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The Study and Application of Studio Design for the Home Studio

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All music is heavily dependent on the space it is created in. These spaces are often referred to as studios and vary greatly in design and budget. Most studio designers agree that there is no perfect studio; instead a studio should be shaped around the needs and budget of the owner. This allows for a lot of disparity from studio to studio as designers attempt to balance the needs and the overall financial resources available to their clients.

The purpose of this paper is to examine the different areas of a recording studio, establish best practices and then to apply those fundamentals to a home-built studio. In order to do so, we must first begin with the principles that guide studio design. At the core of studio design is a lot of science, and most of it centers around sound propagation. Sound is measured in hertz (Hz) , and the audible spectrum ranges from approximately 20-20,000 Hz ("Measuring Sound"). Unimpeded, sound propagates spherically out from a source ("Measuring Sound"). As sound encounters walls or other objects, sound will reflect or be absorbed - to different degrees depending on the object's composition. Sound can also refract as it transitions through two different mediums or travels through a fundamental change of the same medium, for example a stark temperature gradient due to an air conditioner or heater (How Sound Propagates). It is important to note that how sound will reflect, absorb or refract is dependent on where the source falls in the frequency spectrum and the characteristics of the medium with which it is interacting (How Sound Propagates). This is because sound wave characteristics change throughout the spectrum, and these characteristics have a huge impact on how those waves interact with their environment.

Sound waves are described by their wavelength, frequency, amplitude, time period, and velocity (Goyal). For the purpose of this paper, we will focus on the first three. Wavelength refers to the distance measured from one peak of the wave to the next. Frequency is how many complete wavelengths occur in one second (Goyal). So it stands to reason that lower frequencies have longer wavelengths and complete less cycles per second than higher frequencies (see fig. 1). Amplitude is directly correlated to the volume of an audible source.

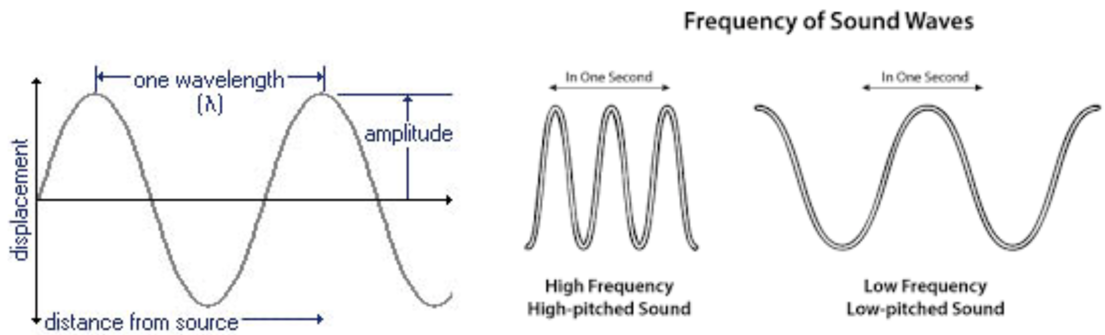

Fig. 1 (Goyal)

An audible wave with a larger amplitude is being transmitted with more power and will usually be perceived to be louder by a listener (Goyal). Wavelength, frequency and amplitude all change how sound will interact with its environment. Studio designers exercise these fundamental truths to keep sound in, to keep sound out and to create ideal listening environments that do not let waves reflect problematically.

So what defines a space that is adequate for music creation? Most designers say a studio space should be designed bearing in mind four separate purposes: recording, mixing, controlling, and to aid in creativity. A recording space is where the performance would occur. That performance would be monitored and tracked from a control room or a controlling space. Once the recording is complete, an engineer will add post-effects, volume automation and other production techniques. This process is referred to as mixing. All of these spaces should have an ambience that speaks to the operator's creativity, whether it be lighting or decor. Unfortunately, these purposes have different requirements. Creating the perfect space for recording may not be the best space to make mixing decisions and vice versa. Similarly, building the ideal control room may be different than designing an atmosphere that bolsters creativity and comfort. But there are practices that can be applied to all of these spaces, especially when it comes to keeping environmental sounds out.

When a studio is being built, one of the first factors to consider is the external environment. Few studios in the world are strictly for private use. Most depend on clients for revenue and therefore need to be accessible. For this reason, a lot of the bigger studios in the world are located in large cities. Abbey Road Studios is credited with recording the majority of the tracks released by The Beatles and is located on a busy street in London (Home Page). Sunset Sound Recorders boasts over 200 Gold Records and is located in the heart of Hollywood, California (*Sunset Sound*). These world renowned studios could not have achieved what they did if city noise was bleeding into all of their recordings.

A large portion of noise mitigation has to do with the structure of a building, giving a studio being built from the ground up a large advantage over a space being adapted for studio purposes. For example, and perhaps surprisingly, the floors of a structure can become a channel for unwanted sound. Sound travels through all mediums. Perhaps we are most accustomed to experiencing sound as it travels through air, but it can also travel through solids such as wood joists in a floor or even concrete (Walker). To reduce the effects of sound traveling through floors and walls, designers will employ a tactic known as *decoupling*. Decoupling refers to breaking up a mechanical connection between two mediums in order to reduce sound transmission and is an integral part of keeping unwanted sound out ("Concept of Decoupling"). Decoupling is best achieved by placing sound absorbent materials between two mediums of different density. As the sound waves travel across the differing densities, they lose energy and, in effect, are unable to travel as far ("Concept of Decoupling").

The tactics used in walls and floors are similar in principle but vary in execution. In order to stop sound transmission in a floor, designers decouple the floor by building what is known as a floating floor. A floating floor is a superficial structure that exists over the original floor or poured slab ("How to Build a 'Floating' Floor"). There are several methods to do this and plenty of products on the market available. The idea is to frame out a new floor, typically with wood, on sound absorbent feet. The feet have a different density than the framing and the floor they are resting on. This is the first step to absorb some of the sound that could be transmitted to the upper structure. Once the new floor is framed on top of the feet, sound absorbent material will be placed in between the frames, typically a mineral fiber or rigid fiberglass insulation is used. This insulation helps to absorb more sound. It is important, however, that the mineral fiber not be touching the original floor. This space is known as an air gap and is a critical part of slowing the energy of sound. This is because air itself has volume and density. The drastic change of density in an air gap greatly reduces the energy of sound. Next, the first layer of subflooring is placed on the framed floating floor. This will mostly likely be a form of plywood in large sheets, but can also be steel or even concrete. Regardless of material being used, it is important to maintain an air gap on this side of the mineral fiber as well. If using plywood, this step should be done using as few sheets as possible to minimize the total number of joints. Every joint is an opportunity for sound transmission. Once the first subfloor is installed, all seams will be filled with a dampening material similar in appearance to builder-grade caulk to close any air gaps between the sheets, and then the next layer of subfloor will be installed. This layer will typically be constructed of a very dense material, and the sheets will be laid to ensure no seams from the previous layer are aligned with the new layer. Finally, the third and last layer will be laid on top, following the same guidelines and methods for the other layers. If done correctly, a floating floor traps sound by robbing waves of energy as they pass through each new material and air gap of a varying density ("How to Build a 'Floating' Floor").

While constructing the walls of a studio is different, it follows the same principles. Walls must be decoupled to stop sound transmission as well. This is typically achieved by one or two framing techniques: staggered stud wall construction or double stud wall construction (Dominic). In a standard wall, 2x4s are used to provide structural support and framing. Along the floor and ceiling are 2x4s, laid flat running parallel to the direction of the wall. These 2x4s are referred to as "plates" and are the backbone for the rest of the framing (Guertin). Because the plates are constructed of 2x4s, the rest of the framing exists in the same plane due to the limit of the plate's width. This means it is impossible to truly decouple this wall. No matter what you do, the sound on one side of the wall will have a mechanical connection to the adjacent wall. To get around this, staggered wall construction utilizes a 6" top and bottom plate (see fig. 2) (Dominic). The vertical studs are then placed alternating between the interior and exterior sides of the plates (Dominic). This extra space reduces the mechanical connection between adjacent walls and introduces a significant air gap (Dominic).

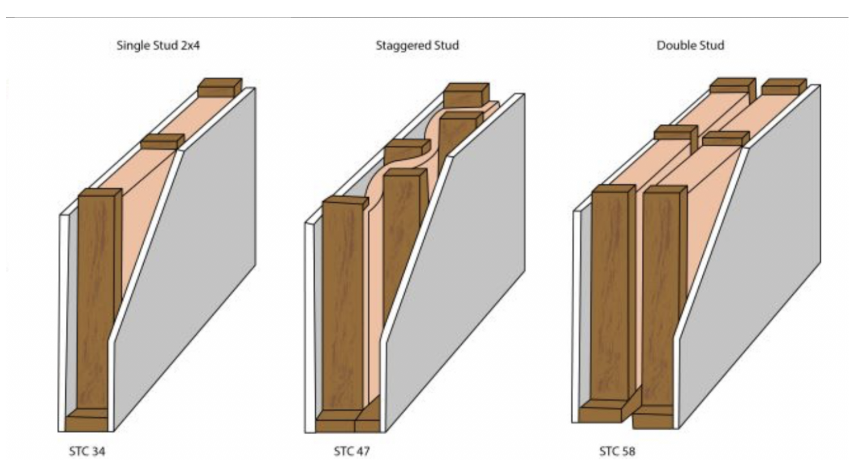

Fig. 2 (Rachel)

As with decoupling floors, the air gap is an essential part of stopping sound. It is essentially two standard framed walls, put together with an air gap in between. With a single layer of gypsum board on each side of the wall, the double stud wall is superior for sound mitigation, but requires more space (Dominic).

Regardless of which framing technique is used, the space in between the walls needs to be treated as well. Ideally, two different forms of insulation will be used. On the inside of the exterior wall, a spray foam insulation closes all gaps between seams and makes a tight seal in between the frames. Then, mineral wool or fiberglass insulation is installed on the interior wall's framing - an air gap should remain between the two layers of insulation. As we discussed with the floors, the varying densities and the different absorbent qualities of each insulation teamed with an air gap are integral for sound absorption. With the insulation installed, isolation clips are screwed to the framing of the interior wall. Isolation clips have a similar purpose to that of the absorbent feet used on the floating floor. On one side of the isolation clip is the framing and connected to the otherside is a hat channel. The gypsum board will be screwed to the hat channel and not the framing - decoupling the interior wall from the framing. Typically two layers of gypsum board are attached with a dampening compound in between the two layers (Risinger), By decoupling the floors and walls, designers ensure that sound cannot get in.

While decoupling and sound treatment aim to mitigate unwanted sound in a recording, they only treat mechanical sound transmission. Electronic sound can also find its way into recordings through guitar amps, microphones or any other piece of electrical equipment. Electrical sounds typically produce a humming or a buzzing sound, and their sources can be tricky to track down. Any loose wire, overloaded wire or improperly grounded wire can cause electrical interference (Welti). But even in a world with no wiring issues, electrical noise can still show its ugly face. Most hums are artifacts from a power source and are caused by ground loops. A ground loop occurs when multiple pieces of electrical equipment are grounded separately, but connected to each other via a grounded communication cable - such as an instrument cable. When given ample power and ample space, the area inside the pathway of these power and instrument cables becomes a source of electrical interference and can manifest as unwanted noise on a recording (Welti). The trick to minimize, if not eliminate, ground loops is to run power and audio cables in separate conduits along the same path. When building a studio from the ground up, these conduits could be poured into the slab or under a floating floor (Brandt). With ground loops minimized, any remaining electrical noise can likely be solved with a power conditioner. A power conditioner operates to protect electrical equipment from surges, but also establishes a uniform electrical power signal to all studio equipment (Welti).

As mentioned, each space in a studio has different requirements concerning design, gear and sonic properties. By modern standards, isolation booths are an essential part of any studio. Though they can be used in many ways, they are most often used to record vocalists. When trying to record a vocalist in the same room as a band, or even just a guitar, the other instruments can inadvertently show up on the recording of the vocals. This is known as *bleed* (Sweetwater). While there are circumstances in which an artist or engineer may want that bleed, most recording today aims to minimize it. To reduce bleeding, a vocalist will be placed in an iso booth and listen to the band's performance through headphones. This enables the vocalist to still hear the band, perform their part and capture a recording that is free of bleed. Isolation booths don't have to be a huge space. They should be designed around the needs of the studio. A booth that is meant for a single person doesn't need to be as big as one designed to house a barbershop quartet.

As with many topics concerning studio design, the parameters regarding isolation booths are pretty subjective. There is much debate over shape, acoustic properties and the right size. While there are always exceptions, iso booths should typically be a *dead space* - meaning sound reflections inside the space are minimized and absorption is maximized (Bubel). Tracking vocals in a dead space helps to facilitate the clarity of the performance (Miller). Low ceilings, parallel walls and square foot prints should all be avoided when possible to avoid problematic reflections. Ample sound absorption via decoupling walls and floors should be practiced to help acoustically seal the space. Special care should be taken to avoid problematic reflections in corners. Often studio designers will utilize *bass traps* to help mitigate this sonic congestion (Miller). Bass traps are specialized absorbers designed with specifications that target lower end frequencies that are not absorbed by other sound absorbing techniques. They are typically placed in corners and are an essential part of an iso booth to promote clarity and help define low to low-mid frequencies of a performance (McIver).

Many isolation booths will have a window that allows the vocal artist and other band members to see one another. Windows can be problematic because of the reflective qualities of the materials used and their ability to let sound through. Any window used in an iso booth would ideally be of special design. Windows for this type of purpose typically are three-pane with no two panes parallel. The three panes maximize transmission loss each as the sound loses energy through each pane and air gap (see fig. 3) (Gilby). The glass panes not being parallel with one another increases energy loss and helps to avoid problematic reflections.

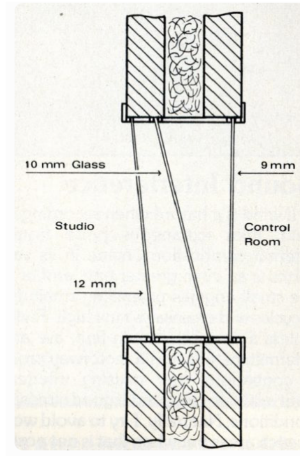

Fig. 3 (Gilby)

Control rooms and listening rooms can often be one in the same. A control room is typically where the engineer would sit while recording an artist or band. Oftentimes, studios will mix in a control room. Control rooms will contain equipment that allows the engineer to capture, mix and listen to a band's performance. Typically this will be a recording console, a computer, a set of monitors and many other pieces of hardware that facilitate the processes (Fazenda). Listening rooms, on the other hand, are spaces that are specifically setup for the sole purpose of listening. These spaces are often used during the mastering phase and contain very little furniture or equipment. The design of both spaces should avoid parallel walls, low ceilings and rooms with small cubic footage ("The Mastering Room").

While the design of iso booths aimed to deaden the space and to absorb as much sound as possible, control rooms and listening rooms are usually designed for a more lively listening experience. The goal for these spaces is to create an "ideal" natural listening environment (Acoustic Geometry). Designers want to eliminate the build up of problematic frequencies, but still allow for some reflections to create an optimized, real world experience. Control rooms and listening rooms still use absorption elements like bass traps and acoustic panels, but they will be teamed with diffusers.

Diffusers work to equalize a room's frequency response and to tame/standardize decay rates throughout the spectrum. To do this, diffusers do not aim to absorb sound, instead they force it to reflect in varying directions. This still reduces the energy of the sound wave, but allows a listener to experience some reflections (Foley et al.). The most popular type of diffusion is quadratic diffusion (Foley et al.).

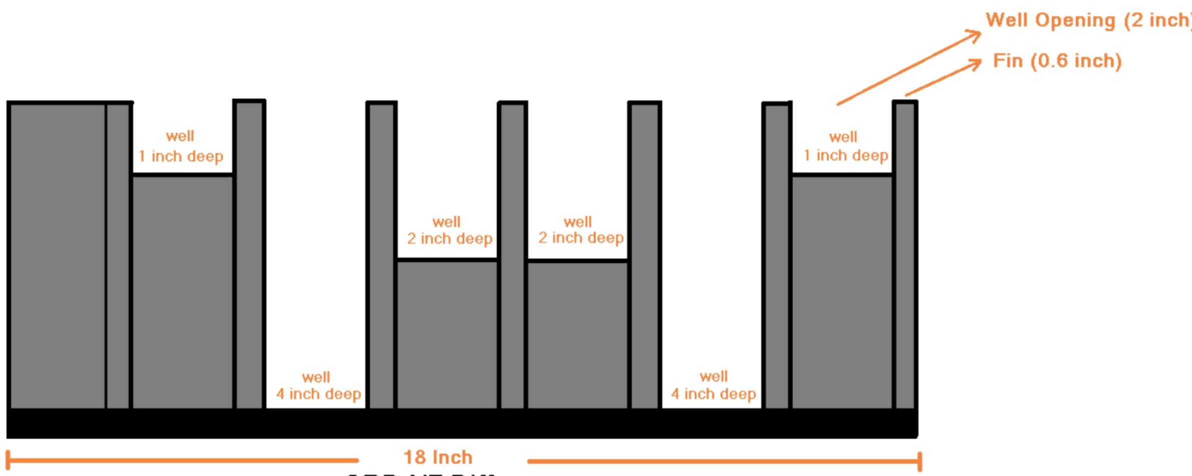

Fig. 4 (Foley)

A quadratic diffuser consists of wells of different widths and depths (see fig. 4). These specifications are designed to capture specific frequency ranges. Predetermined frequencies will then get caught in different wells and will be projected back into space. The end result is a balanced listening experience throughout the spectrum with no echo. Oftentimes rooms employing great diffusion tactics will sound larger than a room of the same size with no diffusion (Foley et al.).

While much of studio design can be built on the scientific properties of sound, it still remains a highly subjective enterprise. Science can lead a designer through best practices to minimize unwanted noise, how to create a balanced listening environment and even how to best set up electrical equipment, but science alone can't speak to the needs or limits of a specific studio. For that, studio designers must listen to the needs of their clients, employ good scientific based practices and make necessary compromises in hopes to create the best case scenario for each studio.

Studio Design in Practice

The space that I am converting into a home studio is a small, semi-basement room of a two-story home. It measures 9'x13' with a closet that is 2'x5'. Both the closet and the mainspace have a 94" ceiling. The room has one door, one window and a ceiling fan. Three of the walls are standard framing covered with ¼" pressed board veneer, while the wall with the window is concrete modular unit construction or CMU.

Put simply, this is not enough space to create an ideal multi-purpose studio. Design will prioritize the intended use of the space and make necessary compromises around the size restraints. The space must be able to keep unwanted noise out. The space must be able to create professional grade acoustic and vocal tracks. The space must create an adequate work environment for controlling and mixing studio sessions. The space must have ample, comfortable and adaptable space to allow for future projects that may involve collaborating with multiple musicians. The space must have a keen aesthetic that represents the owner's taste, making it an ideal location for social media videos and a space with an ambience that bolsters comfort and creativity.

Perhaps the most problematic characteristic of the studio-to-be is the overall dimensions. With a footprint of less than 130 sq. ft., the space is inadequately sized to have professional grade spaces for simultaneously recording and listening. When referencing information provided by Acoustic Fields, a company that specializes in treating spaces to create optimal listening environments, at least 2310 cu.ft. is required to get a space into a treatable range (see fig. 5). The space we are hoping to convert is only 936 cu.ft. - placing it well below the volume recommended (Foley et al.).

W	H	L	cu.ft.	m^3	
9' | 2.74m	11' | 3.35m	10' | 3.04m	990	27.09	[RED] Find a larger room. Extensive low frequency treatment required
10' | 3.04m	11' | 3.35m	11' | 3.35m	1210	34.12	
11' | 3.35m	11' | 3.35m	12' | 3.65m	1452	40.96	
12' | 3.65m	11' | 3.35m	13' | 3.96m	1716	48.42	
13' | 3.96m	11' | 3.35m	14' | 4.26m	2002	56.51	
14' | 4.26m	11' | 3.35m	15' | 4.57m	2310	65.21	[YELLOW] Treatable/large areas of coverage. Good low, middle, and high end.
15' | 4.57m	11' | 3.35m	16' | 4.87m	2640	74.55	
16' | 4.87m	11' | 3.35m	17' | 5.18m	2992	84.51	
17' | 5.18m	11' | 3.35m	18' | 5.48m	3366	95.09	
18' | 5.48m	11' | 3.35m	19' | 5.79m	3762	106.29	
19' | 5.79m	11' | 3.35m	20' | 6.09m	4180	118.12	
20' | 6.09m	11' | 3.35m	21' | 6.40m	4620	130.56	[GREEN] Minimal EQ required. Strong low, middle, and high end.
21' | 6.40m	11' | 3.35m	22' | 6.70m	5082	143.64	
22' | 6.70m	11' | 3.35m	23' | 7.01m	5566	157.33	
23' | 7.01m	11' | 3.35m	24' | 7.31m	6072	171.66	

Fig. 5 (Foley)

An ideal listening space typically has the listener sitting in the center of the room and avoids placing monitors close to walls. When monitors are placed next to, or even close to, the walls of a room reflections are created that cloud the listening experience. Without an honest listening experience, it is not possible to produce a track that feels balanced - instead, all mixing decisions will be made around the sonic flaws of the room. Because of this, our design will mostly abandon all considerations that would be needed to convert this space into an optimal listening room. Sacrificing the listening environment will help to optimize other, more attainable features of the space. With listening aspirations disregarded, the desk can be placed up against the CMU wall, below the window. This increases floor space, which can be used for other functions of the studio. Also, it puts the window above the workspace, which is an ideal lighting situation for recording videos for social media posts. In order to offset the poor listening conditions, the studio will be stocked with a pair of Slate VSX Modeling Headphones. These headphones are designed to simulate different world class listening rooms (Steven Slate Audio). While they certainly can not compete with a professionally treated space, they are an obvious solution for this studio.

This does not imply that the room no longer needs to be treated. Our studio still needs to keep unwanted environmental noises out. Unfortunately, the space is not large enough for staggered or double stud wall construction. And with such a short ceiling, a floating floor would only further exacerbate the confined quarters. This means most of the room will not be decoupled. The veneer currently attached to the framing will be removed, and rigid 2" fiberglass insulation will be added between frames. Two layers of gypsum board will then be attached to the existing framing with a layer of green goo sandwiched in between. This level of treatment is inadequate for tracking so a dedicated area must be created.The 2'x5' closet will have the veneer removed from the framing as well. The existing framing will be removed and a staggered wall will be framed in its place. Four-inch rigid fiberglass insulation will be added between the frames with two layers of gypsum board closing off the space. The portion of the wall above the closet entrance will be removed opening the entrance to the closet floor to ceiling. A 5'x5' floating floor will be constructed in the recessed closet space and will protrude into the mainspace of the studio. The floor will be framed on Auralex U-boat Floor Floaters and filled with 2' rigid fiberglass insulation (How to Build a 'Floating' Floor). Special care will be taken to ensure the fiberglass is not resting on the slab. The frames will then be topped with two layers of standard ACX plywood sandwiching a layer of cement board with Green Glue noiseproofing adhesive between each layer. Finally, a nice sound absorbing luxury vinyl plank floor will be added for a clean aesthetic and additional absorption from unwanted transmissions through the slab. A modular wall system will close in the 5’x5’ space. The construction will resemble a standard single-framed wall with insulation between frames. An anchor system will be attached to the floating floor allowing the walls to fall into place or easily be removed, while remaining completely decoupled. The removable walls will only be 6.5’ tall, and they will have an open space 12” above the floor - allowing the space inside to remain at a comfortable temperature without a ventilation system. Once the removable walls are constructed, tests will be done to determine how the modular recording booth should be treated for optimal results. While this information cannot be determined definitively at this time, it is assumed 4” acoustic panels on the walls and ceiling, and bass traps in the corners will be necessary.

The current jealousy-style window must be removed to battle environmental sounds and constant humidity and temperature fluctuations. A jealousy window is a window that is constructed of several 4” glass strips that are able to open and close simultaneously. They offer no real protection from inclement weather and do nothing to stop sound transmission. Constant temperature and humidity changes are harmful to a lot of equipment in a studio. Musical instruments constructed of wood can swell and shrink causing irreparable damage. Electrical equipment can collect moisture in their circuits causing damage and unwanted noise. A soundproof window will be installed in its place to reduce sound transmission and to take an integral step toward a climate controlled space. With the room closed off, a climate control system can be installed to provide air conditioning and humidity control, and the ceiling fan can be removed - eliminating unwanted mechanical noises. As the studio is located on island Oahu in the Hawaiian Islands, a heating system will not be required. The controlled climate creates a safe place for studio equipment and establishes a comfortable environment to work in.

The main workstation will be a Mac desktop with a 3.7 Ghz 6-Core Intel i5 processor, 40 GB of RAM and a 27-inch Retina display, located on a 6'. desk constructed of monkeypod, a Hawaiian hardwood. Two JBL 306 monitors will sit on opposite sides of the desk on foam speaker pads. A Presonus Quantum 2626 interface will sit on a rack below the desk along with Furman PL-8C power conditioner to power and protect all electrical studio equipment. The studio will be stocked with several different microphones and guitars, allowing for many creative and recording options. To allow the ability to track without the help of an engineer, a flip down monitor with a mouse and keyboard will be installed in the recording booth. The monitor will be tethered to the main work station with the mouse and keyboard allowing the operator to start and stop takes while in the booth.

With the room designed to meet its primary functions as a studio, there still must be care taken to ensure the room has an aesthetic that catalyzes creativity. Dimmable 6" RGB LED recessed lights will be installed in the cieling. These lights will be controlled with a remote. The operator will be able to select from a myriad of colors and brightness options. This feature allows the vibe of the room to marry up with the mood of the current workflow.

The walls and ceiling will be painted matte black as per the owner's taste. The long wall, opposite of the recording booth, will be turned into an accent wall. Walnut strips will be attached at varying angles, covering the entire surface. Each strip will be backed with felt and will be separated from the adjacent strips by approximately one inch. The felt offers mild decoupling, and the spaces between the strips act as wells. When completed the wall will be beautiful, but it will also act to tame and diffuse the sound waves in the space. The remaining walls will be decorated with art of the owner's choosing. The end result will be a comfortable space with an aesthetic appeal that nurtures creativity for the owner.

Designing in any circumstances less than the ideal always seems to come with a sense of irony. The studio was designed around the intended functions of the space, but the design itself also dictates function and workflow. The space is tailored to prioritize recording and establish a comfortable space to create in. Because of this, there is not room for an adequate listening space. This compromise will affect the workflow and budget of future projects for the studio owner. Projects will need to be sent out to other businesses that are properly equipped for mixing and mastering services. However, even when considering the studio's limitations, it does meet all of the owner's parameters while placing heavy concern on best practices for the space available.

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