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Building a Recording-Specific Amplifier Cabinet

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The electric guitar has become a staple in modern music with its varied tonality, vast expanse of sound configurations, and ability to be played at many different amplitude levels associated with band and live applications. With the prevalence of electric guitar in almost all genres and styles of contemporary music, we have seen an influx of specialized guitar designs and necessary amplification demands for almost any style of playing. Guitar has always had a unique allure to its sound and method of playing, and the glorification of guitarists as virtuosic musicians dates back since before the roots of rock 'n' roll - and even as far back as the beginning of the 20th century. It is therefore no surprise that if you glimpse into any professional recording studio around the globe, chances are you will see a designated amplifier or amplifiers used specifically to record the electric guitar. But this studio amp is not simply the artist's performing amp rolled into the studio. It is a specialized piece of gear designed to produce the best sound in the studio.

During my time at CSUMB, I became fascinated with how to record my favorite instrument in the studio and sought to understand what it was about the cabinet's design and the speaker inside that produced the best sound. As I have progressed through the Recording Technology pathway, I have explored many different methods of capturing this audio source with experimentation of microphone choices, placement, double-tracking, and even software implementation of analog components, such as guitar processors and digital representation of the audio data. One of the most important aspects of capturing a quality audio track is the understanding of how the data is being represented, both in waveform and through frequency analysis. Being able to interpret an audio signal and recognize the

dynamic range and the level of a signal being recorded is crucial in making modifications to enhance the quality of the audio through modification of recording parameters, or the addition of audio processing such as equalization and compression. I recognized that for whatever comparison I would be attempting to construct, I would need to utilize these audio tools to provide an unbiased and accurate real-time representation of the audio signal. When comparing audio examples, continuity between takes is key. The use of a direct input box, or DI, is a common accessory found in studio environments that allow for the recording of a guitar straight into a DAW, rather than first being amplified and transmitting vibrations through the air. The use of a DI box takes the signal from the output jack of the guitar directly into a microphone preamp, which eliminates any amp coloration of sound and lets the engineer either use software modeling or reamping techniques[1] to achieve the perfect sound for the recording. This is especially important if we want to eliminate any discrepancies or slight variations in playing from one test to another during comparison. Ensuring that there is data to support the information being discovered allows for a closer examination of the characteristics between different audio sources when looking at resonance and timbre.

One of the main problems with guitar recording is how open to interpretation the mechanics and tonality of the sound produced are, and that there is no one true answer to the question, "what truly sounds good?" Often this label can be misapplied to the sound the guitarist is trying to replicate or create- and that it truly means it works well for the intended track and application. When determining performance, especially in a comparative atmosphere, I feel that relying on one's ears is not enough to give a full representation of the audio data being portrayed through soundwave projection. For the application of determining the viable parameters in a studio-friendly amp, the use of spectral analysis

[1] Reamping involves the use of a pre-recorded audio track of the instrument, which is then sent out of the mixing console and back into the amp to give the audio enhanced characteristics of resonance, sustain, and saturation over that of an audio track which is not recorded through an amplifier. Allows precise supplementation without changing performances or having slight discrepancies between recording takes.

would prove invaluable for use in comparison between models. I recognized, however, that comparing two existing amplifier cab models would not give me full control of the materials and construction to provide a detailed analysis of composition and its effect on tonality. Then I decided to just build one. In order to successfully fulfill the vision I had for this amplifier's application, I decided to restrain the build to a few choice parameters that would limit the breadth and application of this undertaking. Firstly, I wanted to build the amp cabinet that utilized a single 12" speaker, while keeping the weight of the complete frame and speaker under a maximum of 30 lbs. in order to stay applicable for movement in studio use. The second parameter I chose to include would be a power rating that is meant for that of an amp head unit of less than 30 watts. While specifics are explored further on as to why this value is important, the main reason for a reduction in power handling is to ensure the speaker performs properly at a lower volume than its stage-intended counterparts. We want to provide microphones with enough clean signal that they provide a detailed and dynamic recording, but without exposing them to amplitude levels that would cause damage to the capsule or preamp by running the amp too loud. The last component of these restraints is the cost of completion and materials needed to build the custom cabinet. As a reference number, I didn't want the cost of the build to exceed the cost of the amp available for retail purchase at market price. For example, if I was comparing the build against a $300 amplifier cabinet model, then the cost would need to be less than or equal to that amount to complete my build. Recognizing these constraints to the build allowed me to design a schematic that would be cost effective, portable, and made to handle the proper power ratings of a studio amp head.

I. Guitar Amplifiers in the Studio – A Brief History

The incorporation of pickups within the guitar developed in conjunction with big-band jazz ensembles with ever-growing rhythm sections and large horn sections, both of which effectively drowned out the sound from acoustic guitars used at that time. There were early acoustic-electric hybrid guitars such as the Electro-Spanish Ken Roberts model or the Gibson ES-150 model that incorporated a single bar-style pickup into the semi-hollow body of the instrument (Maloof). Another notable creation was Les Paul's Log Guitar, which he fashioned out of a single plank of 4 x 4" lumber with detachable sides for aesthetics (Meeker). This was the first truly "solid body" electric guitar, since it effectively rejected the open resonance of a hollow cavity where the sound amplifies itself through the wood and chamber. As electric guitars started to catch on and full solid-body models began to emerge as the new industry standard, the reliance on proper amplification techniques grew since the guitar's resonance came entirely from the strings into the pickup magnet without first resonating through the body cavity of the guitar.

Les Paul pictured with his "Log" Guitar - The first solid body electric guitar in the world (*lespaul.com*)

The use of guitar amplifiers grew along with the milestones being attained in guitar technology. In big-band settings, often the amplifiers used for early acoustic-electric hybrids were essentially PA speakers used solely to amplify the signal of a guitar. These amplifiers were used only for the purpose of bringing the guitar's output level to an equivalent amplitude to the other instrument sections of the band. Early amplifier systems often provided a more transparent representation of the signal source (guitar pickup) than their later evolution models, but at the cost of instrument tonality through small speakers and thin cabinets. With the invention and inclusion of transformers and vacuum tubes within the circuit, however, amplifiers started to become more portable and effective at amplifying the guitar pickup's weak output signal in an application-specific method. There were now speakers being produced that enhanced the guitar's midrange register and worked in a plug-and-play manner rather than the

gain-staging components of early PA speakers (Teagle). As the desire for better and louder amplification started to direct the market, amplifiers specifically for the electric guitar became available in packages with electric guitars. Thereafter, amplifier companies and designers began to incorporate different materials and design intricacies in the name of tone-chasing, which is how some of the popular variations in amplifiers rose to prominence.

Throughout the history of the electric guitar amplifier, beginning in the 1950s, many different materials have been used in various methods of production to achieve a balance between the range of tonality versus the unwanted resonance within the cabinet. Fender Instrument Corporation is well-known for using solid white pine for most of their flagship amplifier models since the 1960s. The lighter density of pine lent to the natural resonance of the wood in combination with the speaker vibration, while still being sturdy enough to stand up to the abuse that travelling music gear is accustomed to taking. The trade-off to these amplifier designs was between weight and reduced rigidity, because these tone woods are much softer than other options (Hunter). This is an important distinction to recognize, especially in two-speaker configurations or even the hefty 4 x 10-inch speaker configuration. The most notable incorporation of larger speaker configurations was the Fender 1959 model Bassman amplifiers that became popular for their enhanced low-end thump, which was incorporated heavily into the iconic sound of 1960s rock and roll music (Owens).

Amplifier power demands increased as the electric guitar became an integral part of most ensembles and bands - and from that, the inevitable chaining of multiple amp cabinets together arose for larger scale concerts as more guitar-driven musical styles developed. Gone were the days of a small combo amplifier to bring the level up to surrounding amplitude levels of brass instruments and drums; by now, amplifiers had become the main focal point of a musical piece, and all the other instruments were now being brought up to the enhanced dB level of the guitar amplifier's output in both live and recorded settings. With this newfound attention on the tonality of the electric guitar and its various

components in the signal chain, cabinet design became increasingly important and therefore the subject of much discussion and tweaking for multiple situations. Amplifier head and cabinet combinations emerged, with the amount of power a separate head unit could feed a specific cabinet or series of cabinets chained either in series or parallel becoming even greater than the power outputs of large combo amplifiers with the preamp section included within the frame of the amplifier chassis.

II. Identifying Key Design Criteria

At the outset of my research, I identified a number of design criteria for a studio-specific guitar amplifier. These criteria are important to explore for several reasons and illuminating the issues with common amplifier setups within a recording capacity helps provide insight into how to best capture audio for the clearest, most pristine sound possible.

A good guitar recording depends on clarity, signal level, and the inclusion of full-bodied dynamics within the recorded audio (Marshall). With the widespread and extremely common use of electric guitar in all genres ranging from radio-smash pop hits to avant-garde compositions for four-piece ensembles, the nuances of capturing these performances all vary, and any audio engineer should both understand the mechanics of proper amplification guidelines as well as master a range of techniques and develop preferences in capturing this versatile instrument for different applications. What becomes a common problem in many recording scenarios is the use of stage-designed amplifier cabinets and wattages for this purpose. In the Recording Technology concentration at California State University, Monterey Bay, we were involved in several practical application settings where we would record outside artists from all genres. In addition, through personal recording projects and classwork, we learned the technology and relationships between audio and the listener. Within these sessions, we used the department's readily available amplifiers for the artists to play through; all three with enough power to easily fill small clubs or venues (>60w RMS power handling). During these recording sessions,

the performer would often leave the amplifier's volume at a minimal value of 20-30% of the amplifier's total amplitude. This is problematic from a recording standpoint because the amplifier is not allowed to fully 'breathe' and produce its most natural, organic sound, particularly since the tonality of guitar amplifiers is highly dependent on the amount of power it is being fed and is accentuated in the sought-after tone of tube preamp and power amp sections.

Add to this the complicating factor surrounding vacuum tube technology. Vacuum tubes are a finnicky type of amplifier power, dating back to the early 20th century in conception and first application in electronics. Often meant to perform at certain rated wattages, the tubes tend to become "choked" or muffled when being underpowered and not sent a strong enough input signal. Since the path of the signal through the head unit of the amplifier is all analog, the resistors and capacitors all get the signal passed through them before then being sent through to the cabinet and speaker, where the final output signal is then recorded from (Barbour).

Pairing a cabinet with the proper head unit is crucial in getting the correct performance out of the cabinet and, ultimately, the recorded product. Through extensive practical application, this knowledge allowed me to tailor the amplifier's power and tonality to accurately represent studio-level amplitude and size. Using an all-tube preamp and power section of the amplifier was another important factor in choosing the right model head unit, since the coloration and dynamics that tube amplifiers exhibit over solid-state provides a more saturated response from the cabinet due to the harmonic breakup introduced by pushing the tubes to an acceptable level of overdrive. While running the tubes at almost full capacity is not the intended purpose of this experiment, it is also important to ensure you have the proper headroom to use in live-recording situations without getting lost in the mix or becoming drowned out by other players and high-amplitude instruments such as horns and drums. For this purpose, it was exemplified in practice that a maximum of 30 watts was acceptable for studio use without being overpowered and choking the dynamics and tonality of the amplifier by running the amp

at a volume that prevents it from articulating the signal (Marshall). I opted to use a head that was roughly 15-20 watts total so that the user can push the master volume past a third of its total value and thereby allow the tubes to produce a dynamic and clear recorded sound.

Even using a lower-wattage amplifier, the relationship between decibel level and wattage is not as intuitive as one might expect. Reducing the amplifier's power (wattage) by half from 30 to 15 watts only reduces the master volume by -3dB, which means that in order to effectively reduce the perceived amplitude of the guitar by half we would have to make an amplifier that is 10 times less powerful (Altunian). For example, the 30-watt maximum value would need to be a mere 3 watts of power to halve the effective output level. Even so, a 15-watt head would still be much closer to $1/10^{th}$ of the output used by the Roland JC-120 120-watt Jazz Chorus amplifier available for use at the MPA department facilities (12 watts would be the effective halving decibel level for the JC-120), which would still provide a welcome reduction in amplitude and recording amplifier volume.

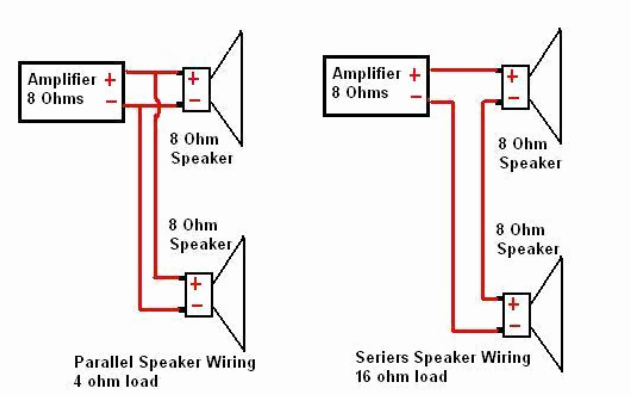
Recognizing these parameters of concern in a studio-designed amplifier helps reign in the build schematics I was creating and allow me to set values that would aid me in building a cabinet that was ideal for recording purposes. I strategically planned on incorporating a speaker that would perform best with a lower-wattage head unit, ideally rated with less than 70 watts to allow for proper movement of the woofer for articulation when being fed lower volume levels. To ensure that there was continuity between the amplifier and head unit power values, I opted for a maximum of 30 watts power handling- which would translate well to a speaker rated for a head less than 100 watts, unlike the two speakers in the Jazz Chorus previously mentioned. Another major factor in design consideration is what a manageable weight would be for an amplifier cabinet. Adhering to the versatility of studio configurations and setups, I wanted to create a frame that could be easily transported or set up without the use of casters or multiple people. When researching materials and weights of specific cabinet models, it became apparent that I would need to keep the weight under 30 lbs. to ensure that it was a

practical amplifier that did not need to stay stationary to be effective for use in recording. The final parameter I wanted to set was a margin of cost for the build. I knew that for whatever amplifier cab I would be testing against, I wanted to have the custom build cost less than the retail cost of the incumbent amplifier. For example, if I was testing my build against an amplifier that sells for a retail price of $300, I would need to keep the price of my build under that $300 to ensure that I was constructing comparable for less than or equal to what one can buy from a musical instrument store. Setting these parameters helped limit the scope of the build and keep the cost and design modest in comparison to some amplifier cabinets available for sale by specialty companies such as Paul Reed Smith or Riviera amplifiers, which can often run in excess of $600 for one unit. Keeping a relatively small footprint for the build would also allow me to cut back on material costs, as well as help keep the amplifier cab practical for both home and professional recording applications.

III. Design Choices and Gear Settings for this Project

After careful consideration, I chose to use the Egnater Amplification Tweaker 15 model head unit, which is extremely well suited for studio application. This head unit keeps the signal path simple through the amplifier while allowing the user to tailor the sound to their specific styles through a series of voicing switches: “Bright” and “Deep” parameter controls adding an equalization bump to either 2 kHz or 120 Hz when activated. The voicings allow for ‘USA,, ‘AC,’ or ‘Brit’ style responses from the three-band EQ included in the preamp section. After distinguishing the most transparent pairing for the guitar chosen to record the direct input track, I kept the EQ curve to the USA setting which provided a brighter, more balanced response from the guitar than the mid-scooped and chunkier low-end response of the UK-inspired voicings.

The preamp section of an amplifier head is often the most colorful tonal component of the signal path. The use of designated tubes for the preamp section is often the driving factor of tube amp characteristics over those of solid-state amplifiers. This section of the amplifier usually consists of a two or three-tube configuration. The first preamp tube handles the gain factor, or how much overdrive is introduced into the signal path. A clean sound exemplifies a lower gain value, while a screaming lead guitar like that of Van Halen or AC/DC defines the characteristics of a high-gain parameter setting. The second part of a preamp section is the phase inverter tube, which is a second tube added to help translation from the preamp section to the larger and more robust power tubes- this is the tube that gets pushed to the point of distortion in the output stage and not the power tubes (Rose). This particular Egnater amplifier consisted of two 12AX7 tubes in both the V1 and V3 tube sockets, respectively running the preamp and phase inverter sections. The V2 socket is used for the effects loop send and return, which originally had a third 12AX7 tube. I swapped to a 12AT7 preamp tube instead earlier in initial testing sessions of the amplifier head itself. The reason for this was the 12AT7 tube is a lower-gain tube than its AX7 counterpart; this contributes to the 12AX7's earlier breakup which produces the iconic overdriven sounds so prevalent in rock, blues, country, and even heavier genres (Malaker). Using a 12AT7 preamp tube in the effects loop provided a clearer definition of the effects being fed, especially time-based effects such as tremolo, delay, and reverb which can often get muddy at the end of a signal chain feeding to the main input of the amplifier. One of the other important factors in this specific model was the inclusion of variable-Ohm (4, 8, or 16) settings to provide a range of useable configurations without limiting to one specific resistance, since versatility and the ability to experiment is a crucial component of recording and



Series vs. Parallel Speaker Wiring Configurations

studio use. Speaker cabinets often come in different levels of resistance, depending on the expected power handling of the head unit, as well as the configuration of the speakers themselves. Series-wired speakers send the positive signal from the source to one speaker, and this signal then is fed into a second speaker from the first speaker's negative connection terminals. This is important to recognize because adding a second speaker in series effectively doubles the resistance of the cabinet while parallel wiring cuts the original impedance by half, since both the positive and negative terminals are being fed simultaneously, rather than flowing from one into another. Both methods of wiring are common in guitar amplification cabinets, but often the speaker cabinet must be carefully chosen to match the requirements of the separate head unit in impedance (Ohms) and power handling specifications (Saefong). Inclusion of variable-impedance capabilities further tailors this amplifier head to a more versatile use in many different situations and provides more useable options when recording.

The guitar I chose for recording, while not the main focal point, is worth mentioning to understand the parameters of the experiment and the tonality of the signal recorded. I used an Ibanez RG421 model electric guitar, which I had customized with all new wiring and internal components. In the neck position, I installed a Seymour Duncan SH-2N Jazz humbucker for full and resonant body, and in the bridge position I installed a Seymour Duncan JB (Jeff Beck) model humbucker, which is a high output and treble-heavy pickup for exceptional rock and lead tones. I wired both of these to a three-way configuration switch with no special coil-splitting or phase inversion techniques, and then I fed to the two 500k potentiometers with a single Orange Drop capacitor with a value of .022 microfarads. Finally, I shielded the entire body cavity with a layer of copper tape to eliminate radio interference and then ran the ground to the tremolo claw at various points of contact throughout the interior cutout of the instrument to prevent interference.

For continuity, I chose to set the amplifier head's knobs to 12 o'clock, providing a transparent equalization curve to the signal and preventing any extra colorization of the audio before reaching the

cabinet and speaker. Both the gain and master volume controls were set to 12 o'clock as well to provide an equal relationship between preamp and power amp tube performance. Often in recording situations, I have experienced stage-power amplifiers with the master volume at an eighth of its maximum value, and the preamp or gain section cranked to almost full capacity to compensate for the throaty growl and added sustain and harmonics that the power amp section provides to the signal before hitting the speaker. The most consistent issue with this method of compensation is the lack of dynamics in the produced sound, and how compressed the signal becomes when pushing the preamp tube(s) too hard. In an article for *ToneReport.com* highlighting the characteristics of the preamp tube, Rusty Wiseman explains:

> Preamp tube distortion, although 'hotter', is usually fizzy, sometimes thin, and doesn't respond as well to varying degrees of attack since the sound is much more compressed. Power tube distortion is where the dynamics and 'natural' sounding overdrive characteristics come from. You will also notice a fatter thump even though the gain might not sound as intense.

Upon initial testing of the amplifier in a recording setting using these settings, the relationship between both gain stages provided a natural-sounding strong signal while also providing a slight breakup from the tubes and adding a bit of harmonic content and grit, which is exemplary of tube amplifier technology. "Grit" can be defined by the saturated characteristics that occur when a tube is fed a high level of power and reaches the point of breakup and begins to distort. Mr. Wiseman continues to explain the breakup characteristics of the preamp tube:

> Without getting too technical it's because they distort in a more musical fashion than transistors. When a transistor is pushed over its threshold the signal gets chopped off, it dramatically distorts in a "square wave" fashion. A tube on the other hand has more "headroom" and distorts along a smoother curve with less harsh artifacts. Even a tube amp

played clean has a little of this clipping in the signal that comes through as layers of harmonics that fatten up the tone and give that essential sound to the guitar.

This is important to recognize, since the clipping occurring is what ultimately causes the overdriven sound we associate with rock guitar riffs and is one of the most inherently recognized characteristics of tube amplifiers. For this project's purposes, saturation manifests itself as any of the harmonic distortion we experience with amplifiers and can be directly reflected in the amount of gain being introduced in the V1 preamp section by how hard the tube is being pushed.

IV. The Cabinet Build

The design choices I made when creating the custom speaker cabinet were based on extensive research and examination of multiple different cabinet models from manufacturers such as Hughes & Kettner, Mesa/Boogie, Peavey, Egnater, Marshall, Fender, and Vox amplification. Many of these companies have been producing combo amplifiers and discrete head-and-cabinet configurations for decades and have refined their designs to all create subtle nuances in tonal response when fed a signal from the amplifier head. While exact ply count and grade of wood differed within these popular 1 x 12-inch speaker configurations,[2] I was able to determine median values for frame size and dimensions. The most compact model was the Fender Champ cabinet, with a footprint of 17"x 17.5" and a depth of only 9". The lightest model was the Egnater Tweaker cabinet, weighing a mere 18 lbs. with speaker included while still having a larger footprint than the Fender Champ. The heaviest contender was the fender Hot Rod cabinet; it weighed in at 41 lbs., which surpassed my goal weight value significantly. After close comparison of all height, width, and depth values of the many different options, I chose the values of

[2] Mesa/Boogie made a point to ensure their wood was 7-ply marine grade birch plywood, which was the highest quality option I found.

18.5" height by 19.5" width by 11.5" depth to allow for proper resonance of the cabinet and also to ensure it would be portable yet stable upon completion.

The choice of wood type was an integral component when it came to the construction of my custom amplifier cab. Based off my research and examination of market-available options, the most common type of wood was Baltic Birch plywood. Another common cabinet material was white pine, which is a softer wood and less dense than birch but has better resonant qualities. White pine can contribute to the classic 'tweed' sound of certain Fender amplifier models such as the Twin Reverb, which is one of their flagship designs still being reissued to this day. Another wood that received honorable mention for cabinet builds was the use of Canary wood. While maintaining the rigidity and structure of birch, canary wood still carries resonant properties like that of white pine. However, its high cost and exotic look make this wood more of an artisan-style choice where one might choose to showcase the grain by using varnish over a traditional Tolex covering. Here, with my relatively small budget criteria, I opted for another material.

Baltic birch differs from other standard plywood options due to the internal structure compared to that of plywood manufactured elsewhere. In an article for *Hackaday.*com defining some of the characteristics of Baltic birch plywood, woodworker Gerrit Coetzee explains:

> True Baltic Birch is made in the Baltic Region with the biggest producers being Russia and Finland. Outside of the US it is sometimes called Finnish Birch or Russian Birch plywood for this reason. It is made from only top-quality birch veneers laminated together with no filler wood. It is also unique in the care taken to make sure each layer of the wood is patched so there are no voids. All Baltic Birch is made with exterior grade glue, and when properly sealed will work for outdoor applications. There are grades of Baltic birch for marine applications and exceptionally void free aircraft grade plywood at a much higher cost.

Translating that into a musical application, there are a few reasons why one might opt for the use of Baltic birch over another material mentioned, and Mesa/Boogie, for example, uses the more expensive option of marine-grade Baltic birch plywood in their closed-back Widebody series amplifier cabinets (*Boogie Compact Cabinets*). Even without the extra grade certification, Baltic birch seems to be one of the most reliable options when it comes to rigidity and articulation of sound. The inherent property of void-less ply adhesive in this wood type ensures there is no trapped air between the plies (Stephens). The use of void-less material in guitar cabinets prevents the dreaded rattling of the cabinet when playing, and this factor in conjunction with the better stability is something that is commonly seen in closed-back applications such as 2 x 12" or 4 x 10" speaker configurations (Sutton).

The combined advantage of rigidity and long-term stability, as well as the extra vibration protection against unwanted resonance outweighed the slightly higher weight that inherently came with this choice. It isn't all in the structure, however, as the makeup of plywood also creates some interesting tonal changes over solid wood core. When compared to a traditional solid wood chassis, cabinets made of Baltic birch "[t]end to deliver a more uncolored picture of the sound of the speaker itself, although they do toss their own resonance into the brew. Vintage Vox and Marshall cabs, to name just two, were made from Baltic birch ply, so this wood has long earned kudos in the tone stakes" (Hunter). This is an important factor to note due to the intended application in a recording capacity, where a more transparent representation of the audio would benefit the recording engineer for use later in a mix.

The build process was relatively straightforward, falling into three distinct sections after careful consideration and extensive blueprint revisions from my first schematic. For this portion of the project I enlisted my father's assistance with construction and assembly, which helped the process go more quickly and enhance the form, fit and finish of the components used in the build. First, the four box pieces needed to be cut to size for both the top, bottom and sides, and then we assembled the chassis which was reinforced with interior bracing to enhance structural support. In the second phase, we cut

and fashioned the baffle frame and speaker grille. We then prepared the cabinet for final mounting after covering it in Tolex vinyl and attaching necessary accessories. The final phase consisted of mounting the speaker in the baffle, fitting the grille cover to the front opening, and installing some rubber feet for stability and appearance.

For the cabinet box construction, I opted for ¾" thick 7-ply Baltic birch plywood. We used white pine for the interior bracing and rear panels adjacent to the baffle in an open-back configuration, which added resonance and tonality while being incorporated in a way that would not compromise the strength of the frame's composition. Initial cuts were made from two 2' x 4' birch plywood sheets using a hand saw to match cuts and ensure there was minimal discrepancy. Once the four sides to the amplifier cabinet had been cut, the initial assembly began using a combination of wood glue at the seams to prevent air pockets or rattling, while we used numerous wood screws to hold the components strongly in place along five different points of contact. White pine bracing was added 1¾" inside the front of the cabinet on all four sides to act as a barrier for the baffle to sit against and affix to, while still being structurally sound. We used wood clamps to attach the top and bottom pieces and let the wood glue set properly with the applied pressure. Once all four corners had been set and properly bonded, the four sides stood ready for the baffle to be affixed to and to have the rear panels attached.

Frame completion before installation of baffle.

We also used ¾" Baltic birch plywood for the baffle, since a thinner baffle would be too thin to be structurally sound while also being a bit too resonant in quality. In addition, the ¾" plywood was a good choice of material for affixing the speaker vertically given its structural rigidity.

The speaker footprint on the baffle was 12 inches in total diameter, with the outer metal lip included in the measurement; the lip and screw holes were a mere ¼" from the edge of the woofer itself

to the edge of the speaker. This meant I had to be extremely careful and conservative when making the hole cut by hand using a jigsaw (used for lack of better woodworking equipment on hand at the time). I believe this was one of the inconsequential but aesthetically displeasing errors in the build process, since the use of a jigsaw required a very steady hand and is prone to slight errors when rotating the saw even with a tracer line and extremely slow pace.[3]

After marking and using a small drill bit to carve pilot holes for the speaker screws, we set the speaker aside and continued to finish the frame. Installation of the white pine rear panels was a last-minute design choice, and I had the option to either use equal size horizontal pieces creating a uniform gap in the middle of the amp or use different sized pieces, so the bottom piece sat taller than the top piece, exposing half of the magnet and the top part of the woofer as well. Upon examining the different options, I chose to use a uniform gap right in the middle, to prevent any unexpected discrepancies or dead spots in the cabinet construction, while still allowing someone to mic up the rear section of the amplifier if so desired. Once installed and sealed with wood glue and screws, the frame was now complete and ready to be covered.

The covering portion required a level of finesse, since the corners and intersections of material needed to be precise to prevent the cabinet from looking cheap or unsightly. There are a few common methods of applying vinyl wrap, one of which is to use a single sheet of vinyl to wrap around and attach to itself. Another common method was the use of three sides affixed to a top or bottom flap that covers the original piece's ends and completes the cover in a nice seam. The inclusion of top and bottom rear panels led me to use the second approach, since the flaps needed to be big enough to wrap from their

[3] When I had finished carving out the speaker hole, I had nicked the wood creating a notched 'v' in the circle and had come a little too close to the inside on another section of the cut. Initial placement of the speaker indicated that my cut was too small, and with gentle precision I shaved down the interior with a combination of medium-grit sandpaper and small corrections with the jigsaw. Upon second placement, the speaker fit nice and snugly within the enclosure opening, and the small discrepancy in the circumference sat neatly between two screw holes covered by the lip of the speaker (out of view from any discerning eye).

respective side over the back and into the interior of the cabinet. I chose to affix the bottom Tolex panel first, creating a nice tight bond with the wood using Tolex adhesive designed for this specific application. Using a longer piece, I was able to wrap the extra length up the rear panel and fold it neatly under the lip of the pine, thereby achieving a solid corner without wrinkles or air pockets. The second piece was much larger, covering three sides and the top rear panel. This piece was cut much more in a specialized fashion since I needed to address corner seams, as well as even coverage of the main chassis, and the rear pine panel that would be folded under to complete the wrap. Applying one side at a time with a generous amount of Tolex adhesive, the wrap came out amazingly well. As the sides were covered, I began to cut the intricate folds that create the nice even corners we see on the finished product. Once the vinyl wrap was properly applied and set to the wood with adhesive and cured, the cabinet was ready for the final touches.

Corner fold after adhesive is applied. Note the angle of the seam.

Instead of affixing a mono ¼" plug from the speaker itself, I chose to give the cabinet a more classic and refined look by incorporating a small jack plate with a jack installed for a speaker cable. Rather than using standard cable wire gauges of 28-24 AWG, I opted for something much more robust – 20 AWG solid-core wire – to attach to the jack from the speaker's terminals. I drilled a small hole into the rear of the top back panel, right at the center of the amplifier's width, and screwed in a neat three-hole circular jack plate. I then used the wire to connect to heavy-duty spade connectors on one end (for the speaker terminals and easy installation) and soldered the other ends to a Neutrik ¼" mono jack so that the internal wiring sat out of the way and out of view of the user. I attached rubber feet to provide stability, and the speaker was front-mounted for access and screw placement pointing away from the grille of the amp.

I fashioned the grille frame from ¼" regular plywood. The properties of birch plywood were not necessary for this ornamental piece of construction, as it served no tonal value and acted solely as an aesthetic choice. I chose vintage Marshall-style salt and pepper colored grille material, which is coarser weave and accentuated the black Tolex covering in a sharp and appealing manner. Using a staple gun, we pulled the grille cloth taut and folded it over the frame before fixing it into place. Then we folded a small piece of leftover Tolex into a small pull-tab for the grille frame removal from the cabinet itself in the future. With the initial build now done, the next step was to plug it in and make sure it worked!

Upon initial use of the cabinet, it was astounding how much different it sounded than other cabinet models I had previously used. The high register seemed more articulate than other designs, especially the Bassbreaker cabinet I was using prior to this build's completion. The low-end seemed much tighter and less muddy, and I switched the bass response switch from its permanent "tight" setting down to "deep" to hear the full range of the amplifier. The cabinet responded nicely to the low E string and full chord strums without detracting from the mid and high register clarity. Much analysis still needed to be done on the true performance of the cab in comparison to the Fender but based off an initial aural analysis and an A/B comparison I could safely say that my custom cabinet provided much more timbral richness and clarity over the signal output of the other amplifier cabinet.

V. Testing and Analysis

For the testing and analysis of the cabinet's performance, I chose to test it against a model of cabinet that would be a comparable option on the market for relatively the same price range, with a maximum cap on price of $300 MSRP. While there are multiple options within this price range, I chose to use a Fender Bassbreaker 1 x 12" cabinet (model BB-112) to compare to my project because of its material, speaker configuration, Ohm resistance, and a power handling of 70 watts RMS. The cabinet includes an 8 Ohm Celestion G12V-70 speaker, which is important since the

speaker I chose is also rated at 8 Ohms and has a similar power handling level. The Fender cabinet is semi-open back, meaning there are two ports located at the rear of the amplifier for sound diffusion, while still allowing the cabinet to resonate with the speaker output and provide a low-end punch that is synonymous with closed-back amplifier styles. It also is constructed of birch plywood, although the ply count and thickness are left out of the information available on the amp schematics (Fender). At a total weight of 21 lbs., the Fender Bassbreaker cabinet provides a strong control subject to for comparison purposes, since the major factors of construction have a level of continuity that other amplifiers in the price range did not.

Testing the amplifier cabinet consisted of a thorough analysis of the frequency response when recorded through two common guitar cab microphones and the Slate VMS system. The Slate Virtual Microphone System provides an extremely flat frequency response and allows the user to apply different microphone frequency responses within the DAW and estimate how different microphones would present the signal through their individual colorations and nuances. The first of the other two microphones used was a Shure SM57, which is the most universally accepted microphone for electric guitar recording in the world. It is also one of the most common instrument microphones readily available in studios and an inexpensive option for the novice producer. The second is the AKG C-414 large-diaphragm condenser microphone, which is another microphone capable of handling high SPL levels that has been used extensively in recording electric guitar. All microphones were placed an inch away from the speaker, two inches off axis from the center of the speaker for a good balance of body and crispness.

To ensure the nuances of the performance would be identical between takes and cabinets, I used a pre-recorded track that was fed into the amplifier head through the use of a reamping box, which converts the low-impedance XLR signal into a high-impedance instrument cable level that the amplifier can work with in its intended method. The track consisted of different chords, strums, rhythmic

patterns, lead riffs, and harmonics. Less of a musical piece, the track is designed to see how the cabinet reacts to a range of common guitar techniques. Using an FFT analyzer or spectral analysis software with a timecode and waveform view, I can isolate certain moments of the performance and compare them either in real-time or with screenshots of the result. I was able to feed signal into the amplifier head before recording any signal to test the output level, and my predetermined knob values were perfect settings for a healthy signal and plenty of tube saturation.

The process to conduct the analysis itself was straightforward. I received some invaluable assistance from close acquaintance and Department Technician, Drew Lassen, in setting up and executing the recording component. All microphones used were fed into the Slate Digital VMS One microphone preamp to ensure continuity. This was because the VMS microphone I used relied heavily on the use of this preamp for the most accurate results, and the preamp worked well with the other two microphone choices as well. For both the AKG C-414 and the Slate VMS, the -10dB pad had to be engaged to attenuate the signal to a level comparable to the Shure SM-57. Outside of this one change, no other parameters were changed throughout the duration of the testing process. While each microphone was set up, the pre-recorded track was sent out of Pro Tools and through the reamp box into the Egnater head, which then was picked up by the microphone after coming out of the cabinet being tested. After conducting the separate tests with all three microphones on both cabs, I had a session full of perfectly synched and clear-sounding audio I could solo or mute for real-time aural comparison in an effective manner. Upon first listen in comparison to the DI track recorded straight into a microphone preamp, it is amazing how much character and presence the use of both amplifiers enriched the signal with: almost as if the DI signal was in black and white, and the amplified signal was in full high-definition vivid color. The most noticeable difference when amplified was the introduction of some grittiness and very apparent tube saturation. This is important to note, because the distinct and clean signal we had started with now had elements of overdrive and a sort of edgy ‘crunch’ which could

be right at home in a swamp blues or classic rock song. Recognizing this allows the recording engineer to set the relationship between gain and volume on the amplifier head to their taste, depending on the need and tonality required for a specific track or part. Now that the recording had been completed and preliminary listening indicated proper execution of the recording process for analysis, I could look at the audio with some spectral analysis tools that would give me more in-depth information about the frequency response and overall range of both cabinets.

Analysis of the two cabinets indicates that the custom cabinet performed quite similarly to the Bassbreaker cabinet. The differences we are looking at between the two are small EQ dips and curves that reflect the resonance and prominent frequencies within a variety of playing positions. Using the Slate VMS, the most prominent of these was how the Bassbreaker cabinet had higher peaks of certain ranges, but deeper notches of frequencies surrounding these points and their respective overtones (Appendix: Fig. 3). At roughly 120 Hz, there is a deep notch in the frequency response that registers at around -60 dB, which is one of the most prominent curves in the signal's frequency response across all chord positions on the fretboard. When comparing to the frequency response of the custom-built cabinet (Appendix: Fig. 4), the signal seemed to be more uniform across the spectrum and had less prominent dips in areas than the Bassbreaker did. For example, at 120 Hz, the custom cabinet's dip at the frequency registered at around 10 dB higher than its opponent, which means that we are getting a fuller and flatter response from the custom cabinet, and therefore a more transparent representation of the signal for recording purposes. Another thing to mention was the difference in high-frequency content between the two cabinets; more specifically, the larger peak at 2 kHz exemplified in the built cabinet over the Fender. The area that surprised me, however, was the loss of frequencies above 5-6kHz in the custom cabinet that were retained in the Fender - even though my impression while listening indicated the custom cabinet to be brighter and more articulate with this frequency range than with the Bassbreaker. I thought it would be the reverse result given the listening portion of the analysis. Since the

construction of the cabinet I made is denser and much sturdier in construction, it may have a slight dampening effect in comparison to a lighter and thinner-designed chassis. The incorporation of Izotope's Insight software allowed me to take an even more elaborate view of the signal changes, and I chose to focus on the SM-57 recordings since these seemed to reflect the changes more prominently than the two condenser microphones. For this section of analysis, I chose a section of audio where an open G-chord is strummed in succession and allowed to ring out, which has a clear start and end to the section and exemplifies the fundamental frequencies of each string better than another section. The waveform and spectral analysis of this section indicated that there were more high-frequency overtones in the Fender cab than in the custom, but that the midrange of the custom cab seemed to be much more gradual in response to the dips we see in the other (Appendix: Fig. 1 and 2).

VI. Conclusion

The inclusion of this spectral and frequency analysis ensures that the information deduced from this experiment is correct and documented in a fashion that allows someone to make an informed decision in materials and design choices in a custom amplifier cabinet. Recognizing the differences in tonality and resonance between the two cabinets is just as important as the build itself, if not more so. A quality product is the direct result of proper research, development, design, and execution - all of which were incorporated in my build. The choices I made regarding materials and dimensions were based on the vision and implementation I had for the amplifier cabinet, and I believe that for the application it is designed for it completely surpassed my expectations. In comparison to the Fender cabinet I tested it against, I feel that it is a strong alternative for a different sound and musical style, while still retaining the constraints of a portable 1x12" speaker cab. I believe that spectral analysis showed that there is some loss of high-end frequency content that might be important for presence and crispness against other high-register instruments, but the guitar is a midrange instrument and I feel that the main frequency content we come to expect from an amplifier is accurately represented and in a less biased

way than the Fender in terms of certain EQ notches and loss of certain frequencies within the range of the instrument.

The process of this build and then analyzing the result has taught me an invaluable amount about the specifics, nuances, designs, and incorporation of guitar amplifier cabinets in todays modern recording environment. Recognizing the components that make a quality amplifier and being able to put these concepts into practice helped me understand the differences in material and tonality when choosing or building an amplifier cabinet. I am pleased with how the custom build turned out, and if I were to build another one, I believe I would keep the chassis and construction the same, and maybe tweak the dimensions if needed. I accomplished the build while still confining to the build parameters I had set, and the final weight with speaker and grille mounted came to 29 lbs., which was shy just a pound from my goal weight. Total cost came to around $175 after recognizing that we had a little too much wood initially and that wouldn't be reflected in the cost of what it took to make the cabinet itself. The cab is thicker than the Bassbreaker and also much sturdier in construction, which should translate to many years of repeated use expected from a recording environment. I firmly believe I completed my goal of building a studio-grade amplifier cabinet that performs better in its intended environment than something you can buy on the market for roughly the same budget. While there are discrete differences to both cabinets and therefore is hard to say one is arbitrarily better than the other, I feel that the cab I built performs well under the conditions I had designed it for, and when listening to the recorded content through the speaker cab I felt that I had designed an instrument amplifier that accurately and properly represents the audio signal being played through it while keeping power requirements and size to something useable outside of a stage setting.

Appendix: Spectral Analysis Images

Fig. 1: Spectral analysis of Fender BB-112 Cabinet

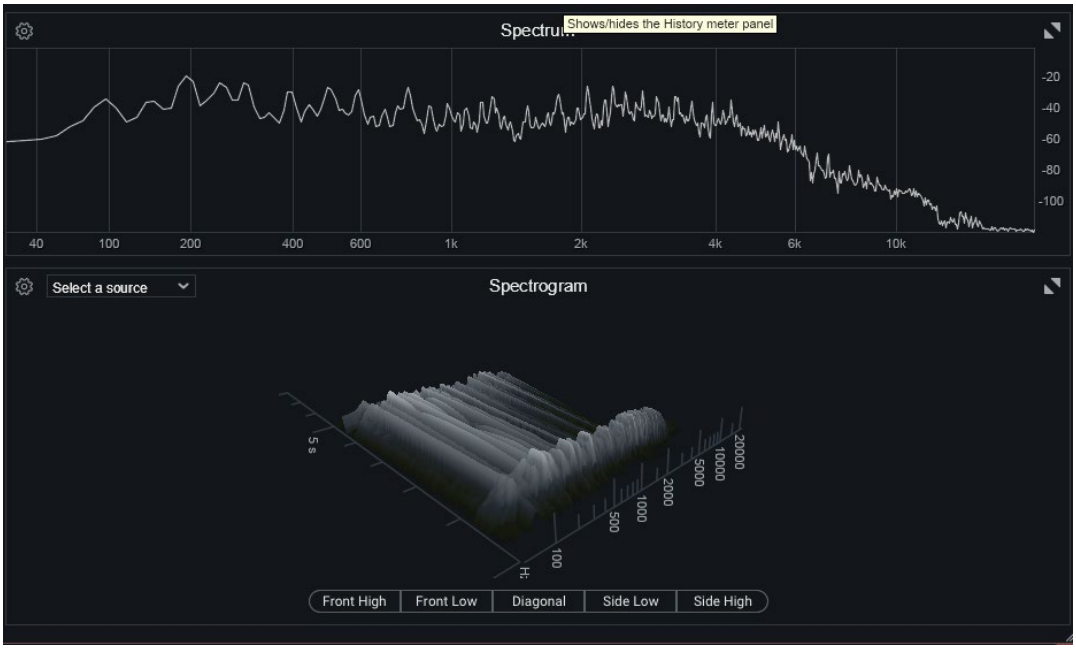


Fig. 2: Spectral Analysis of Custom Cabinet

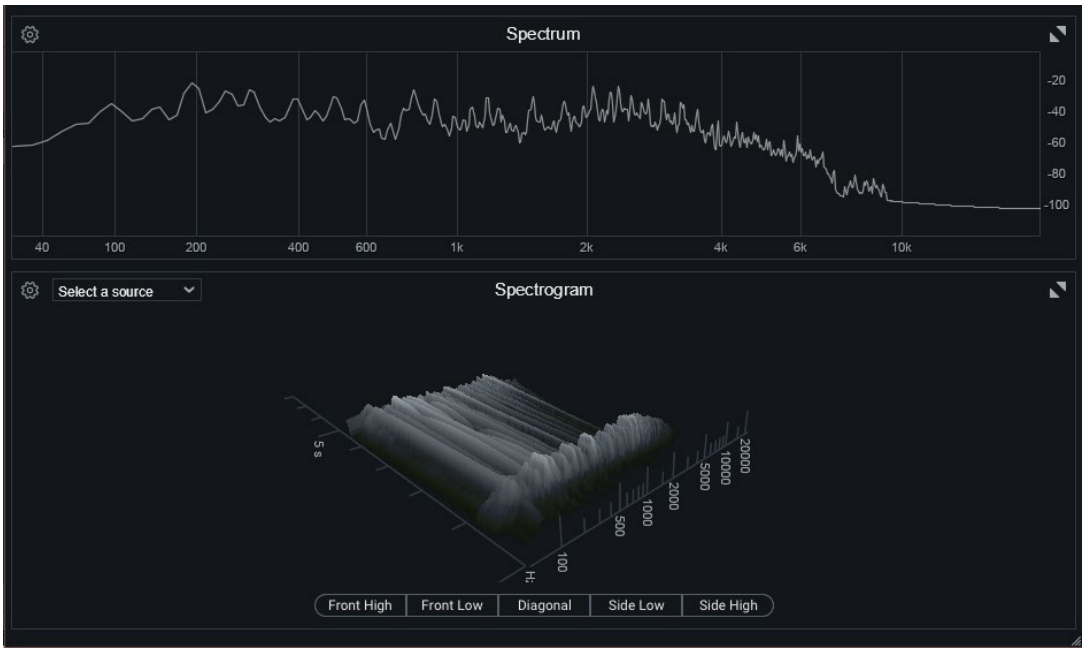


Fig. 3: FFT of BB-112

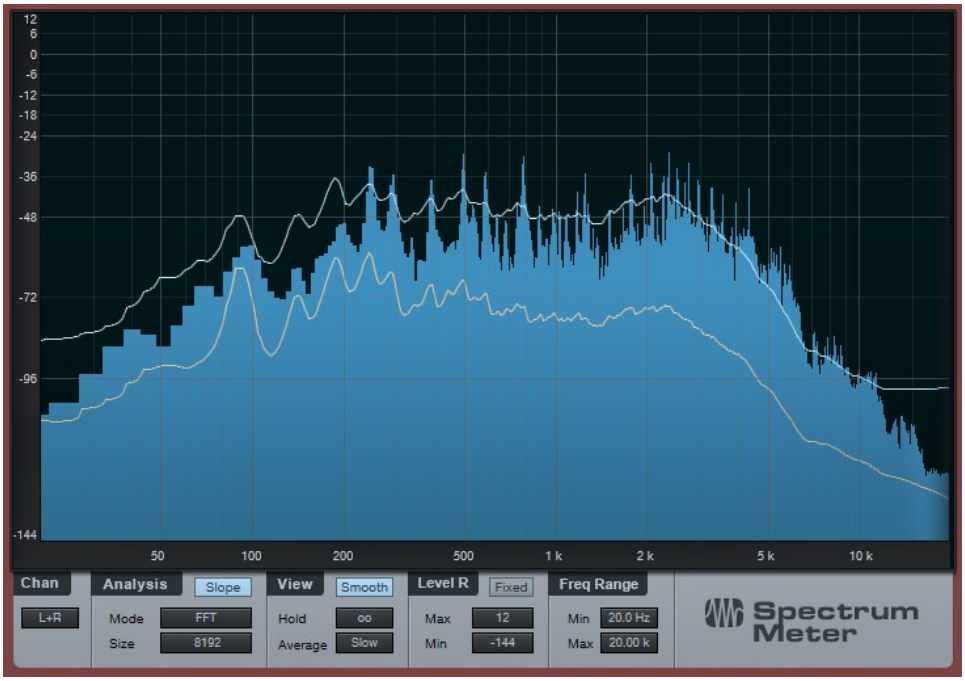
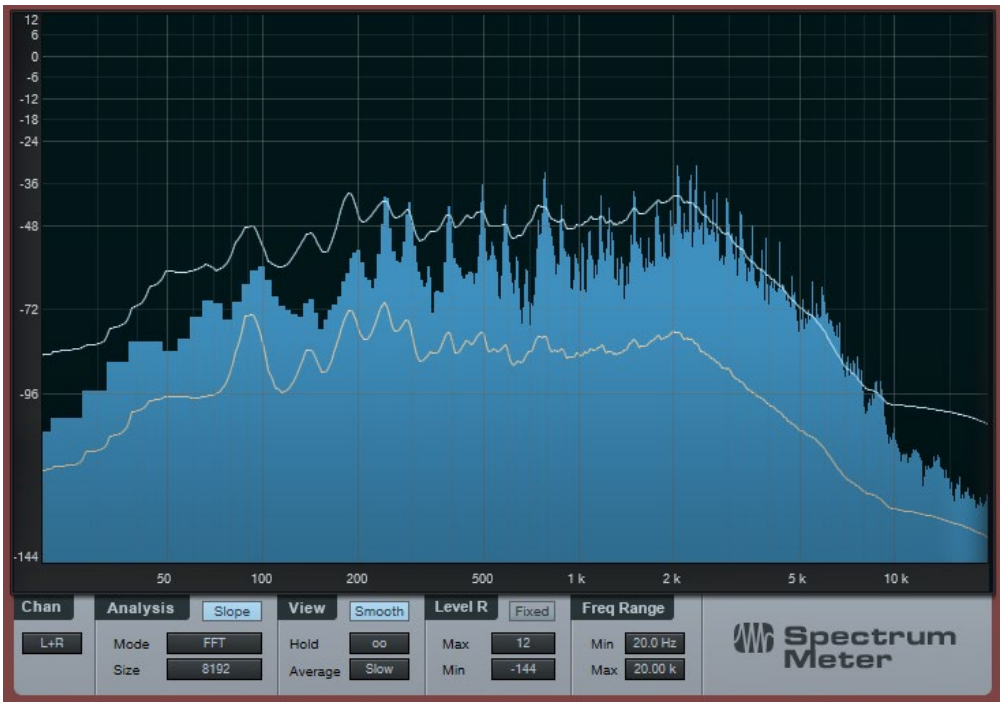


Fig. 4: FFT of Custom Cabinet



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