An Implementation of the Equipment and Techniques used by The Beatles at Abbey Road during the 1960s

by

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A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College

Spring 2018

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Abstract

This project consisted of three distinct, but interrelated components: (1) research into the REDD series of equipment, particularly the passive equalizer design, used at Abbey Road, (2) documentation of Beatles' recording sessions, including layout, equipment used, and how the equipment was implemented, and (3) production of new sound recordings on analog tape. The over-arching goal was to mimic conditions of the Abbey Road as closely as possible, including microphone positions, instruments used, duration of sessions, and other variables to produce recordings in the *style* of The Beatles. To better capture this distinctive style, I also used several effects frequently used by the Beatles, including varispeed, half speed overdubbing, and repeat echo. Thus, I generated an extended play album consisting of three analog songs: "Neon Sunrise," "Words," and "How the Tune Goes."

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Introduction

The Beatles are considered to be one of the most prolific and successful music groups of all time (Cox, Felton, & Chung, 1995). Besides having a significant impact on pop culture (Hecl, 2006), they have also had a huge impact on the recording industry (Kehew & Ryan, 2007). As with many aspiring musicians, the recordings of The Beatles influenced me while I was developing my musical interests and they affected my career aspirations. Furthermore, the technology used to create their recordings has become a fascination for me. Many techniques pioneered or popularized by The Beatles at EMI Studios, which has been referred to as Abbey Road Studios since the 1970s, have changed the way albums are made, and the equipment they used has become idolized by musicians worldwide (Kehew & Ryan, 2007). Unfortunately, much of the equipment used by The Beatles, and other groups, at EMI Studios during the 1960s was destroyed with the evolution of the transistor and, more recently, digital recording technologies (Kehew & Ryan, 2007). As new technologies and equipment were brought into the studio, older, perhaps considered antiquated, equipment was removed. Not only was this equipment lost, but many of the unique ideas were lost along with the equipment, such as EMI's Stereophonic System Based on Blumlein's work on stereo recording (Brice, 2013). Consequently, modern studios use equipment based on completely different designs than those available to The Beatles. The passive constant impedance desks, such as the Record Engineering Development Department (REDD) desks, have given way to active desks, such as the API Vision and SSL Console (Brice, 2013), both of which are used at

Middle Tennessee State University (MTSU). Thus, the analog sounds of the 1960s EMI Studios are difficult to re-create.

For my thesis, I proposed to record an all analog album. Although I was not able to recreate the "sounds" from EMI Studios, I attempted to recreate the signal flow that was present at EMI Studios to determine if I could re-create the "flavor" of their analog music as well as their pioneering special effects. In a sense, I attempted to produce this sound with digital equipment previously. While a senior in high school, a friend and I formed a band (The Busks). We have written and co-written several dozen songs together and produced and released three albums (*Spare Change*, *Nycthemeron*, and *The Menagerie*). I attempted to recreate the Abbey Road sound on many of the songs on these albums, but I have not been completely satisfied with the result. My hypothesis was that by recreating the electronic circuitry used by EMI Studios during the 1960s, I would be better able to produce "retro" sounds that resemble those of The Beatles.

The equipment used to record The Beatles at EMI Studios has received considerable attention, with one well-respected book, *Recording the Beatles* by Brian Kehew and Ryan Kevin (2007), written solely about the equipment and techniques they used. Because some of the equipment at EMI was built in-house, rather than being commercially manufactured, few pieces of each were constructed and fewer still are currently accessible to engineers (Kehew & Ryan, 2007). Much of this equipment was designed or modified by the REDD department, EMI engineering staff, or staff at EMI Hayes, which was their design center (Kehew & Ryan, 2007). The equipment that was purchased from commercial sources had to be modified to match standards the EMI engineers used in their studios, and various other tweaks to the equipment were made by EMI staff before installing equipment in the studio (Kehew & Ryan, 2007). Thus, the signal chain used by The Beatles is difficult to accurately reproduce. Also, the signal chain was different during production of different albums.

While producing my analog album, I focused primarily on how the equipment available at EMI Studios placed limitations on the recording process during a session. Many of these limitations no longer exist because of nearly limitless tracks in Digital Audio Workstations (DAWs) and mixing in the box (mixing within the DAW). Furthermore, I considered how the old equipment might have required recording engineers and musicians to produce creative work-arounds, and how these work-arounds might have influenced the recordings. An example of this type of inherent limitation is evident on the stereo panning of many of The Beatles' tracks (Kehew & Ryan, 2007). I believe replicating the limitations inherent with the EMI equipment, such as 4 and 8 track limitations, helped me gain experience as an engineer mixing to tape, in contrast to recording a path straight to a DAW. While producing my album, I did not attempt to mimic the sound of Beatles, such as the songs, voices, and performances; rather, I attempted to recreate the unique sonic quality associated with their music, such as the distinctive overdrive of the guitars on the song "Revolution" through the REDD preamp (Kehew & Ryan, 2007). I hope that the final result is interesting to anyone inspired by the sounds of The Beatles and wishes to obtain similar results. For this reason, I documented details of my research and recordings below.

Approach and Methods

In addition to producing an album of analog recordings**,** I studied the recording equipment and techniques used by Producer George Martin and his team of engineers, specifically Norman Smith, Ken Scott, and Geoff Emerick, to generate the well-regarded sound of The Beatles' recordings at EMI Studios (Kehew & Ryan, 2007). The equipment associated with these recordings of included consoles (REDD Desks), compressors and limiters, equalizers, microphones, and tape machines. I examined the association of the engineers who designed this equipment, the influences of pre-existing equipment on the design, the topology history of the electronic circuits of the equipment, and how the equipment was implemented in the studio. I was able to draft an approximate replica of a few schematics and layouts for equipment where originals were not available so that others may recreate the gear. I had hoped to reconstruct each piece of equipment, but time and financial restraints prevented me from completing this task. I was, however, able to construct and use a few of pieces of the signal chain at EMI Studios. These include replicas of a Neumann U47, Neumann U67, and AKG C12, a Fender 6G6B Blonde Bassman, and a Vox AC30. I also constructed a power supply suitable for powering four individual REDD.47 preamp modules. As of this writing I am still waiting for parts ordered from London to arrive so that I can build the preamps. Although I was not able to create a REDD desk in its entirety, I did generate designs for some of the equipment I was not able to construct.

Equipment researched. During the 1960s, EMI Studios was equipped with several different forms of REDD Desks (consoles) (Kehew & Ryan, 2007). I had proposed to assemble imitations of the microphone or record path on the REDD.37 and REDD.51 "Stereosonic" Four-Track Mixer Desks. This entailed study into the history of the REDD desk, system architecture, design philosophy, and other circuits and circuit operations. To understand the electronics of the system, I studied valve amplification and power supply (Brice, 2013), constant impedance filter and attenuation circuits (notably bridged-T; Brice, 2013), and spreader and shuffler circuits (REDD, 1959). Although a schematic was available for the REDD.47 amplifier, only system architecture and scant details about circuit operation were available for other components of the desk. Because schematics for much of the equipment were unavailable, I designed certain sections following known specifications of the original gear, such as equalizer curves. These sections included the REDD equalizers, which entailed the design of balanced constant impedance filters, which took me several months to complete. Also, I researched the circuitry of the RS114 Limiter, RS127 and RS136 equalizers, RS124 compressor (a VariMu Compressor modified from an Altec 436c), RS144 (premix box), Fairchild 660 compressor, RS158 (compressor), RS56 (equalizer), several microphones (Neumann KM53, U47, U67, AKG D19C, D20, C12, ATC 4038- Coles), and two tape machines (the J37 and the BTR3). I used the knowledge I gained to help me choose suitable replacements because originals were either not available or cost prohibitive.

By understanding the architecture and circuitry of the REDD Desks and various outboard equipment, I was able to understand how the signal was routed; consequently, I replicated some of the recording techniques and styles of engineers recording The Beatles without owning or recreating the original equipment. This was possible by knowing where in the signal chain the architecture of the studio forced each piece of equipment to be placed and the way each piece of equipment altered the signal. Furthermore, I researched the physical space (dimensions and wall materials) of Studio Two where most of the songs were recorded at EMI Studios (Kehew & Ryan, 2007). I also researched particular recording sessions to determine baffle and instrument placement. Lastly, I researched the following special effects and how they were originally implemented by the engineers of The Beatles: ADT (Artificial Double Tracking), STEED (Single Tape Echo and Echo Delay), Flanging, Reverse Tape, and Varispeed.

Recording—Because of accessibility, I used Studio A and Studio B in the John Bragg Mass Communication Building at Middle Tennessee State University (MTSU) as the sound space for all tracking. These studios were used as facsimiles for EMI studios. I chose microphones that mimicked those used at EMI Studios, and was limited by available monies and resources.

REDD Design and Signal Flow

The following section consists of an overview of the information I uncovered about the architecture and function of the REDD desk. The primary sources for the information about the REDD desks stem from EMI documentation and the book *Recording the Beatles (Kehew & Ryan, 2007)*. The circuitry for these desks was designed in the 1950s and there has been significant change in console and amplifier design during the last 60 years. Consequently, much of my information on how to design replicas of these circuits stem from published works, some difficult to obtain, from the first half of the 20th century.

Designing a Balanced Bridged "T" Pad

The record path of REDD desks begins with an input source switch. I assumed that these switches were simple single pole, 2 deck, two or three way rotary switches fitted with chicken head knobs. An option of one of two microphone (mic) level sources (A or B) was available for channels one through eight. The connectors for these mic inputs were located on the rear of the desk. Only one source could be used at a time on most channels; however, the two sources could be combined on channels four and five. An additional option of a tape level input, or line level, was available on channels one through two and seven through eight. This third option was included on only four channels because of limitations associated with two track and four track tape machines used at the time.

The tape input included a 20db pad to lower the line level signal. This was probably a balanced bridged "T" pad or attenuator (Tremaine, 1959, p. 97), which I describe in the following section (Fig. 1). The term pad is frequently used when referring to attenuators that have fixed levels of reduction; whereas, attenuators are commonly both fixed and variable. A bridged "T" pad contains four resistive elements, two of which, R1A and R1B, are equal to the line impedance (Tremaine, 1959, p. 105). This attenuator configuration is designed to work between impedances of equal value only.

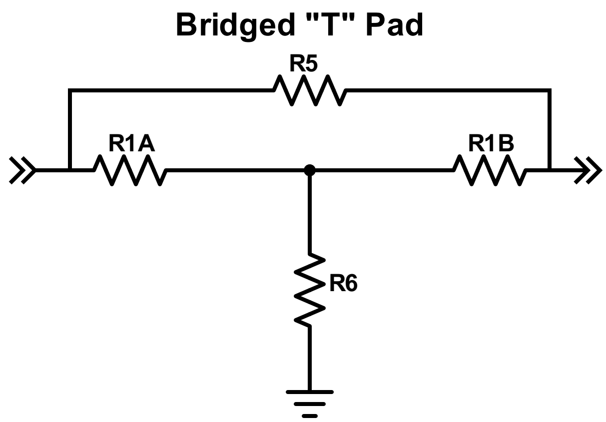


Figure 1. *Basic topology of a bridged "T" pad. The values of bridging resistor, R5, and shunt resistor, R6, determine the level of reduction. R1A and R1B are equal to the line impedance.*

To understand the circuitry, I first calculated the component values for an unbalanced line and then converted this circuit to a balanced topology and, based on this information, I "drew" schematics of the circuits (Figs. 1–4). The formulae for calculating component values are as follows.

$$R_1 = Z$$

$$R_5 = (K - 1)Z$$

$$R_6 = \left(\frac{1}{K - 1}\right)Z$$

Where z = the line impedance

R5 is the bridging resistor

R6 is the shunt resistor

K = voltage ratio for given loss in dB (K=Vi/Vo=10^dB/20)

$R_1 = 200\Omega$

$R_5 = (10\text{-}1)200$

R5 = 1800Ω

R6 = (1/10-1)200

R6 = 22.22Ω

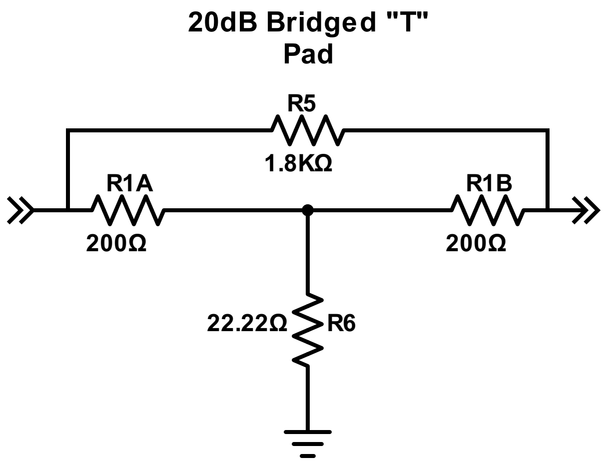
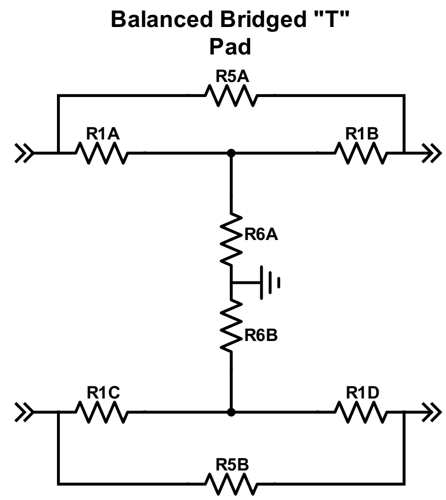
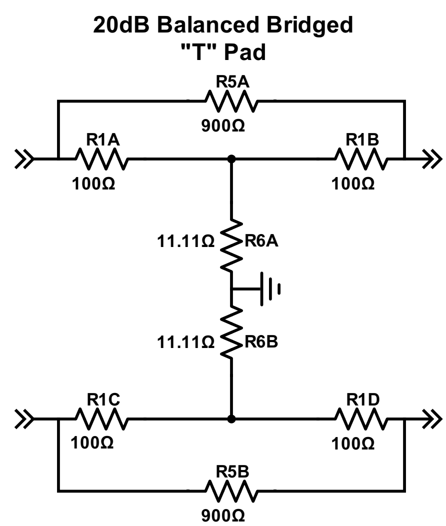


Figure 2. *Schematic of a bridged "T" pad with an insertion loss, or reduction, of 20dB for a line impedance of 200Ω.*

To convert to a balanced line, the resistor elements are divided in half and placed on each side of the line. Ground is connected to the middle of the shunt resistor.





Figures 3 (upper) & 4 (lower). *Schematics of a balanced bridge "T" pad and Balanced Bridged "T" Pad with insertion loss of 20dB.*

Designing a variable balanced Bridged "T" Attenuator.

In the signal flow of the REDD desks, a microphone attenuation knob was placed in the path immediately after the input source switch. Attenuation refers to the reduction of either a sound wave or energy in an electrical circuit (Tremaine, 1959, p. 97). The attenuator adjusted the levels of the mic signals. According to Kehew & Ryan (2007), the microphone attenuation knob on channels one through eight of the REDD desks provided 30dB of attenuation in 6db increments Kehew & Ryan, 2007, p. 86). Based on the passive topology of the desk and what is known about the circuit design of the tone controls, I assume that a balanced bridged "T" type attenuator was used. I used the preceding information to design an attenuator network. Initially I calculated component values for an unbalanced line (Fig. 5) and then I converted this to a balanced topology (Fig. 6). First, I calculated K values for each of the dB losses, or the ratio of change (Table 1). I then calculated the values of the bridging resistors starting with the lowest loss and working up as the individual resistances will add together. This means the value for each dB increment as calculated previously had to be subtracted from the lower increment to obtain the resistance value for the actual resistor, not just the total resistance necessary to create the desired loss.

Table 1. *K values for variable bridged "T" attenuator.*

	K Value
6dB	1.9953
12dB	3.9811
18dB	7.9433
24dB	15.8489
30dB	31.6228

$$R5a = (1.9953-1)200\Omega$$

$$R5a = 199.06\Omega$$

$$R5b = [(3.9811-1)200\Omega] - R5a$$

$$R5b = 596.22 - 199.06$$

$$R5b = 397.16\Omega$$

$$R5c = [(7.9433-1)200\Omega] - (R5a + R5b)$$

$$R5c = 1388.66 - 596.22$$

$$R5c = 792.44\Omega$$

$$R5d = (15.8489-1)200\Omega - (R5a + R5b + R5c)$$

$$R5d = 2969.78 - 1388.66$$

$$R5d = 1581.12\Omega$$

$$R5e = (31.6228-1)200\Omega - (R5a + R5b + R5c + R5d)$$

$$R5e = 6124.56 - 2969.78$$

$$R5e = 3154.78$$

I used a similar process to calculate the values of the shunt resistors, but this time began with the highest decided reduction and worked down. The resistances from each step were again subtracted from one another to create the required resistance at lower reduction levels.

$$R6e = \left(\frac{1}{31.6228 - 1}\right)200$$

$$R6e = 6.5311\Omega$$

$$R6d = \left(\frac{1}{15.8489 - 1}\right)200 - R6e$$

$$R6d = 13.4690 - 6.5311$$

$$R6d = 6.9379\Omega$$

$$R6c = \left(\frac{1}{7.9433 - 1}\right)200 - (R6e + R6d)$$

$$R6c = 28.8947 - 15.4257$$

$$R6c = 13.4690\Omega$$

$$R6b = \left(\frac{1}{3.9811 - 1}\right)200 \text{ - } (R6e + R6d + R6c)$$

R6b = 67.0893 - 28.8947

R6b = 38.1946Ω

$$R6a = \left(\frac{1}{1.9953 - 1}\right)200 \text{ - } (R6e + R6d + R6c + R6b)$$

R6a = 200.9444 - 67.0893

R6a = 133.8551Ω

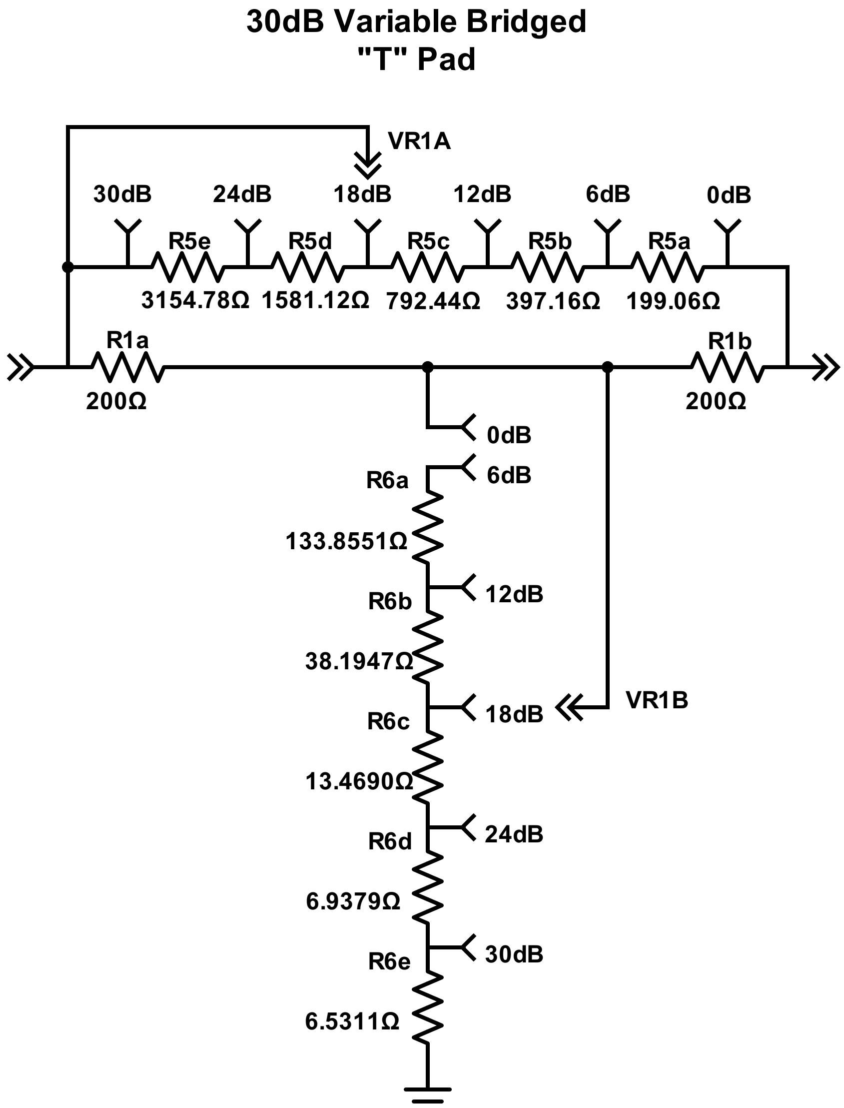


Figure 5. *Schematic of a Variable Bridged "T" Pad in 6dB increments with insertion loss of 30dB for a line impedance of 200Ω. Depicted in 18db loss position.*

As stated earlier, a bridged "T" attenuator contains four resistive elements, two of which, R1, are equal to the line impedance (Tremaine, 1959, p. 105). To vary the attenuation, R5 and R6 must be mechanically linked and varied inversely. To convert to a balanced configuration, I again divided in half the resistance values and split them across the line (Fig. 6).

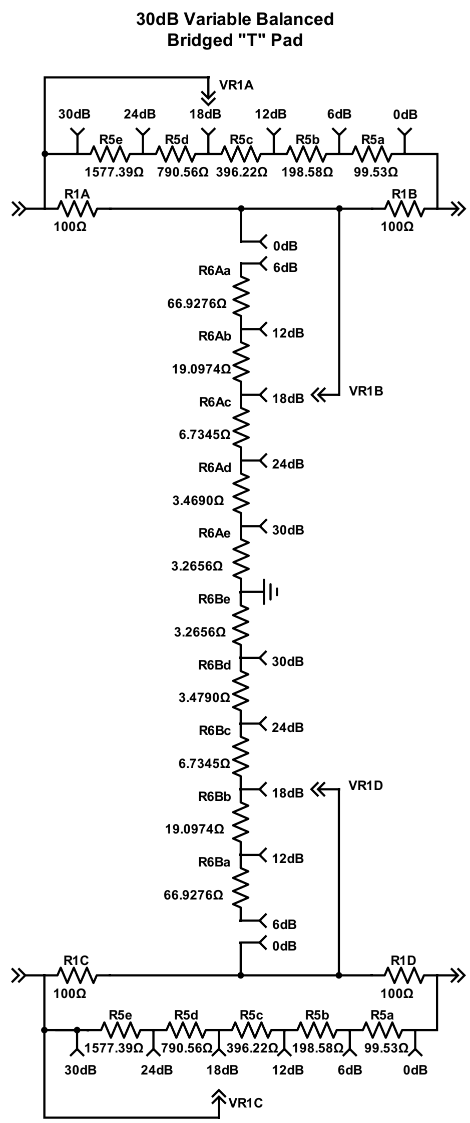


Figure 6. *Schematic of a Variable Balanced Bridged "T" Pad in 6dB increments with insertion loss of 30dB for a line impedance of 200Ω. Depicted in 18db loss position. Values do not represent practical real world components*

Three Way Selector

The next section of the record path featured a three-way switch. This selector switch offered the options of bass lift (designed for figure eight condenser mics), pass through, and a 10dB pad (Kehew & Ryan, 2007, p. 86). This switching function would have been fulfilled by a single pole, 2 deck, three-way switch. The 10dB Pad can be designed the same way as the tape pad utilizing a balanced Bridged "T" topology (Fig. 7), with substitution for the different K factor.

$$K = 3.1623$$

$$\mathrm{R5} = (3.1623 - 1)200$$

$$\mathrm{R5} = 432.46$$

$$\mathrm{R6} = \left(\frac{1}{3.1623 - 1}\right)200$$

$$\mathrm{R6} = 92.4941$$

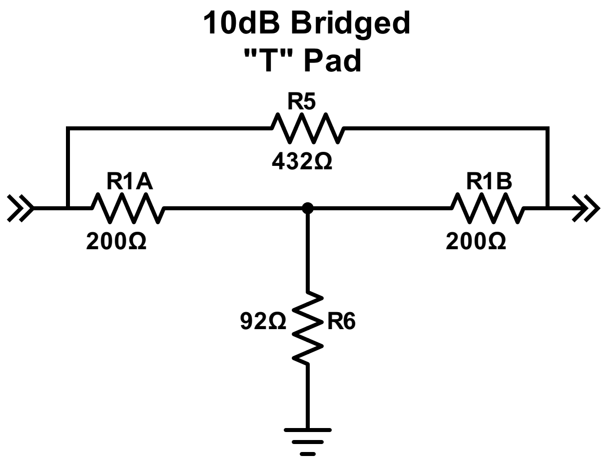


Figure 7. *Schematic of a* b*ridged "T" pad with insertion loss of 10db for a line impedance of 200Ω.*

The design is then similarly converted to a balanced configuration by dividing the elements across the line. The shunt resistor can remain ungrounded because the circuit will be terminated by a grounded balanced circuit. Figure 8 shows the final design for the 10dB Balanced "T" Pad.

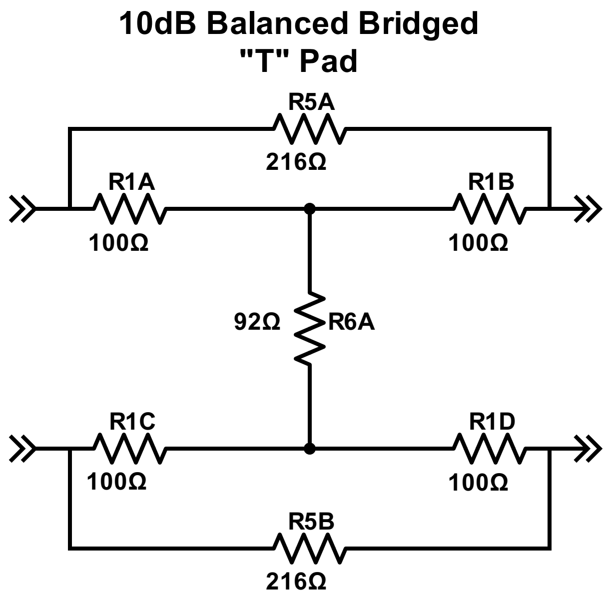


Figure 8. *Schematic of balanced bridged "T" pad with insertion loss of 10db for a line impedance of 200Ω.*

The pass through will carry the signal unaltered to the next stage. The bass lift option provides the first opportunity to alter the equalization, rather than simply attenuating, the incoming signal.

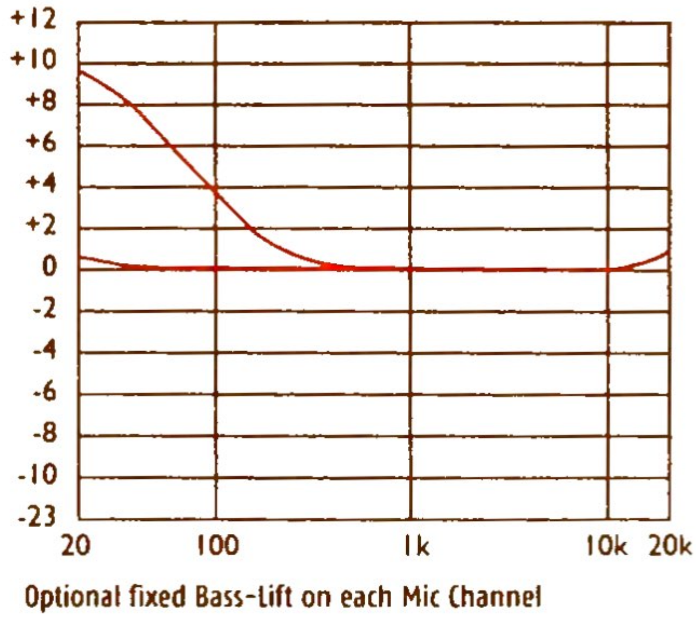


Figure 9. *Graph of Bass Lift Frequency Response. (Kehew & Ryan, 2007).*

The Waves, REDD.51 Abbey Road user guide claims this is a 9dB low shelf filter (WAVES, n.d.). Based on this information and the frequency response graph found in *Recording The Beatles* (Kehew & Ryan, 2007), this bass lift option probably had an insertion loss of 10dB. The frequency response graph of the bass lift feature depicted in the Kehew and Ryan (2007) *Recording The Beatles* allows for reasonable approximation of the half pad loss frequency at around 80Hz (Fig. 9). With this information, I devised a high frequency shelving filter. The resistance values are equal to those found in the 10dB Balanced "T" Pad because the insertion loss will be equal to 10dB. To create the high frequency shelving response, the introduction of reactive elements, an inductor and capacitor, are introduced to the Bridged "T" design (Fig. 10).

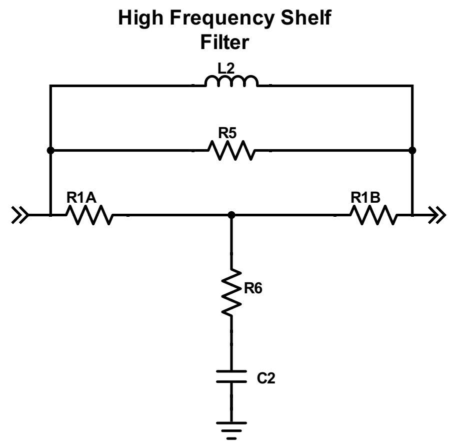


Figure 10. *Schematic layout of high frequency shelf filter.*

To simplify the process of determining values for these two components, I used the information provided by Tremaine (1959; Table 2).

Table 2. *Frequency of 1/2 pad loss*

Frequency of ½ Pad Loss	*30*	*40*	*50*	*60*	*80*	*100*	*120*	*150*	*200*
L2	3.84	2.88	2.30	1.92	1.44	1.15	0.96	0.767	0.576
C2	10.07	8.00	6.40	5.34	4.00	3.20	2.67	2.130	1.610

The values for one half pad loss at 80Hz were 1.44H and 4.00uF. The component values supplied in Table 2 are based on of a 600ohm line impedance and must be converted to a 200 ohm impedance by the following formula

$$K = \frac{Z}{600}$$

$$K = \frac{200}{600}$$

$$K = .3333$$

where K is the ratio of the new impedance to the known impedance (Tremaine, 1959, p. 143). The inductance is multiplied by this K factor and the capacitance is divided for the high frequency shelf (Fig. 11).

$$L = 1.44 \times .3333$$

$$L = .48$$

$$C = \frac{4}{.3333}$$

$$C = 12.0012$$

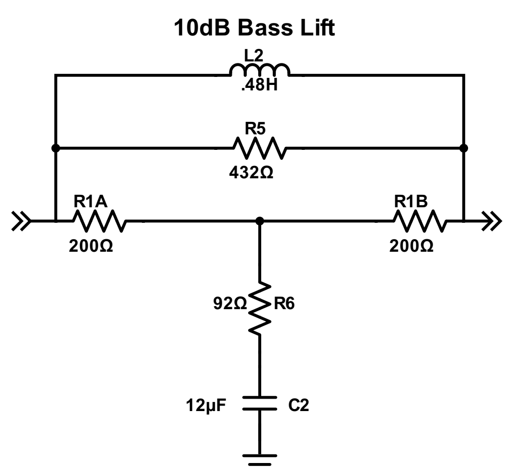


Figure 11. *Schematic of a 10db low shelf filter with half pad loss at 80Hz.*

This filter then had to be converted to a balanced one by the same method as previously described (dividing components across the line). Figure 12 shows the final design for the bass lift with a 10dB insertion loss and a half pad loss at 80Hz.

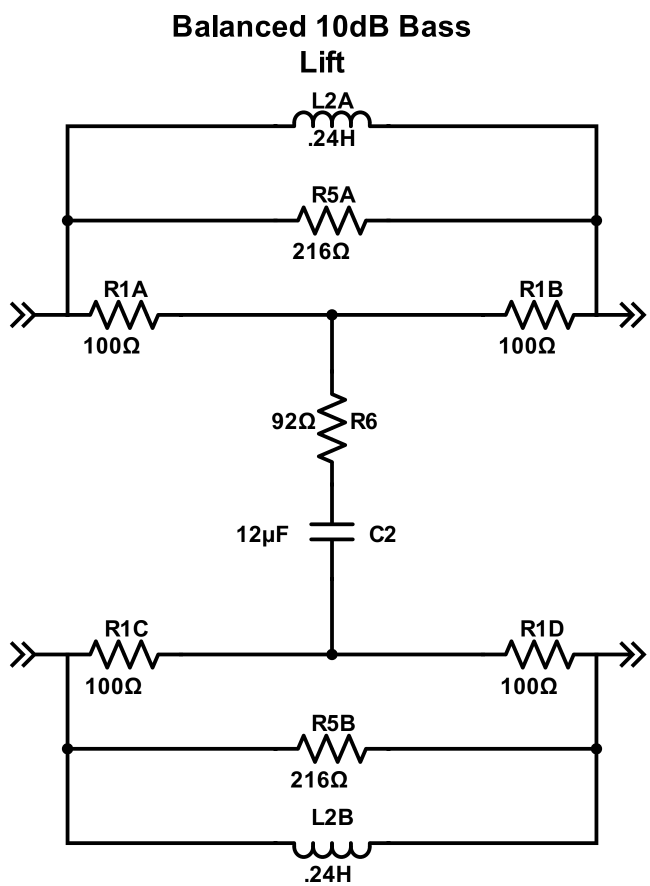


Figure 12. S*chematic of balanced 10dB Bass Lift.*

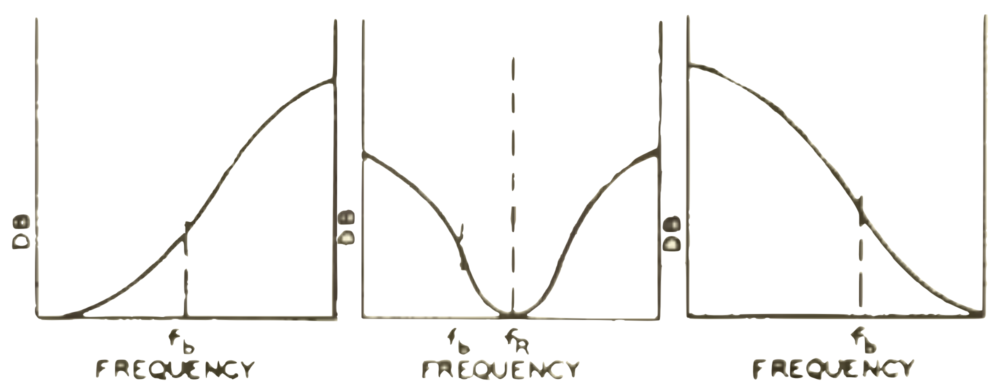
REDD.47 Preamp

The next step in the record path was a REDD.47 microphone preamp for which much information is widely available, as well as a schematic, and is commonly reconstructed. As a result I have chosen not to discuss this in depth but to mention that I designed a cassette plugin chassis like the original in order to facilitate the original layout of components. The preamp was followed by an insert function which allowed signal to be taken out and back into the record path. The next step in the record path of the desk was the equalizer portion of the desk known as the REDD Tone Controls (Kehew & Ryan, 2007).

Designing the REDD Tone Controls

The equalizer functions of the REDD desks consisted of plugin modules each containing the circuitry for two channels. A total of four plugin units were used at a time, and they came in two varieties, pop and classic. The classic module provided shelving boost and cut of 10dB in 2dB increments at 100Hz and 10KHz (Kehew & Ryan, 2007, p. 89). The boost and cut response of the bass frequencies, and the cut response of the treble of the pop module was the same as in the classic module; however, instead of providing a shelving filter boost for the treble, the pop module contained a peaking filter centered around 5Khz similarly adjustable by 10dB in 2dB increments. The REDD Tone Controls were passive filters and to achieve these boosts the tone controls had an insertion loss of 10dB. This 10dB insertion loss gives a starting parameter to begin to design a similar filter circuit to that used in these equalizer modules. Based on documentation I could find, this filter was based on balanced Bridged "T" topology. Based on this information and the frequency response graphs provided in *Recording The Beatles*, a similar circuit can be designed (see below) (Kehew & Ryan, 2007, p. 89). Additional resistive elements R5A and R6A are added to maintain constant insertion loss while varying the amount of boost or cut of desired frequency. A simple peaking filter employing this design is displayed in Figure 17 and is also known as a constant "B" equalizer (Miller & Kimball, 1944). Unfortunately, these graphs provided in *Recording The Beatles* (Kehew & Ryan, 2007) do not provide detailed figures; consequently, to obtain more precise data points, I measured the frequency response of the Waves REDD. 51 equalizer for all configurations. The frequency response for each equalizer function was measured separately then combined together to create graphs. I focused on the "Pop" module response as it was the one primarily used by The Beatles (Kehew & Ryan, 2007).

Three types of insertion lost characteristics or three different types of filters were used. These were a low frequency shelving cut and boost, a high frequency shelving cut, and a high frequency peaking filter (Figs. 13–15).



Figures 13–15. E*qualizer frequency response, with the greater insertion loss the higher up the y-axis. From left to right a high frequency shelf, a peaking filter, and a low frequency shelf (Miller & Kimball, 1938).*

To begin, I discuss the design for the top boost for the "Pop" Eq box (the high frequency shelving filter). Because the transmission line is equal to 200ohm, the boost is centered around 5Khz, and the equalizer has an insertion loss of 10dB. The top boost is a peak type equalizer (Fig. 17). To calculate more precise figures, I used the curves I measured from the Waves REDD desk plugin for the pop top boost filter as shown in Table 3 and subsequent filters. This shows a center frequency of 4Khz.

Table 3. *Equations from Miller & Kimball (1938)*

EQs. for Figures 13 & 15	**EQs. for Figure 14**
$L1 = LB\frac{K-1}{\sqrt{K}}$	$L1 = LB(\frac{K-1}{\sqrt{K}})(\frac{1}{b^2-2})$
$L2 = LB\frac{\sqrt{K}}{K-1}$	$L2 = LB(\frac{\sqrt{K}}{K-1})(\frac{b^2-1}{b^2})$
$C1 = CB\frac{\sqrt{K}}{K-1}$	$C1 = CB(\frac{\sqrt{K}}{K-1})(\frac{b^2-1}{b^2})$
$C2 = CB\frac{K-1}{\sqrt{K}}$	$C2 = CB(\frac{K-1}{\sqrt{K}})(\frac{1}{b^2-1})$

For Figures 13,14, & 15		
$CB = \frac{1}{2\pi f b R1}$	$LB = \frac{R1}{2\pi f b}$	$R3 = 2[R1(K-1)]$

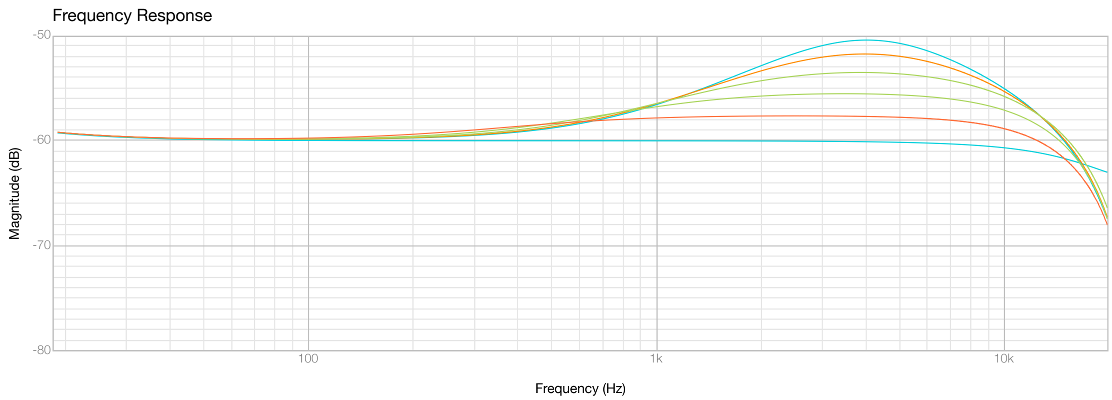


Figure 16. *Response curves of thee Waves REDD.51 Plugin for Pop filter Top boosts +2, +4, +6, +8, & +10. It should be noted at this time that all the WAVES curves display a rounding off of the high end, because some other portion of the signal chain the plugin is emulating not from the equalizer section itself.*

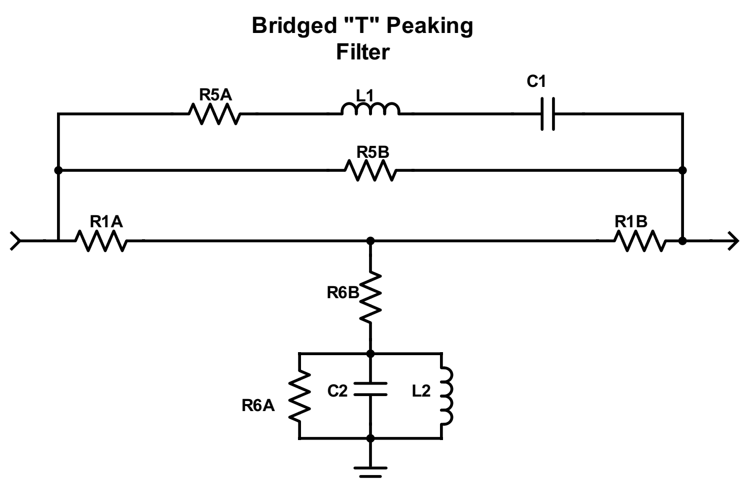


Figure 17. *Schematic of a Bridged "T" Peaking filter capable of creating the curves depicted in Figures 14 and 16 (Miller & Kimball, 1938).*

To design the high boost section of the pop filter the following criteria have been established: line impedance of 200Ω, center frequency at 4Khz and half loss frequency at 1.3Khz as measured from Figure 16, and maximum and minimum loss in dB in varying steps as indicated in Table 4 and measured from Figure 16. Referring to Figure 14 and Table 3, the following terms are needed to calculate component values.

$$\frac{K-1}{\sqrt{K}} = \frac{3.0196-1}{1.7377} = 1.1622 \qquad \frac{\sqrt{K}}{K-1} = \frac{1.7377}{3.0196-1} = .8604$$

$$\frac{b^2-1}{b^2} = .8944 \qquad \frac{1}{b^2-1} = .1181$$

$$LB = \frac{200}{2\pi \times 1300} = .0245\text{H} = 24.5\text{mH} \qquad CB = \frac{1{,}000{,}000}{2\pi \times 1{,}300 \times 200} = .6161\text{mF}$$

The component values can then be calculated by simply if plugging these values into the equations from Table 3. The equations for Figure 14 will be used as this is a peaking filter.

$L1 = 24.5 \times 1.1622 \times .1181 = 3.3638\text{mH}$

$L2 = 24.5 \times .8604 \times .8944 = 18.8538\text{mH}$

$C1 = .6161 \times .8604 \times .8944 = .4741\text{uF}$

$C2 = .6161 \times 1.1622 \times .1181 = .08456\text{uF}$

The resistance values for each step of dB reduction are then calculated as follows based on information for Constant B equalizers taken from Miller and Kimball (1944) constant B equalizers. By introducing two additional restive elements, the amount of attenuation can be varied without altering the reactive elements (the inductors and capacitors) for each step.

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB}$$

$$.4\text{dB} = 20log[1 + \frac{Rp}{R1}]\text{dB}$$

$$.02 = log[1 + \frac{Rp}{R1}]$$

$$1.047 = [1 + \frac{Rp}{R1}]$$

$$.047 = \frac{Rp}{200}$$

$$9.42\Omega = Rp$$

Where Rp is the parallel resistance of $R5_1$ and $R5_2$.

Minimum Loss is equal to insertion loss minus desired equalization, i.e. 10db - 9.6dB for Pos 5.

$R5R6 = R1$^2

$$Rp = (\frac{1}{R5a} + \frac{1}{R5b})^{-1}$$

$$9.42 = (\frac{1}{R5a} + \frac{1}{432})^{-1}$$

$$9.42^{-1} = R5a^{-1} + 432^{-1}$$

$$9.42^{-1} - 432^{-}1 = \text{R5a}^{-1}$$

$$.1062 - .0023 = \text{R5a}^{-1}$$

$$.1039 = \text{R5a}^{-1}$$

9.6299Ω = R5a

9.6299(R6a) = 200^2

9.6299(R6a) = 40000

R6a = 4153.7296Ω

This process is repeated for the next steps. The number of steps have been condensed to save space. The results from these equations are recorded in Table 4.

Pos 4

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 1.7\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 43.24\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 43.24 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 48.0494\Omega$$

$$(48.0494)(R6a) = 200^2 \qquad R6a = 832.4766\Omega$$

Pos 3

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 3.5\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 99.2471\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 99.2471 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 128.8486\Omega$$

$$(128.8486)(R6a) = 200^2 \qquad R6a = 310.4417$$

Pos 2

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 5.5\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 176.7298\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 176.7298 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 299.0842\Omega$$

$$(299.0842)(R6a) = 200^2 \qquad R6a = 133.7416\Omega$$

Pos 1

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 7.7\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 285.3220\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 285.3220 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 840.3380\Omega$$

$$(840.3380)(R6a) = 200^2 \qquad R6a = 47.5999\Omega$$

Table 4. Design Elements for “Pop” Filter High boost.

	dB boost	Rp	Fb	R5a	R5b	R6a	R6b	L1 in mH	L2 in mH	C1 in uF	C2 in uF
Pos 1	2.3dB	285.322Ω	1.3Khz	840.338Ω	432Ω	47.5999Ω	92Ω	3.3638	18.8538	0.4741	0.08456
Pos 2	4.5dB	176.7298Ω	1.3Khz	299.0842Ω	432Ω	133.7416Ω	92Ω	3.3638	18.8538	0.4741	0.08456
Pos 3	6.5dB	99.2471Ω	1.3Khz	128.8486Ω	432Ω	310.4417Ω	92Ω	3.3638	18.8538	0.4741	0.08456
Pos 4	8.3dB	43.24Ω	1.3Khz	48.0494Ω	432Ω	832.4766Ω	92Ω	3.3638	18.8538	0.4741	0.08456
Pos 5	9.6dB	9.42Ω	1.3Khz	9.6299Ω	432Ω	4153.7296Ω	92Ω	3.3638	18.8538	0.4741	0.08456

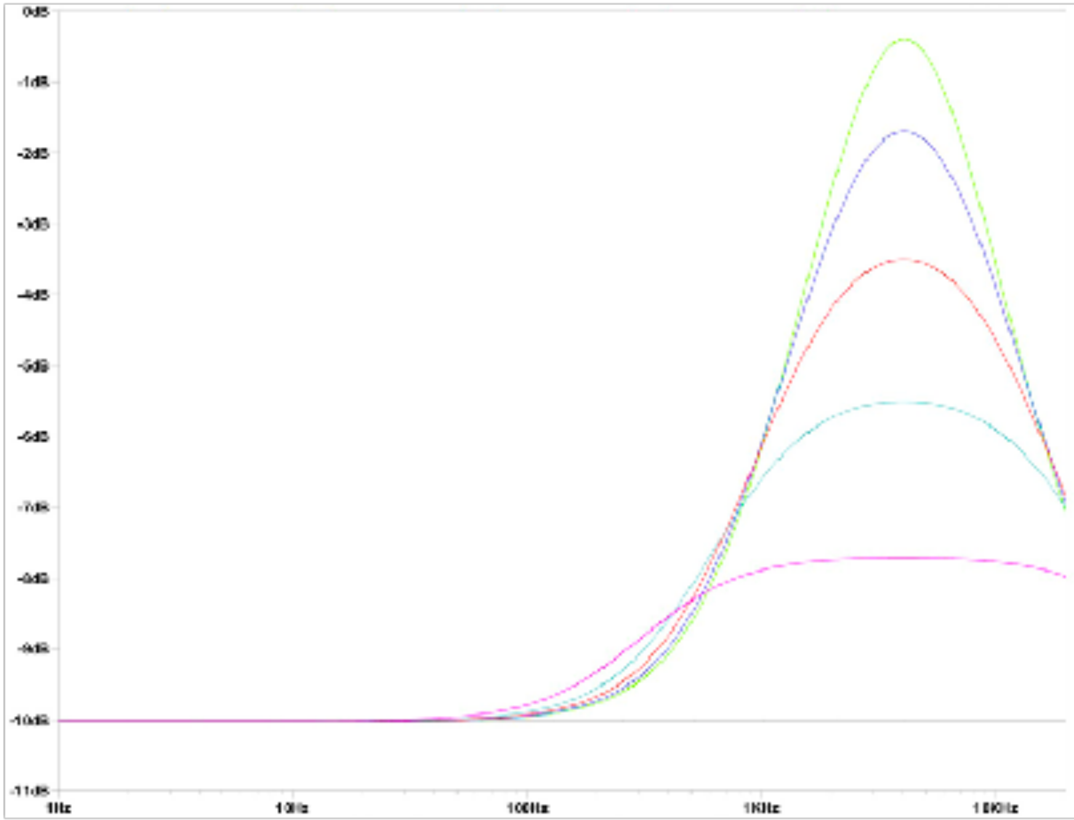


Figure 18. *Curves created using schematic from Figure 17 and values from Table 4.*

Next I evaluated replicating the shelving curves as obtained from the Waves REDD.51 Plugin (Fig. 19). The following will remain unchanged: 200Ω line impedance, and -0dB insertion loss.

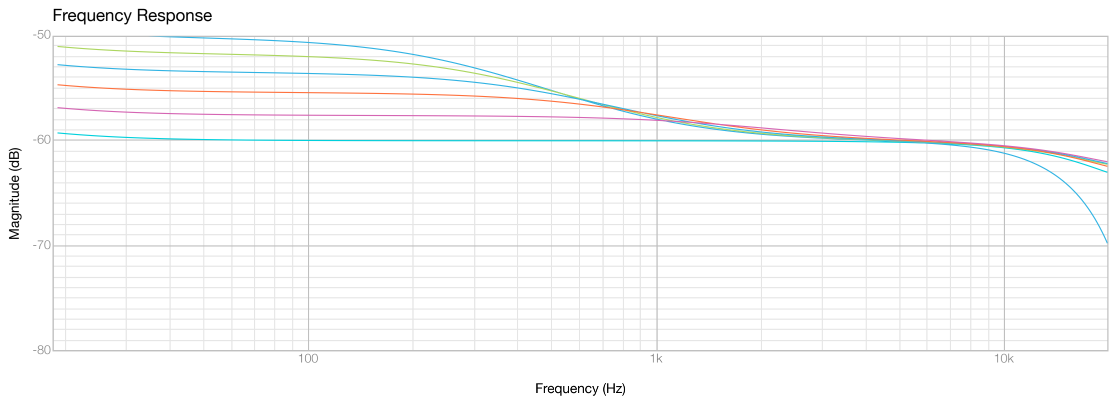


Figure 19. *Response curves of the Waves REDD.51 Plugin for "Pop" filter low boosts +2, +4, +6, +8, & +10.*

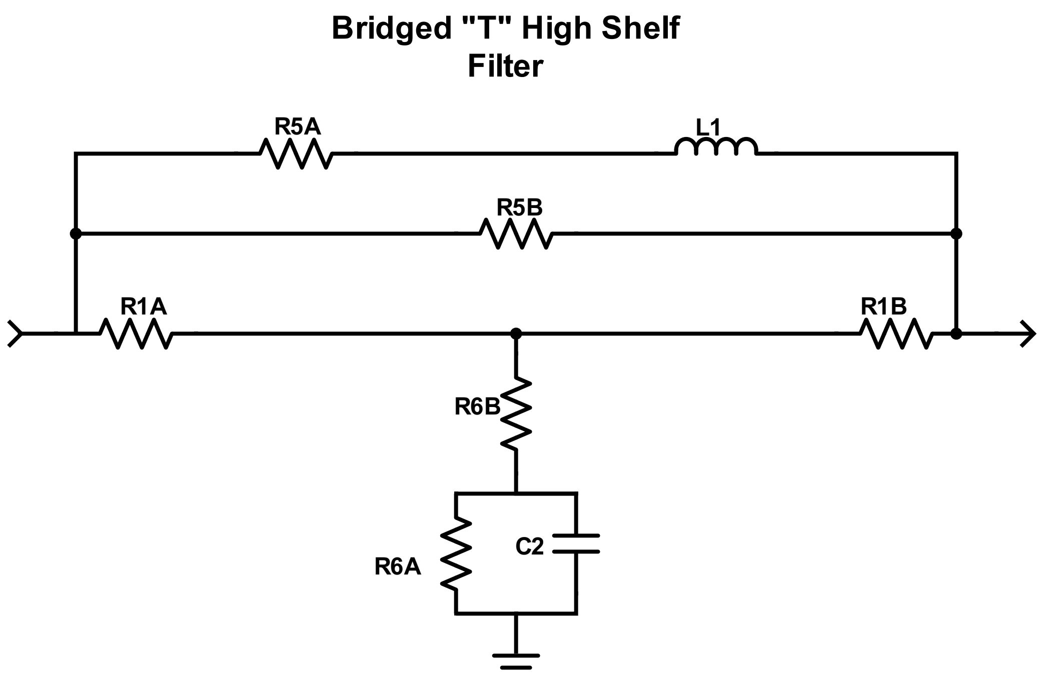


Figure 20. *Schematic of a Bridged "T" Shelving filter capable of creating the curves depicted in Figures 13 and 19 (Miller & Kimball, 1938).*

To design the high boost section of the pop filter the following criteria have been established: line impedance of 200Ω, half loss frequency at 500Hz as measured from Figure 19, and maximum and minimum loss in dB in varying steps as indicated in Table 5.

Referring to Figure 13 and Table 3, the following terms are needed to calculate component values.

$$\frac{K-1}{\sqrt{K}} = \frac{3.1623-1}{1.7783} = 1.2159 \qquad \frac{\sqrt{K}}{K-1} = \frac{1.7783}{3.1623-1} = .8224$$

$$LB = \frac{200}{2\pi \times 500} = .06366\text{H} = 63.66\text{mH} \qquad CB = \frac{1{,}000{,}000}{2\pi \times 500 \times 200} = 1.5915\text{mF}$$

The component values can then be found by simply if plugging the values above into the equations for Figure 13 from Table 3.

$L1 = 63.66 \times 1.2159 = 77.4042\text{mH}$

$C2 = 1.5915 \times 1.2159 = 1.9351\text{uF}$

Resistance values are then calculated the same as for the peaking filter.

Pos 5

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad .1\text{dB} = 20log[1 + \frac{Rp}{200}]dB \; Rp = 2.3159$$

Ω

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 2.3159 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 2.3284\Omega$$

$$(2.3284)(R6a) = 200^2 \qquad R6a = 17179.17884\Omega$$

Pos 4

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 1.6\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 40.4529\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 40.4529 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 44.6323\Omega$$

$$(44.6323)(R6a) = 200^2 \qquad R6a = 896.2119\Omega$$

Pos 3

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 3.3\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 92.4354\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 92.4354 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 117.5979\Omega$$

$$(117.5979)(R6a) = 200^2 \qquad R6a = 340.1421\Omega$$

Pos 2

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 5.2\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 163.9402\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 163.9402 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 264.2029\Omega$$

$$(264.2029)(R6a) = 200^2 \qquad R6a = 151.3990\Omega$$

Pos 1

$$\text{Minimum Loss} = 20log[1 + \frac{Rp}{R1}]\text{dB} \qquad 7.4\text{dB} = 20log[1 + \frac{Rp}{200}]dB$$

$$Rp = 268.8458\Omega$$

$$Rp = \frac{1}{\frac{1}{R5a} + \frac{1}{R5b}} \qquad 268.8458 = \frac{1}{\frac{1}{R5a} + \frac{1}{432}} \qquad R5a = 711.8504\Omega$$

$$(711.8504)(R6a) = 200^2 \qquad R6a = 56.1916\Omega$$

Table 5. Design Elements for "Pop" Filter Low Boost.

	dB boost	Rp	Fb	R5a	R5b	R6a	R6b	L1 in mH	C2 in uF
Pos 1	2.3dB	268.8458Ω	500Hz	711.8504Ω	432Ω	56.1916Ω	92Ω	77.4042	1.9351
Pos 2	4.5dB	163.9402Ω	500Hz	264.2029Ω	432Ω	151.3990Ω	92Ω	77.4042	1.9351
Pos 3	6.5dB	92.4354Ω	500Hz	117.5979Ω	432Ω	340.1421Ω	92Ω	77.4042	1.9351
Pos 4	8.3dB	40.4529Ω	500Hz	44.6323Ω	432Ω	896.2119Ω	92Ω	77.4042	1.9351
Pos 5	9.6dB	2.3159Ω	500Hz	2.3284Ω	432Ω	17179Ω	92Ω	77.4042	1.9351

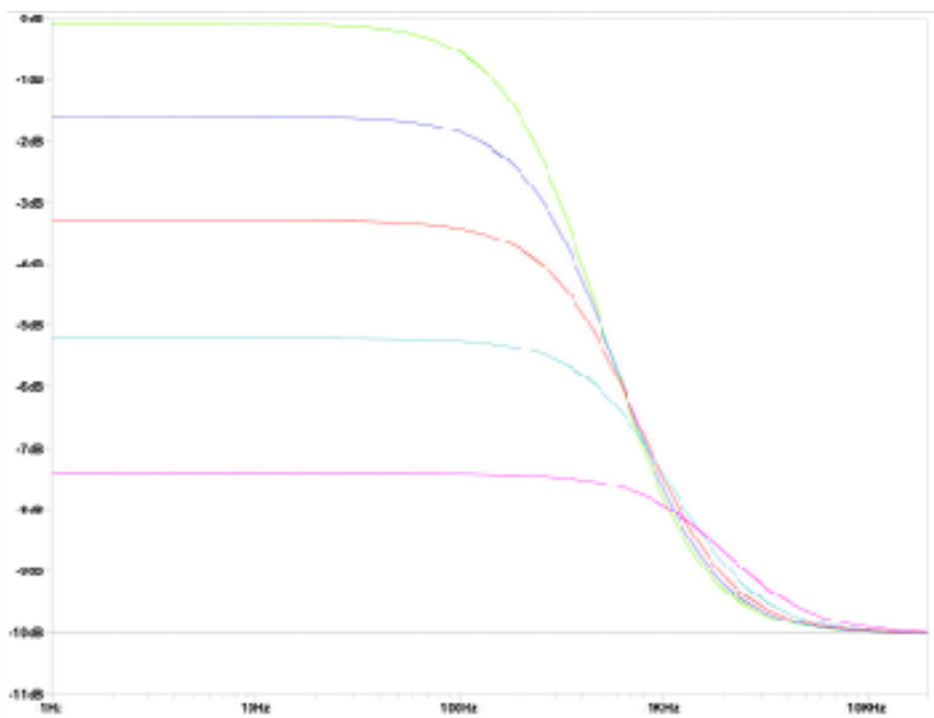


Figure 21. *Curves created using schematic from Figure 19 and values from Table 5.*

To create the next two pieces of the equalizer the following criteria remain the same: line impedance of 200Ω and an insertion loss of 10dB. To create the additional up to ~10dB of reduction past the insertion loss, I have chosen to use type series impedance filters before the bridged "T" attenuator for simplicity.

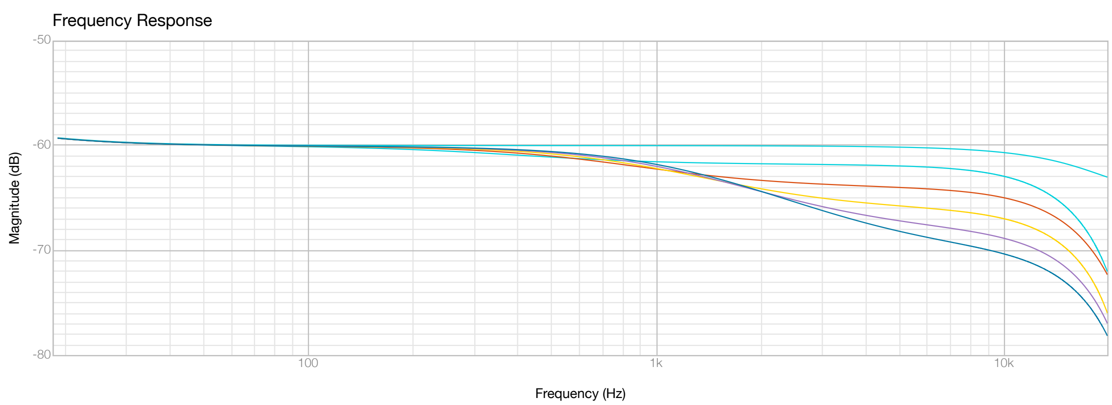


Figure 22. *Response curves of the Waves REDD.51 Plugin for "Pop" filter high cuts -2, -4, -6, -8, & -10.*

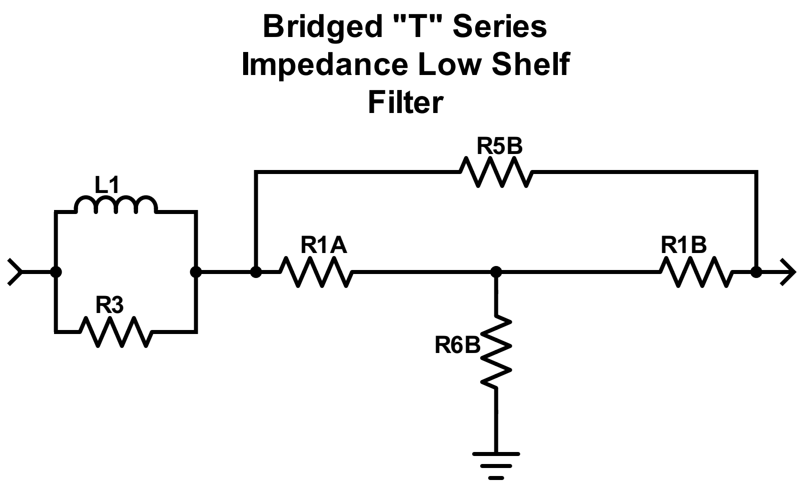


Figure 23. *Schematic of a Bridged "T" Series Impedance Shelving filter capable of creating the curves depicted in Figures 13 and 22.*

Referring to Figure 13 and Table 3, the following terms are needed to calculate component values:

$$\frac{K-1}{\sqrt{K}} = \frac{3.1623-1}{1.7783} = 1.2159 \qquad \frac{\sqrt{K}}{K-1} = \frac{1.7783}{3.1623-1} = .8224$$

$$LB = \frac{200}{2\pi \times 2300} = .0138\text{H} = 13.8\text{mH} \qquad CB = \frac{1{,}000{,}000}{2\pi \times 500 \times 200} = 1.5915\text{mF}$$

The component values can then be calculated by simply if plugging the values into the equations based on Figure 13 and Table 3. L1 and C1 are calculated slightly differently here based on the original charts from Miller and Kimball (1938).

$2L1 = 13.8 \times 1.2159 = 2(16.7794)\text{mH} = 33.5588\text{mH}$

$$\frac{C1}{2} = 1.5915 \times .8224 = \frac{1.3088}{2} = .6544\text{uF}$$

K values calculated from Figure 22 where the curves cross 10Khz.

Pos 5

R3= 2[R1(K-1)]

R3 = 2[200(3.2734-1)]

R3 = 909.36Ω

Pos 4

R3= 2[R1(K-1)]

R3 = 2[200(2.7542-1)]

R3 = 701.68Ω

Pos 3

R3= 2[R1(K-1)]

R3 = 2[200(2.2387-1)]

R3 = 495.48

Pos 2

R3= 2[R1(K-1)]

R3 = 2[200(1.7783-1)]

R3 = 311.32Ω

Pos 1

R3= 2[R1(K-1)]

R3 = 2[200(1.3964-1)]

R3 = 158.56Ω

Table 6. Design Elements for “Pop" Filter High Cut.

	dB Cut	R3	Fb	R5	R6	L1 in mH
Pos 1	2.9dB	158.56Ω	2300Hz	432Ω	92Ω	33.5588
Pos 2	5dB	311.32Ω	2300Hz	432Ω	92Ω	33.5588
Pos 3	6.9dB	495.48Ω	2300Hz	432Ω	92Ω	33.5588
Pos 4	7.8dB	701.68Ω	2300Hz	432Ω	92Ω	33.5588
Pos 5	9.6dB	909.36Ω	2300Hz	432Ω	92Ω	33.5588

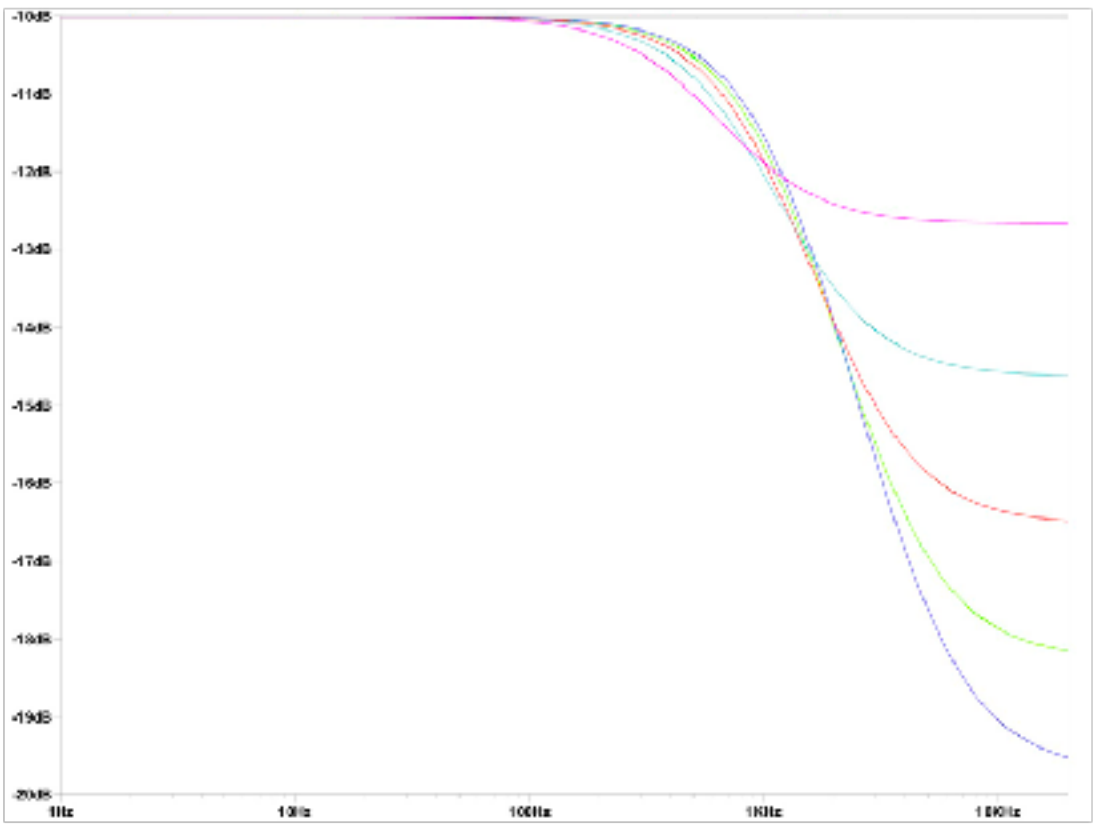


Figure 24. *Curves created using schematic from Figure 23 and values from Table 6.*

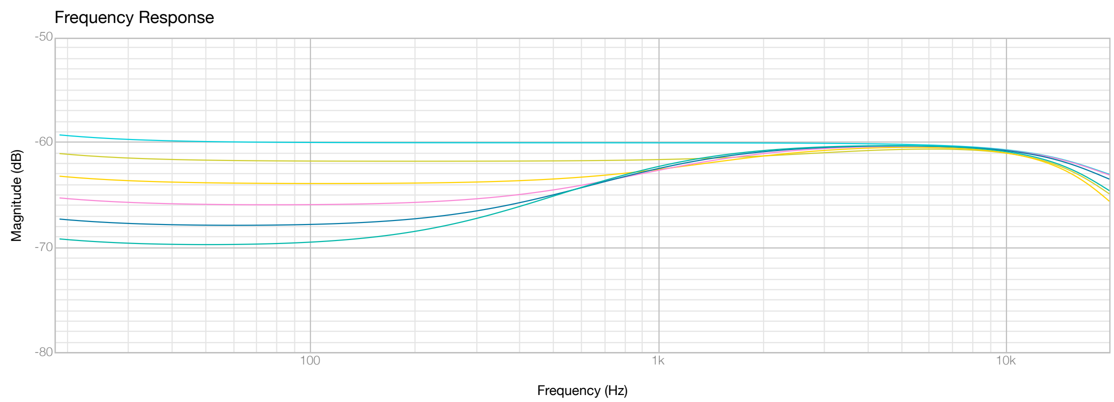


Figure 25. *Response curves of the Waves REDD.51 Plugin for "Pop" filter low cuts -2, -4, -6, -8, & -10.*

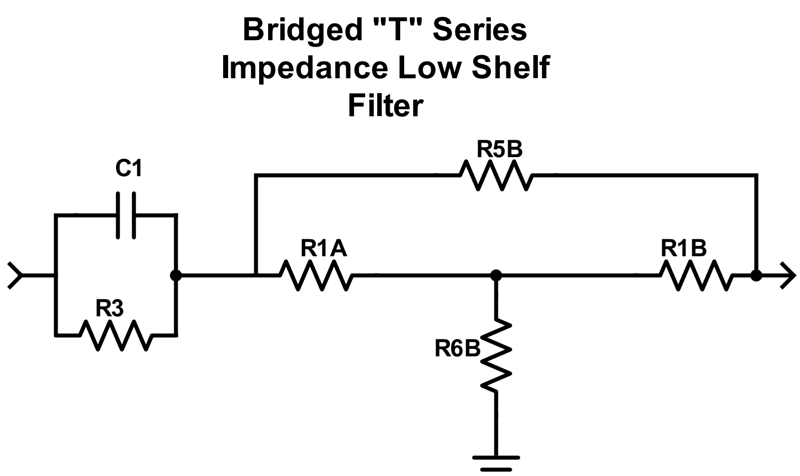


Figure 26. *Schematic of a Bridged "T" Series Impedance Shelving filter capable of creating the curves depicted in Figures 15 and 25.*

Next is the low cut section of the "pop" filter. K values calculated from Figure 25 where the curves cross 40Hz.

Pos 5

$R4 = 2[R1(K-1)]$

$R4 = 2[200(3.02-1)]$

$R4 = 800\Omega$

Pos 4

$R4 = 2[R1(K-1)]$

$R4 = 2[200(2.4547-1)]$

$R4 = 581.88\Omega$

Pos 3

$R4 = 2[R1(K-1)]$

$R4 = 2[200(1.9498-1)]$

$R4 = 379.92\Omega$

Pos 2

$R4 = 2[R1(K-1)]$

$R4 = 2[200(1.5488-1)]$

$R4 = 219.52\Omega$

Pos 1

$R4 = 2[R1(K-1)]$

$R4 = 2[200(1.2162-1)]$

$R4 = 86.48\Omega$

Table 7. Design Elements for "Pop" Filter Low Cut.

	dB Cut	R3	Fb	R5	R6	C2 in mH
Pos 1	1.7dB	86.48Ω	500Hz	432Ω	92Ω	.6544
Pos 2	3.8dB	219.52Ω	500Hz	432Ω	92Ω	.6544
Pos 3	5.8dB	379.92Ω	500Hz	432Ω	92Ω	.6544
Pos 4	8.8dB	581.88Ω	500Hz	432Ω	92Ω	.6544
Pos 5	10.3dB	800Ω	500Hz	432Ω	92Ω	.6544

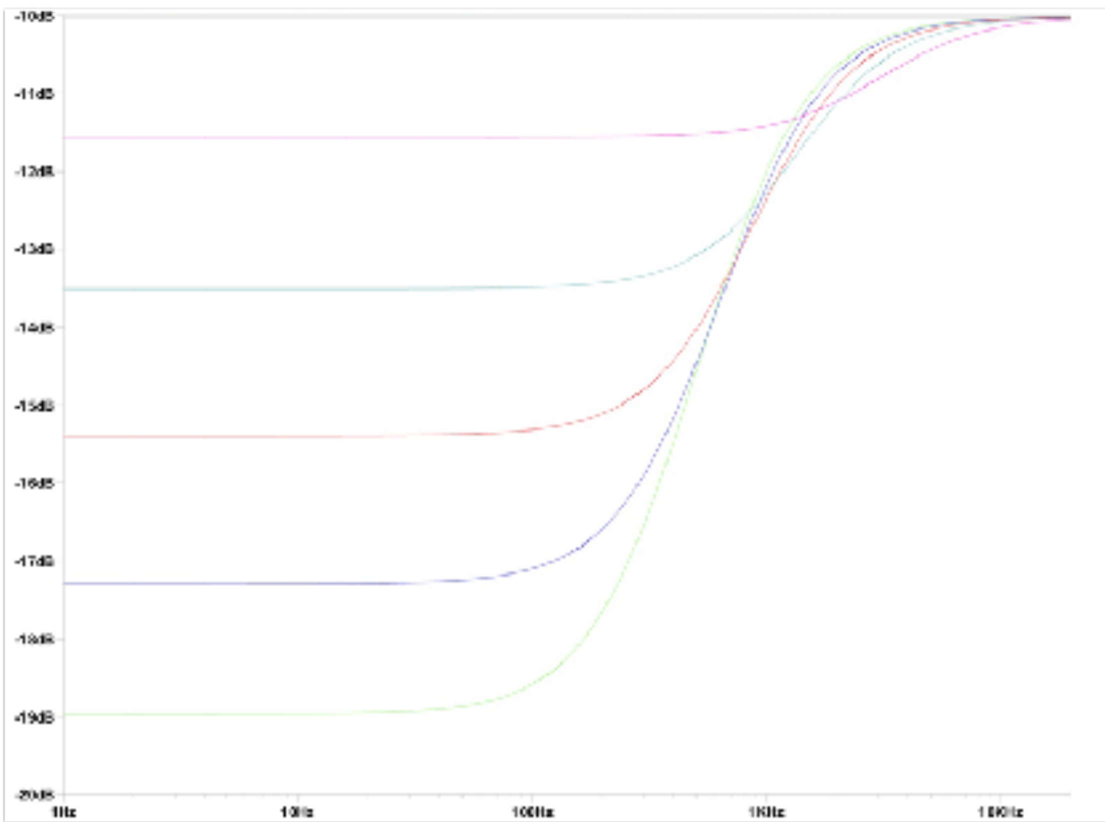


Figure 27. *Curves created using schematic from Figure 26 and values from Table 7.*

These four elements are then combined together to create a replica of the REDD "Pop" Tone controls (Fig. 28).

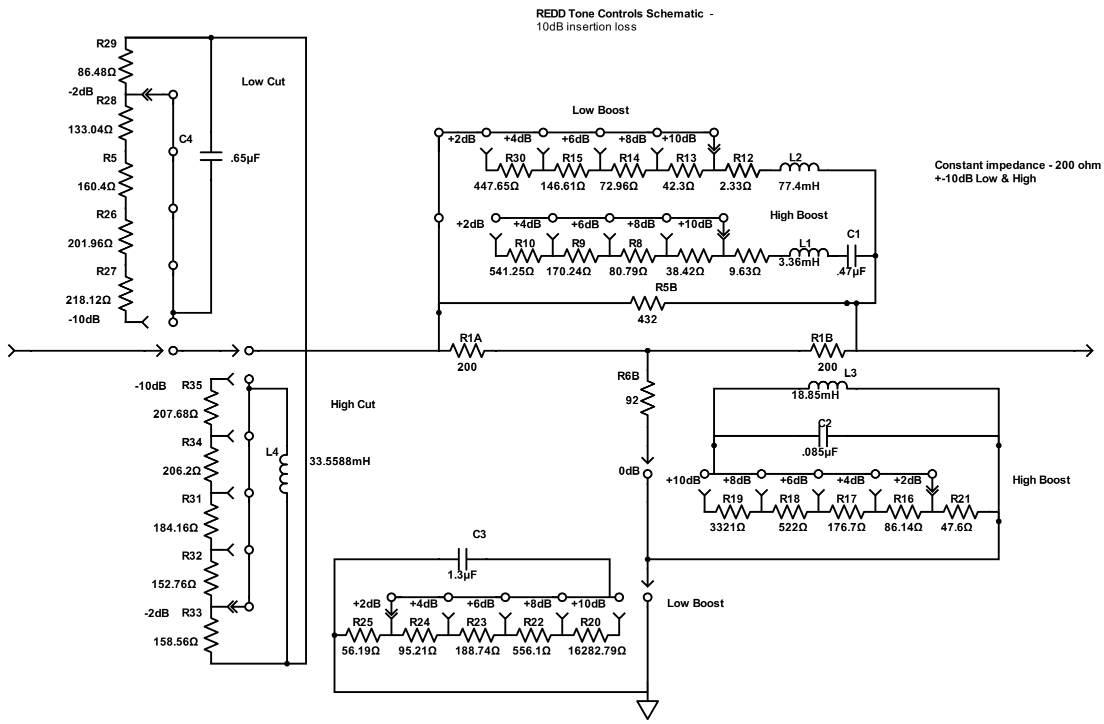


Figure 28. *Schematic of REDD Tone controls for the "Pop" Plugin Module. Component values listed do not represent practical real world components.*

I determined the individual resistor values which are again calculated described previously, by subtracting down the chain.

The Stereophonic System

The last part of the signal chain was E.M.I's stereophonic system, which is beyond my knowledge and skills to attempt to recreate; however, I documented the individual sections of this system in the diagram for signal flow of the record path of the desks (Fig. 29).

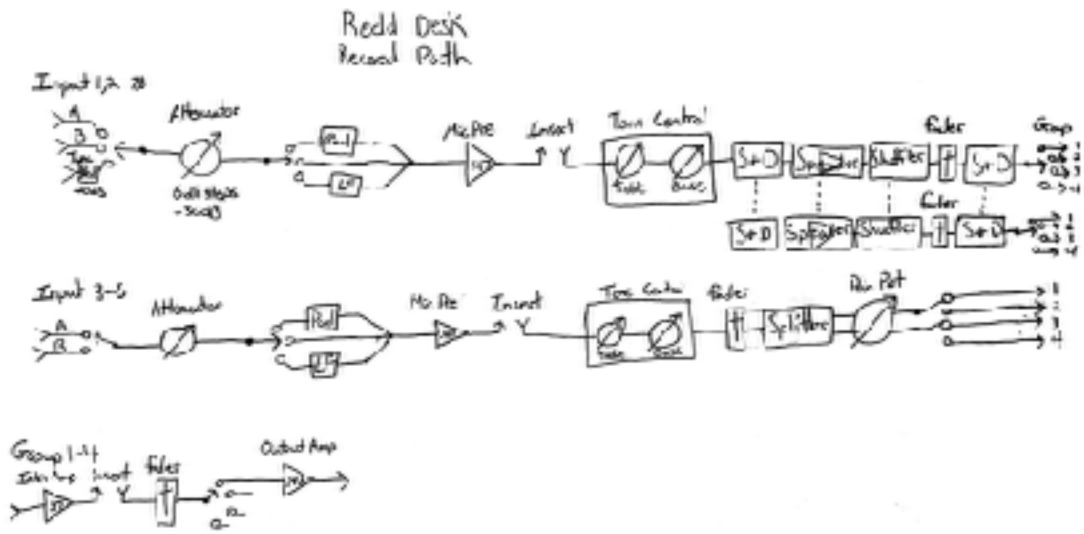
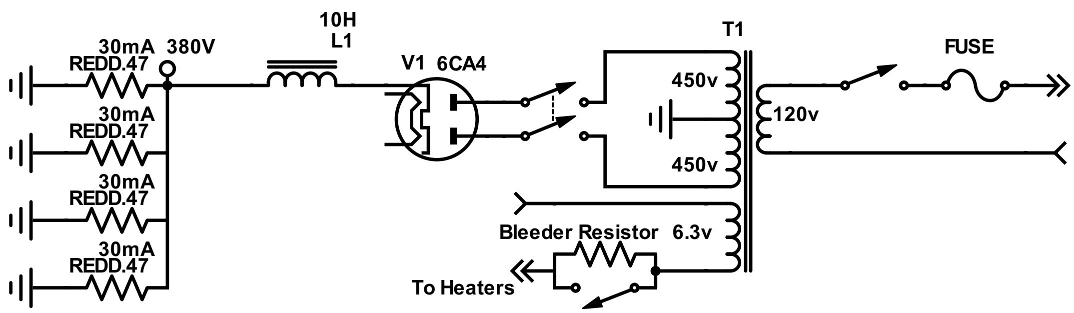


Figure 29. *Signal diagram of REDD desk record path.*

Designing a Suitable Power Supply for the REDD.47 Preamps

I could not find much information on the power supplies for the REDD.47 preamps, other than a designation of REDD.43/D23/2. This unit was suitable for powering preamps with the alternate circuit as shown in the schematic above (Fig. 29). Because I could not find any usable information, I chose to design a tube power supply capable of powering four REDD.47 units concurrently. The REDD.47 schematic tells us then that this supply must be capable of supplying 120mA at 380V and 2A at 6.3V. With this information, I could design a suitable supply. I have included my design and a few necessary calculations below, but have decided not explain this part in full because it is not fully based on design information gathered about the REDD.51 Desk power supply.

REDD.47 Power Supply 4x



Calculations

VL (Voltage Load) = 380vdc
IL (Current Load) = 120mA
Vpeak-PI = VL + √2(VL) = 917.32v
Ipeak = Ipavg(4) = 240mA
<u>6CA4</u>
Ua invp = 1,300v
Ip = 500mA
ukf = 500v
Lmin = 1H
utr eff = 2 x 450v
Idc = 150mA
L = 10H
Ud.c. = 378v

Figure 30. *REDD.47 Power Supply Capable of powering four REDD.47 units.*

Product: Sound Recordings

The major goal for my project was to replicate various techniques and effects used at Abbey Road by The Beatles; consequently, the success of this goal could best be determined by a practical implementation of my research. I produced three sound recordings, each on two-inch analog tape. I used four tracks for one of the recordings, which represented the number of tracks usually available to The Beatles while they were recording at Abbey Road. I used eight tracks for the other two recordings. The Beatles had an option to use eight tracks during recording sessions for their album entitled *Abbey Road*, and for some of their recording sessions for their album that became known as *The White Album* (Kehew & Ryan, 2007). I used four tracks to record the song "How The Tune Goes" during an eight hour session (Table 8). I chose to record in a short session to mimic the time constraint often imposed on The Beatles during their early years (1962–1965), and also because of studio availability. In contrast, I used eight tracks during two other sessions: an initial twelve-hour session and a subsequent eight-hour session. For the eight track recordings, I used several effects heralded by The Beatles during their later years (1966–1970). I relied heavily on Kehew and Ryan (2007) *Recording The Beatles* to determine microphone choice and placement, effects used, and instrument placement during the recording sessions. The following sections detail how I implemented the above information during my recording sessions.

Effects

Because of innovative techniques that led to significant modification and advancements of popular music during the 1960s, The Beatles and engineers at EMI are considered pioneers in popular music (Hecl, 2006). These innovative techniques include implementation of effects, which were not necessarily invented at EMI, but were used on popular sound recordings. A few examples, given in chronological order, include backwards vocal or retrograde and varispeed on the song "Rain", tape loops on "Tomorrow Never Knows", STEED on "Paperback Writer", and ADT on the *Revolver* album (Kehew & Ryan, 2007, p. 265–311). What follows is an overview of the effects I successfully implemented during my recording sessions.

Plate Reverb—This effect was only occasionally used while The Beatles were recording at EMI. More often, an echo chamber was commonly used for spatial effects on Beatles' records. Nevertheless, I used plate reverb on my recordings because of the availability of a plate and lack of availability of an echo chamber. EMI had four plates available during the Beatle's tenure, two with valve amplifiers and two with solid state amplifiers (Kehew & Ryan, 2007, p. 282). The Beatles did use plates on recording sessions for their album, *Sgt. Pepper's Lonely Hearts Club Band* (*Sgt. Pepper*), and they continued to use them during sessions for subsequent albums (Kehew & Ryan, 2007, p. 282).

Tape Echo/Repeat Echo—Although The Beatles were not the only artists to use slap back echo, as they were with ADT, it was a commonly used effect that is simple to recreate. Unfortunately, I was not able to incorporate either STEED or ADT in my recordings. I successfully implemented ADT into songs recorded at the studios at MTSU previously, but I could not at this time because one of the Studer tape machines in Studio B was inoperable. Echo Chambers with pre delay were common practices at many studios during the 1960s, and involved sending a signal to a tape machine and taking the delay created and sending that to an echo chamber to create a pre-delay. This was specifically referred to as STEED at EMI studios when additional repeat echoes were added. ADT is an effect that was invented by an EMI engineer, Ken Townsend, and involves taking a vocal take and recording it to a separate tape machine, then varying the speed of the second tape machine up and down to create a pseudo double track as the vocal would vary in front of and behind the original (Kehew & Ryan, 2007). Tape echo is created by sending the sound to be delayed to the record head of a tape machine, then mixing the signal from the play head back with the original sound. Multiple delays can be created by creating a feedback loop between the play and the record head. This was referred to as repeat echo by EMI engineers (Kehew & Ryan, 2007, p. 285).

Half-Speed Overdubbing.—Perhaps the most notable example of use of half speed overdubbing by The Beatles is the piano solo by George Martin on the song “In My Life.” The overdubbing effect is created by recording a part at half the intended playback tape speed and an octave lower than intended to be heard (Kehew & Ryan, 2007, p. 289). The part recorded will be an octave higher than when recorded when played at the intended speed.

Frequency Control (Varispeed).—Varispeed is similar to half speed overdubbing, but instead of running the tape at half the playback speed, the speed is variably adjustable up and down. The first Beatles first used this effect on the song “Rain.” The backing track was recorded at a faster speed than final playback, and the vocals were recorded at a slower speed than the final play back (Kehew & Ryan, 2007, p. 293). The Beatles apparently appreciated the sound created by varispeed as this was one of their most often used effects, which was used on dozens of their songs.

My Recordings.—All recording sessions for my album took place in Studio A and B in the John Bragg Building at MTSU. Studio A is the largest open-space recording studio; consequently, I used Studio A to approximate Studio Two at Abbey Road, which consisted of a single open recording space. Studio B is a smaller recording studio that is subdivided into several small, separate recording spaces; consequently, I used it as a substitute for Studio Three at Abbey Road, which consisted of small, subdivided rooms. I used eight different types of microphones. I used five microphones from the MTSU collection, including a Coles 4038 and an AKG d20. I chose these microphones because they are good approximations of two microphones used by The Beatles, the STC ribbon and AKG D12, respectively. I built three microphones, which were replicas of the Neumann U67, Neumann U47, and the AKG C12.

Before I began to work in the studio, a friend (Dylan Miller, no relation) and I wrote several songs, and we recorded acoustic and vocal demos of each of these songs. I recruited members from The Busks (Dylan Miller, Wesley Sadler, and me) as musicians for the recordings. Wesley played drums on “Neon Sunrise”; whereas, Dylan and I provided vocals, drums, and played several instruments on all recordings. I did not make a decision on which songs to record until we were in the studio and ready to record. Also, I chose microphones during the pre-production stage, primarily based on what was available at MTSU and in my own collection.

Although I decided on which microphones to use during pre-production, I chose all outboard gear, and pre-amps when we started to record. Unfortunately, I was not able to construct any REDD.47 preamps as originally planned. The use of gear, instruments, microphone placement, and effect implementation is covered in a synopsis of the recording process for each sound recording below.

How The Tune Goes

Table 8. "How The Tune Goes" Tracks

Take I	Track I	Track II	Track III	Track IV
		Drums, 12 String Acoustic	Vocal	Vocal
Tracks III & IV bounced to I	Vocals	Drums, 12 String Acoustic	Electric Guitar, Piano	Bass, Tambourine

Recording Synopsis—"How The Tune Goes" was the last song I recorded and consisted of an eight hour tracking session, with about two hours allocated for mixing on a different session. The session began at 12am. At this time, I discussed song options with my recording partner and decided on this particular song while we setup to track the drums and an acoustic twelve string guitar in an isolation booth. I was acting as musician and as a recording engineer during this session as well as all others; consequently, it took me longer than anticipated to set appropriate levels between the two instruments. When the levels were finally set to my satisfaction, I decided to keep the first take, or first attempt at recording the song. I then overdubbed two vocal tracks, each in a single take. One vocal track was recorded in the isolation booth and one in the open room. These tracks were originally intended to serve as guide vocals for overdubs, but I kept them in the interest of time and track availability. I then bounced the two vocal tracks to a single track, to which I added piano and electric guitar with their own shared track. This took about an hour as the two of us worked out our parts and a harmonized instrumental break. At approximately 5am, I overdubbed a bass guitar with tambourine to the final open track, and put together a rough mono mix. The three of us left the studio at approximately 7am, with the entire song recorded, but not mixed. Although there were imperfections in the ending and in the vocal tracks, I did not think that the imperfections were serious enough to warrant scrapping the recording. My goal was to use four tracks to create a mono record, which I had accomplished. For the final mix, I let the tracks dry, in homage the relatively dry soundscape of the *Revolver* album. The recording was influenced primarily by the albums *Help!* and *Revolver*.

Instrument & Amp Usage Synopsis.—I chose the instruments and amps used on this recording to reflect as closely as possible the instruments used by The Beatles in their 1965–1966 era, which is when the albums *Help!*, *Rubber Soul*, and *Revolver* were recorded. I used a 12 string acoustic guitar to pay tribute to John Lennon, who played a 12 string guitar on the song “Help!” (Kehew & Ryan, 2007). Furthermore, I used an electric Epiphone casino with flat wounds, Hofner bass with flat wounds, and a replica

VOX AC30 amplifier, which were similar makes and models as those used by the Beatles (Kehew & Ryan, 2007). Also, I used the Kawai grand piano available in Studio A, a Mapex drum kit, and a tambourine during tracking of this recording.

Microphone Usage Synopsis.—I used only four different microphones during this recording, each of which was chosen to reflect common microphone practices used by The Beatles during their recording sessions. As an overhead for the drums, I placed a Coles ribbon microphone directly above the snare, near head-level of the drummer. I rounded out the drum kit microphones with an AKG d20 on kick and a Neumann KM84 underneath the snare, and I flipped the polarity of this signal. I modeled this entire setup after the 1966 microphone setup for drums by Geoff Emerick, as shown in *Recording the Beatles* (Kehew & Ryan, 2007, p. 411). I also used the Coles 4038 microphone for the piano. I used a replica U47 on the acoustic and electric guitars, and on the vocals. I used close miking techniques for most microphone placements. The drum overhead was a few feet from the top of the snare, all other microphones were within a foot of the sound source intended to be captured.

Effects Usage Synopsis.—I recorded the base track for this song a half step down and sped up to E at 15ips. Instead of implementing a multitude of effects, I used this recording to focus on the use of internal bouncing to free up track space. This is a simple example of track reduction, with just the use of one generation. As illustrated in Table 8, the vocal tracks were recorded to tracks III and IV and then internally bounced to track I to free up space for additional overdubs.

Outboard Gear Usage Synopsis—The only outboard gear used in Studio A was a VariMu Compressor, an 1176 compressor, and the API equalizer modules. The compressors were used between the input of the tape machine and the output of the console as this is where a compressor was always in the chain recording The Beatles (Kehew & Ryan, 2007).

Neon Sunrise

Table 9. Neon Sunrise Tracks

Take 3	**Track I**	**Track II**	**Track III**	**Track IV**	**Track V**	**Track VI**	**Track VII**	**Track VIII**
	Drums, Electric Guitar, Acoustic Guitar	Electric Guitar	Piano	BKD Vocal	Vocal	Vocal	Bass	

Recording Synopsis—I initially intended to use *Neon Sunrise* only as a practice session and demo for thesis material, but I eventually chose to include this song because it illustrates several techniques used by The Beatles and follows a similar technical restriction process. Instead of using four tracks, I used eight tracks (Table 9), which were available to The Beatles during their later *White Album* sessions and for the entirety of the *Abbey Road* sessions (Kehew & Ryan, 2007, p. 511). I used Studio B for all tracking sessions. I tracked together live recordings of drums, an electric guitar, and an acoustic guitar to one track and in one take; however, several takes of rehearsals were recorded as I set levels. This was a fairly quick process, which was completed in less than two hours from load in. I then developed an electric guitar part that mimicked the rhythm guitar part on track one. It was recorded through an AC30 amplifier with tremolo on the next track, followed by a piano part inspired by the cartoon *Rugrats'* theme song on track III. I then recorded two vocals to tracks IV and V, background harmonies to track VI, and finally, bass was recorded, direct injection, to track VII. I then bounced a quick stereo mix for this song. Unfortunately, this would be the only bounce before the vocals were accidentally erased. The whole process took approximately five hours.

Instrument and Amp Usage Synopsis.—The Epiphone Casino was again used for all electric guitar parts and the Hofner for bass parts. The electric guitars were run through a replica VOX AC30. A custom Dark Horse drum kit was used for drums, and a miniature martin acoustic for acoustic guitar. I also used the Kurzweil piano in studio B.

Microphone Usage Synopsis.—The microphone choices made on this recording are similar to those used on "How the Tune Goes." The microphone choices for drums were an expansion of the three described earlier, and were inspired by a later microphone setup for drums used by Geoff Emerick during 1967 as pictured in *Recording The Beatles* (Kehew & Ryan, 2007, p. 436). I added two Yamaha MZ-204 microphones to the toms and a Sennhieser MD421 to the hi-hat. I used a replica U67 microphone for both electric guitars and for all vocals. I recorded the acoustic guitar with a replica U47, and the piano with a replica C12. The bass was run direct injection. Close miking techniques were similarly employed as on "How The Tune Goes".

Effect Usage Synopsis.—This recording features extensive use of the varispeed recording technique and of half-speed overdubbing. I recorded the base track containing drums, acoustic guitar, and electric guitar, a half step down in Bb at 14.16ips and played back at 15ips in B. The piano track was recorded as two different sections. One section was recorded at half speed, the other at normal speed. The first verse was the portion recorded at half-speed, and tape echo and echo repeat were applied throughout both sections. I also recorded the overdubbed guitar a half step down, similar to the base track. I recorded both vocal tracks with varispeed applied; one track slightly above 15ips and the other slightly below 15ips, and both within a semitone. I double tracked the harmony vocals, which were both recorded slower than 15ips, with one a whole step slower, and the other a few more steps slower than this. These speeds were randomly chosen. When played back at full speed, it created a fast vibrato effect due to the sped-up natural vibrato of the voices. I used the tape echo and repeat echo effects frequently on this recording. For example, the overdubbed guitar, the double tracked vocal, and the piano all feature this effect.

Words

Recording Synopsis.—"Words" was the second song I recorded for this project, and the second I recorded in studio B. This song was tracked and completed during two separate sessions. The original tracking session was performed as a tag-on at the end of the "Neon Sunrise" session. This track was notably influenced by several songs by The Beatles, including "A Day in the Life", "Hello, Goodbye", and "Lucy in the Sky with Diamonds." The base track consists of piano and guitar on the same track I, with a live vocal performance recorded simultaneously to track II (Table 10). This vocal was subsequently overwritten with another vocal during the following overdub session.

During the next session, two vocals takes were completed and recorded to tracks two and three, overwriting the original vocal take. A Hammond B3 was recorded onto track VI, an electric guitar on track VII, followed by drums on track VIII. A bass was the final overdub completed on track IV. Background harmony vocals were originally planned for track V, but this never came to fruition. I used several different effects on this song, including as Leslie'd electric guitar, plate reverb, varispeed, tape echo/repeat. Furthermore, this is also the only recording for the project to use a bass amp instead of direct injection to record the bass.

Microphone Usage Synopsis.—This recording uses the same mic setup for drums as "Neon Sunrise", again modeled after the drum setup of Geoff Emmerick during 1967. I used a replica AKG C12 microphone to capture the piano. I used a different microphone to capture the vocals on this recording compared to the other recordings. I used a Coles 4038 ribbon to combat a particularly strident voice and to give the recording an overall darker tone. I took great care to prevent plosives of air from damaging the ribbon element. For example, I included a pop filter and positioned the microphone at an angle tilted away from the singer's voice to prevent direct breathe from blowing on the thin aluminum. I used the replica U47 microphone and Leslie cabinet for both the guitar and organ. I attempted to mimic the setup of the bass to that used by Paul McCartney during The Beatles' later years (1967-1969). I was a bit disappointed by my results, which I thought inferior to that of McCartney. I attributed my poorer recording to the absence of a few key elements, including Paul McCartney, a Rickenbacker bass, and the RS127 compressor. The bass was recorded on a Hofner into a Fender Blonde Bassman located in the center of Studio B, and was mic'd by a replica AKG C12 approximately twelve feet away.

Effect Usage Synopsis.—"Words" was an effect laden recording. I used several Beatles' effects in an attempt to create a particular sound. These effects included extensive plate reverb, repeat echo, and varispeed.

Table 10. "Words" Tracks

Take 3	Track I	Track II	Track III	Track IV	Track V	Track VI	Track VII	Track VIII
	Drums, Piano	Vocal	Vocal	Bass		Hammond B3	Leslie Guitar	Drums

Post Production

Although I completed the stereo mix for "Neon Sunrise" at the end of the initial tracking session, I did not complete the mono mix at this time. Unfortunately, I inadvertently erased the two vocal tracks; therefore, the mono mix is noticeable different from the stereo mix (it lacks melody vocal). Differing mono and stereo mixes is actually a common occurrence among mixes of songs of The Beatles; however, there are none that completely lack a vocal. For example, the mono and stereo mixes of "Lucy in the Sky with Diamonds" from the (*Sgt. Pepper*) album are very different from each other with the mono mix having much more phasing applied to the vocal (Kehew & Ryan, 2007). I completed all of my other mixes on separate session from their tracking session.

Because of difficulties associated with studio availability, time constraints, and cost, I printed my masters to a digital format. Having a digital master, rather than a master tape, facilitates presentation (I do not need to transport a 1/2in tape machine for presentation) and reduces cost on the purchase of magnetic tape.

"How The Tune Goes" Mono Mix.—I applied additional compression and equalization to the mono mix for this song, but not for the other recordings. This is perhaps because unlike the others, I completed the mono mix before the stereo mix, and I was concerned about losing elements because of masking primarily associated with dryness of the track as there was no space between elements. Furthermore, this song was more hastily recorded and needed additional brightening and taming of the vocal. I had to dynamically adjust the bounced vocal with the fader throughout the print, primarily between sections, and the intro/exit, because of noise floor created by improper levels when recording.

"How The Tune Goes" Stereo Mix.—With the stereo mix for this song, I chose to leave the non-vocal tracks as they were and only use panning to ensure clarity in the stereo spread. I followed a fairly conventional early Beatles' stereo mix of panning both vocals collapsed towards center, but with enough spread to balance the stereo field, the drums and bass slightly to the left (as these were usually on the track in the 1962-1965 days), and the overdubbed guitar/piano track hard right (Kehew & Ryan, 2007). The vocals received additional equalization and compression. The ending for the stereo mix differs from that of the mono mix. In the mono mix, the song fades out on an acoustic guitar strum; whereas, in the stereo mix, the song fades out the electric guitar and piano sounding.

"Neon Sunrise" Mono Mix.—I gave very little thought or time to this mix because there were no vocals, and not enough time available to redo them. With this mind, I worried very little about elements competing with one other and fairly quickly set suitable levels and printed the mix. Mono mix notably does not fade out like the stereo mix.

"Neon Sunrise" Stereo mix.—The stereo mix for this song was intended to be kept within the options available to The Beatles during their later years (Abbey Road sessions) on the TGI desk. It was completed immediately following the tracking session. Only levels and panning were adjusted, as no additional time based effects, equalization, or compression were needed. Many of these effects had already been printed to the recorded tracks, such as the repeat echo on the vocal. This is similar to how the slapjack on John Lennon's voice on "A Day in the Life" was recorded to tape concurrent with his vocal take and was piped to his headphones (Kehew & Ryan, 2007).

"Words" Mono Mix—This mix notably differs from the stereo mix because of the exclusion of the drums until the second verse. The vocals are more present in the mono mix as well as the Leslie guitar.

"Words" Stereo Mix.—The stereo mix is very simple with no additional effects added. The piano/acoustic track panned slightly left of center and the drums fairly hard right. The vocals are split one down the center the other slightly to the right, this was commonly how The Beatles' engineers would pan vocals when applying ADT to stereo mixes, although the ADT signal was often hard panned (Kehew & Ryan, 2007). The bass, organ, and Leslie guitar are kept near the center.

I believe that ultimately each artist sound comes from the artist itself, and I think this project further enhances this notion. While albums recorded in a completely digital format sound may sound completely different from my results, this likely has more to do with the artist than the format, and even more to do with intent. I chose to record these songs in an analog format influenced by The Beatles. I hope ultimately listeners can tell this with playback. Although I may not have been able to complete all that I set out to do, I know that I have laid a solid foundation for me in this thesis to continue my research for many more years.

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