*
10k 0.6w Metal Film Resistor	*271*	*M10K*	*£0.07*	*12*	*£0.84*
15k 0.6w Metal Film Resistor	*271*	*M15K*	*£0.07*	*3*	*£0.21*
20k 0.6w Metal Film Resistor	*271*	*M20K*	*£0.07*	*3*	*£0.21*
30k 0.6w Metal Film Resistor	*271*	*M30K*	*£0.07*	*2*	*£0.14*
40k 0.6w Metal Film Resistor	*271*	*M40K*	*£0.07*	*2*	*£0.14*
100k 0.6w Metal Film Resistor	*271*	*M100K*	*£0.07*	*4*	*£0.28*
47k Potentiometer	*276*	*VP97F*	*£0.99*	*1*	*£0.99*
3.3nF Polyester Layer Capacitor	*87*	*WW25C*	*£0.24*	*4*	*£0.96*
100nF Polyester Layer Capacitor	*87*	*WW41U*	*£0.29*	*8*	*£2.32*
470nF Polyester Layer Capacitor	*87*	*WW49D*	*£0.47*	*7*	*£3.29*
LF351 Op-Amp	*360*	*WQ30H*	*£0.49*	*2*	*£0.98*
LF353 Dual Op-Amp	*360*	*WQ31J*	*£0.79*	*3*	*£2.37*
1N4148 Signal Diode	*304*	*QL80B*	*£0.08*	*6*	*£0.48*
TIP3055 High Power Transistor	*306*	*QH56L*	*£1.29*	*3*	*£3.87*
MCC Tubular R10 Bulb - 6v 4w	*649*	*BT80B*	*£0.49*	*3*	*£1.47*
DIL Socket 8-Pin	*136*	*BL17T*	*£0.13*	*5*	*£0.65*
Stereo 3.5mm Chassis Socket	*109*	*FK03D*	*£0.69*	*1*	*£0.69*
160X100mm Strip Board	*247*	*JP50E*	*£2.29*	*1*	*£2.29*

Total Cost: ***£22.60***

0.6w Resistors are used, as they are the standard size that Maplin supply and also there is no need for resistors with greater power handling.

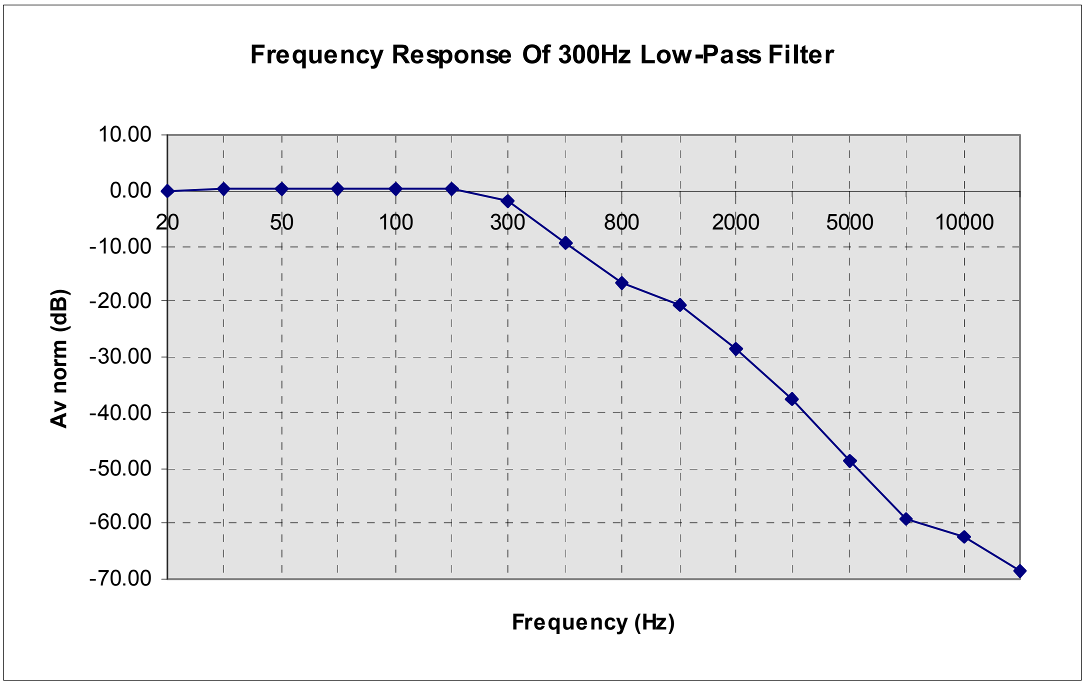
7. Testing

7.1. Filter

To test the frequency response of the filters, a signal generator was connected to the input and an audio mV meter to the output of each filter in turn. The input signal was kept at a constant 300mV and this was checked with the audio mV meter whenever the frequency was changed. The output of the filter was then measured with audio mV meter. Each filter was tested individually and in isolation. After all four filters were tested the high and low pass filters which make up the band pass filter were connected in series and tested together. The signal generator connected to the input of the first filter and the audio mV meter connected to the output of the second filter.

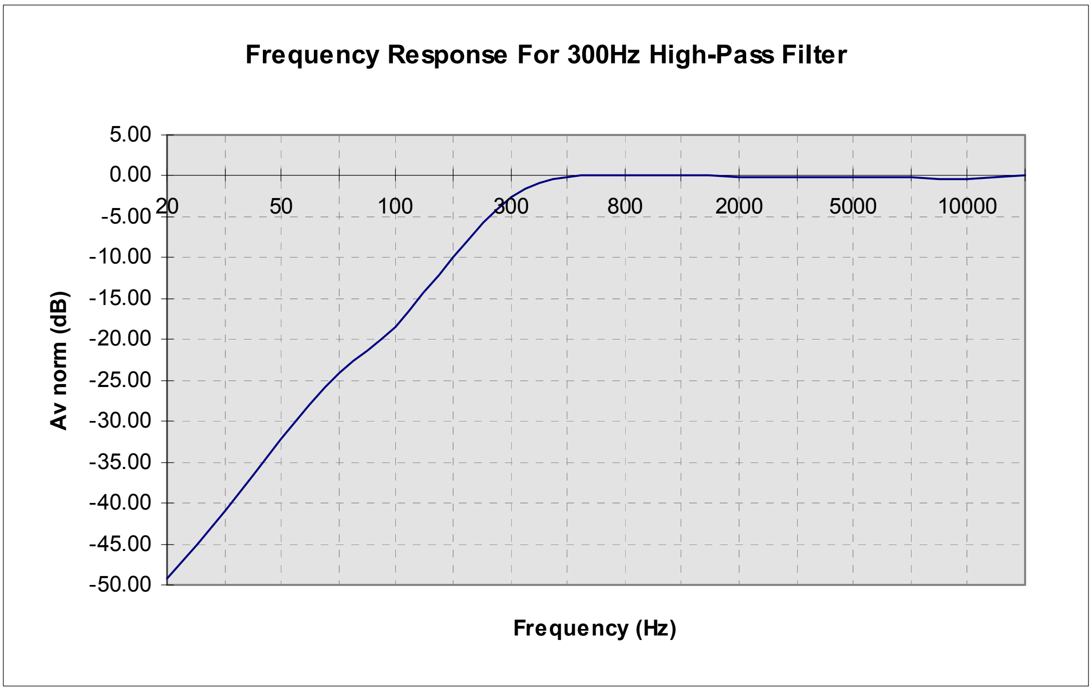
7.1.1. 300Hz Low Pass Filter

Freq. (Hz)	I/P (mV)	O/P (mV)	Av. norm (dB)
20	300	540	0.00
30	300	550	0.16
50	300	550	0.16
80	300	560	0.32
100	300	550	0.16
200	300	560	0.32
300	300	440	-1.78
500	300	180	-9.54
800	300	78	-16.81
1000	300	50	-20.67
2000	300	20	-28.63
3000	300	7.2	-37.50
5000	300	2	-48.63
8000	300	0.6	-59.08
10000	300	0.4	-62.61
20000	300	0.2	-68.63



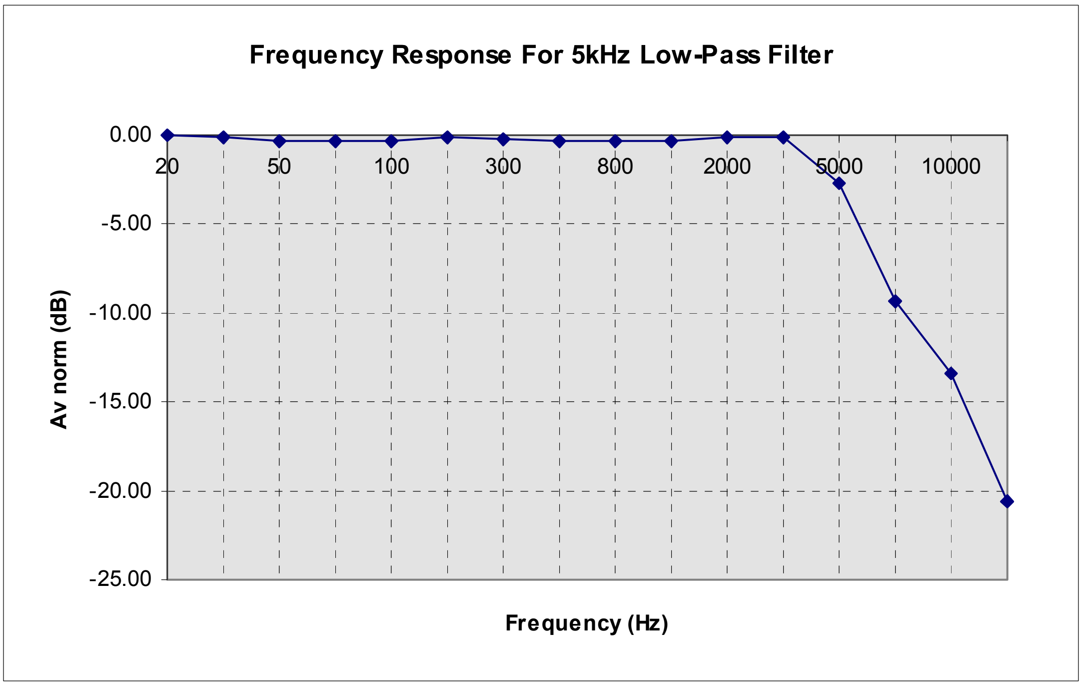
7.1.2. 300Hz High Pass Filter

Freq. (Hz)	I/P (mV)	O/P (mV)	Av. norm (dB)
20	300	1.9	-49.39
30	300	5	-40.98
50	300	14	-32.04
80	300	35	-24.08
100	300	66	-18.57
200	300	180	-9.86
300	300	420	-2.50
500	300	550	-0.16
800	300	560	0.00
1000	300	560	0.00
2000	300	550	-0.16
3000	300	550	-0.16
5000	300	559	-0.02
8000	300	559	-0.02
10000	300	540	-0.32
20000	300	560	0.00



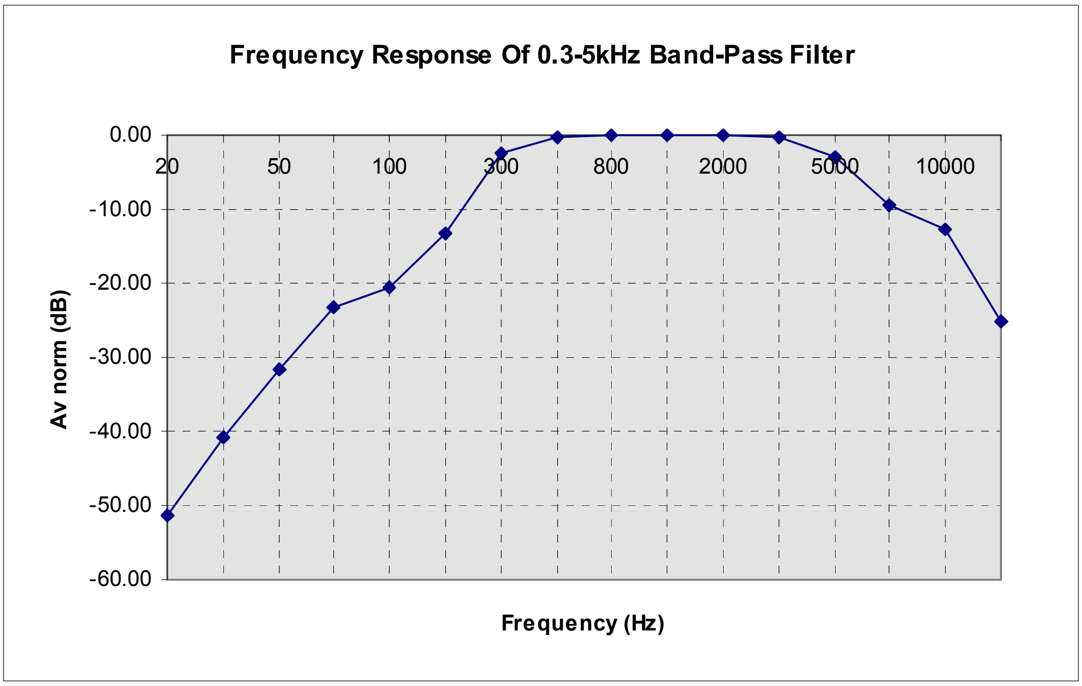
7.1.3. 5kHz Low Pass Filter

Freq. (Hz)	I/P (mV)	O/P (mV)	Av. norm (dB)
20	300	560	0.00
30	300	550	-0.16
50	300	540	-0.32
80	300	540	-0.32
100	300	540	-0.32
200	300	550	-0.16
300	300	545	-0.24
500	300	540	-0.32
800	300	540	-0.32
1000	300	540	-0.32
2000	300	550	-0.16
3000	300	550	-0.16
5000	300	410	-2.71
8000	300	190	-9.39
10000	300	120	-13.13
20000	300	52	-20.64



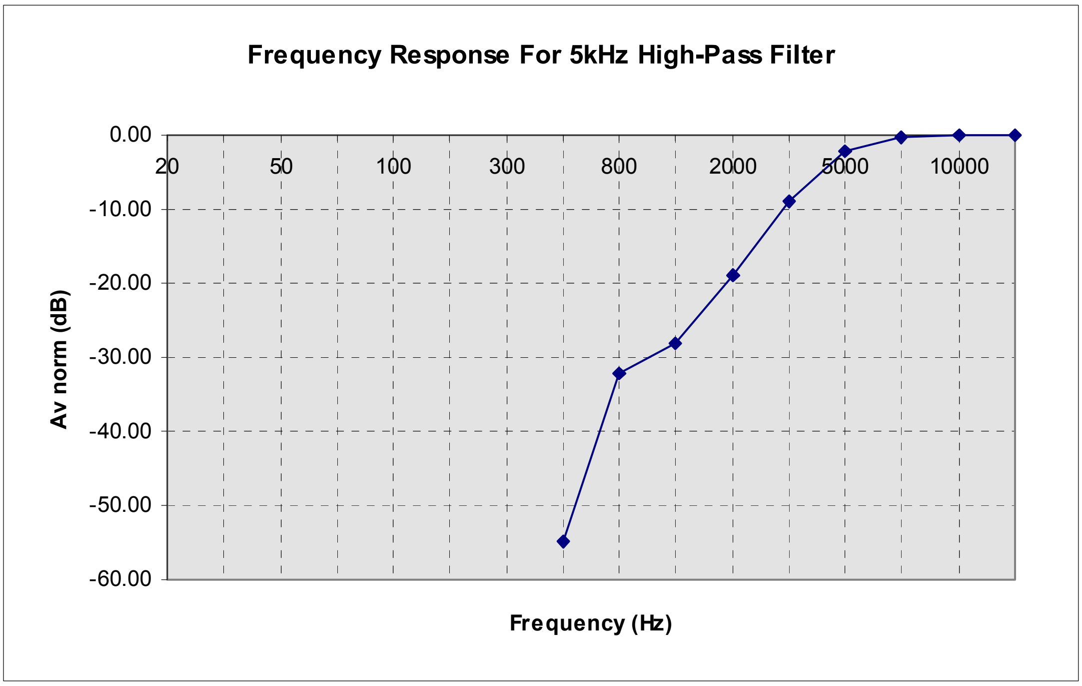
7.1.4. 300Hz – 5kHz Band Pass Filter

Freq. (Hz)	I/P (mV)	O/P (mV)	Av. norm (dB)
20	300	2.7	-51.37
30	300	9	-40.92
50	300	26	-31.70
80	300	68	-23.35
100	300	95	-20.45
200	300	220	-13.15
300	300	750	-2.50
500	300	980	-0.18
800	300	990	-0.09
1000	300	990	-0.09
2000	300	1000	0.00
3000	300	980	-0.18
5000	300	720	-2.85
8000	300	340	-9.87
10000	300	230	-12.77
20000	300	55	-25.19

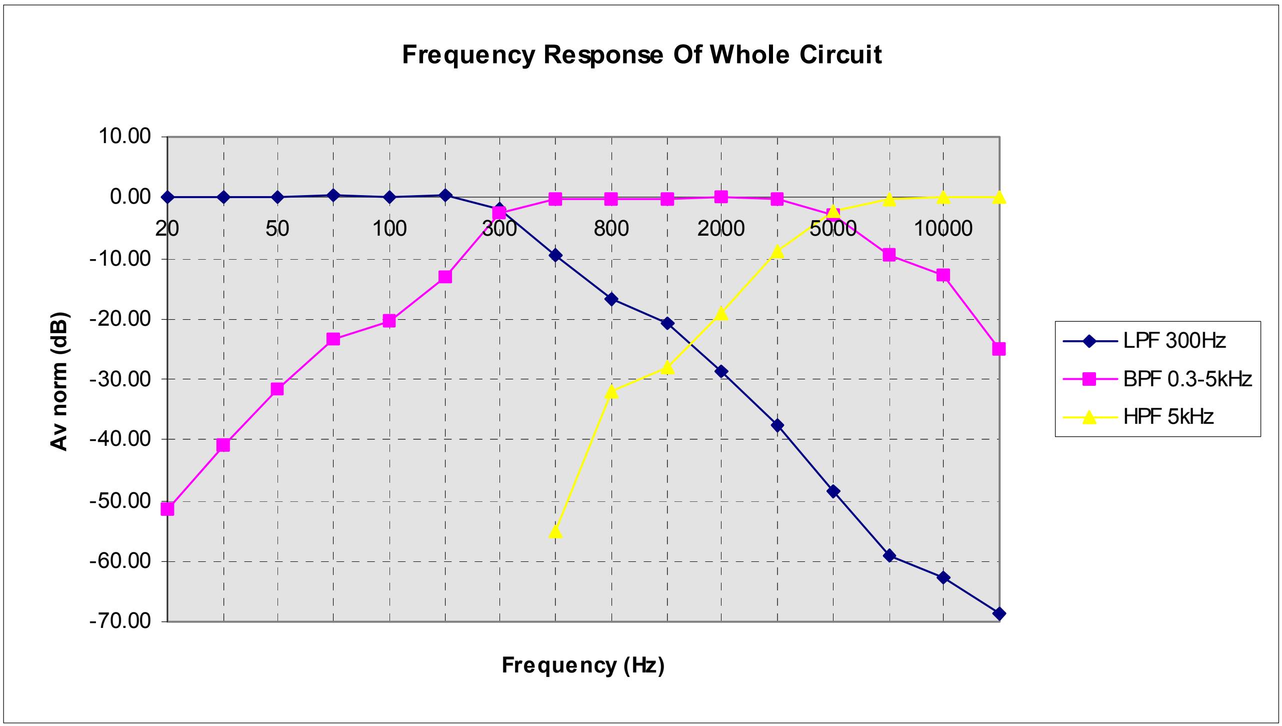


7.1.5. 5kHz High Pass Filter

Freq. (Hz)	I/P (mV)	O/P (mV)	Av. norm (dB)
20	300	0	-
30	300	0	-
50	300	0	-
80	300	0	-
100	300	0	-
200	300	0	-
300	300	0	-
500	300	1	-
800	300	14	-54.96
1000	300	22	-32.04
2000	300	63	-28.12
3000	300	200	-18.98
5000	300	430	-8.94
8000	300	540	-2.29
10000	300	560	-0.32
20000	300	560	0.00



7.1.6. Frequency Response Of Whole Circuit

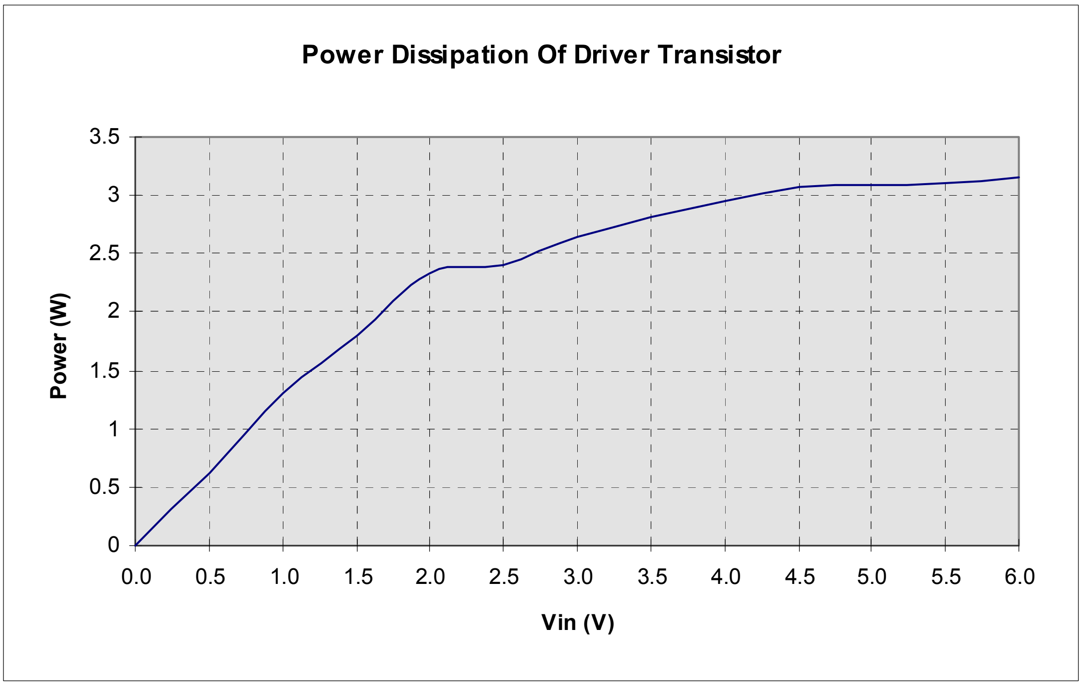


The slight 'dip' that can be seen in all the cut-off slopes of the frequency response graphs was due to the change in voltage range on the audio mV meter. The dips all occur at about the same voltage level and can bee seen in all the graphs.

7.2. *Light Driver*

A static DC test was performed in the light driver stage to verify that it would work as intended and to measure the power dissipation in the driver transistor. The output of a variable DC power supply was connected to the input resistor which is connected to the base of the transistor. The collector current and collector-emitter voltage were measures using a digital multi-meter to measure the power dissipation of the transistor.

Vin	Ic	Vce	Power
0.0	0.000	13.810	0
0.5	0.045	13.680	0.6156
1.0	0.098	13.360	1.30928
1.5	0.139	12.950	1.80005
2.0	0.172	13.580	2.33576
2.5	0.198	12.110	2.39778
3.0	0.228	11.600	2.6448
3.5	0.253	11.150	2.82095
4.0	0.277	10.660	2.95282
4.5	0.300	10.210	3.063
5.0	0.319	9.680	3.08792
5.5	0.333	9.330	3.10689
6.0	0.355	8.880	3.1524



8. Evaluation

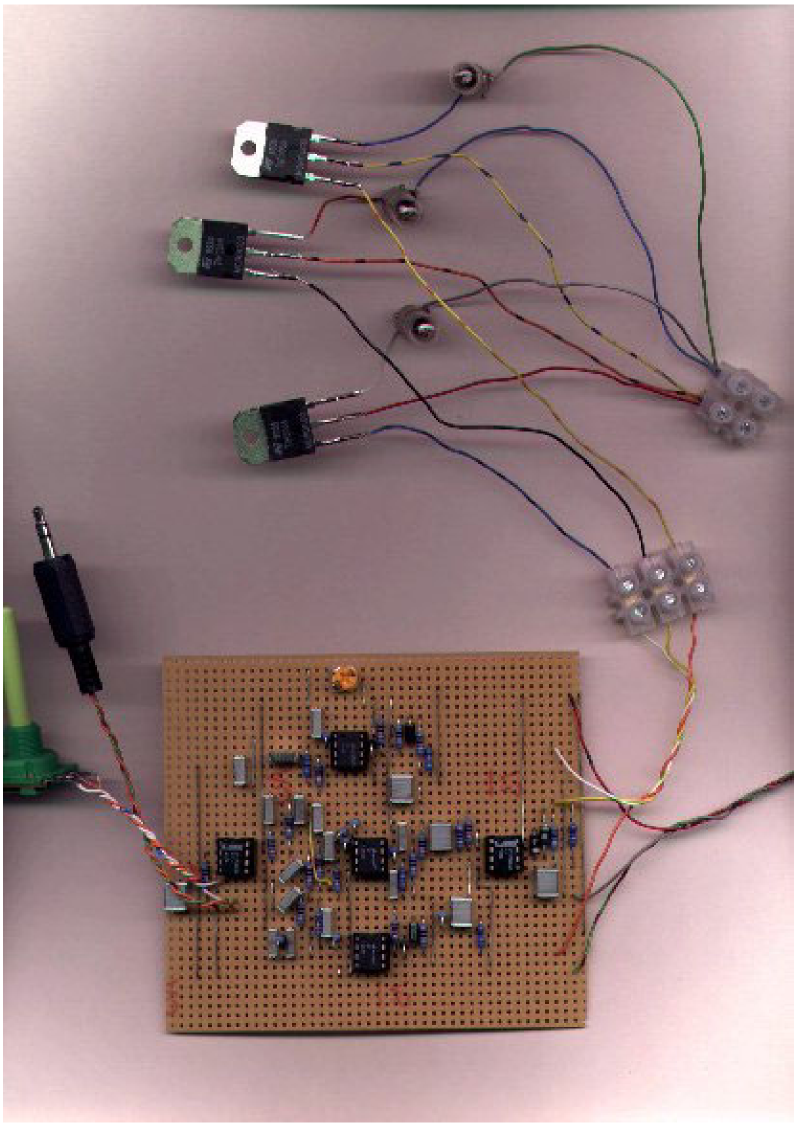


Figure 8 – Finished Project

The light display functions correctly and meets the required specification:

- The total bandwidth of the display of 5Hz > over 100kHz. This meets the minimum bandwidth of 20Hz > 20kHz which is the hi-fi range.
- The filters all cut off at the correct frequencies of 300Hz for the low pass filter, 300Hz – 5kHz for the band pass filter, and 5kHz for the high pass filter.
- The display has variable sensitivity and can be driven from typical lone outputs of 115mV to 775mV
- The display runs off of a 12V split rail supply.
- The filters and rectifiers draw 16.7mA quiescent current and a maximum of 22mA when all the bulbs are illuminated.

During testing it was noticed that with some types of music, mostly dance music, the bass was louder than the mid range or treble frequencies. This meant that the input sensitivity had to be turned down in order to not overdrive the bass output. Doing this decreased the already small signal levels of the other two outputs. To cure this an attenuator was added after the output of the 300Hz low pass filter so as the attenuate the signal level. Another improvement that could be added is a voltage limiter. This would eliminate the possibility of the outputs being overdriven causing and the bulbs to blow.

9. References

[1] *Electronics and Beyond, June 1997 - A History Of Disco Lighting*
[2] *Active Filter Cookbook, by Don Lancaster*
[3] *LM3916 Datasheet*
[4] *Operational Amplifier User's Handbook, by R.A. Penfold*
[5] *Own AS Electronics course notes and project*
[6] *Own GCSE Electronics course notes and project*