Audio Technology in Musical Theater

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science

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Date: 15 March, 2009

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This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review.
# Table of Contents

Abstract ................................................................................................................................. 1

Introduction ......................................................................................................................... 2

Conception .......................................................................................................................... 2

The Space ............................................................................................................................ 3

The Pit ................................................................................................................................. 3

Equipment .......................................................................................................................... 4

Preparations ........................................................................................................................ 5

Understanding the audience configuration ................................................................. 5

Understanding the set design/layout ............................................................................ 5

Planning the rig .................................................................................................................. 6

Planning special microphone/speaker layouts ............................................................ 6

Monitors ............................................................................................................................. 7

Setting up rentals ............................................................................................................. 8

Recruiting help, if necessary ........................................................................................... 9

Gathering sound effects ................................................................................................. 9

Construction ...................................................................................................................... 10

Executing the plan ........................................................................................................... 10

Modifying setup as needed ........................................................................................... 10

Execution ........................................................................................................................... 11

Tuning the system ........................................................................................................... 11

Adapting to actors ........................................................................................................... 11

Taking good notes/mastering cues ............................................................................... 12

Follow Up .......................................................................................................................... 12

Reflecting on how the show went .................................................................................. 12

Identifying short comings ............................................................................................... 12

Troubleshooting ............................................................................................................... 13

Microphone placements ................................................................................................. 13

System ............................................................................................................................... 13

Conclusion ........................................................................................................................ 14
Abstract
As technology presses forward, it is important to understand its benefits and uses in traditionally non-technical applications. This paper discusses numerous ways in which technology, specifically sound reproduction technology, can be successfully integrated into musical theater to enhance the experience for the audience, musicians, and actors. The conception, preparations, construction, execution and common problem areas of audio reproduction in musical theater are discussed thoroughly.
**Introduction**

Putting up a musical production is a very complicated task which requires people with a diverse set of skills to work together. There are actors, musicians, producers, lighting specialists, and audio specialists to name a few. Together, these people must use their own skills to plan and execute the production. Throughout the experience, many compromises must be made between each of the specialty groups in order to create the best possible experience for the audience.

This paper will be dealing with the sound reproduction aspects of a musical production. The planning, execution and troubleshooting stages of the process will all be examined. With this document, an individual with little knowledge of how a production schedule looks should be able to deliver a successful sound system for the specified show.

The planning process for this type of system begins with the conception, and how to formulate an idea of the size and specificity of the system. It then moves on and discusses how to make preparations leading up to the setup and how to arrange equipment rentals. Once equipment and manpower has been established, talk about how to plan the setup and actual execution of the show is examined. Finally, after everything is all said and done, there is discussion regarding how to document lessons learned and make recommendations for and proceeding shows.

**Conception**

There are many aspects to successfully providing sound reinforcement for a musical. Each piece plays a critical role in the show and without carefully assessing all of them; there is a chance that the sound may be less than satisfactory. When conducting the initial planning of the sound for a show, it is important to examine the physical space, the location and composition of the pit orchestra, the show, and the equipment available. The space that the show is being performed is important because it has very important physical and acoustic properties. The location and composition of the orchestra also has the chance to dictate much of the microphone and speaker placement and must not be overlooked. Since most shows do not have Broadway’s endless budget, equipment availability plays a very key role in achieving the best possible sound reinforcement on a limited budget.

Before beginning the detailed discussion of the necessary steps to design and execute successful sound reinforcement of a musical production, it is important to remember a key goal of the sound system that is being designed; a successful system is one that the audience never notices, both physically and
acoustically. Excellent sound reinforcement should amplify the actor’s, the on-stage sound effects and instrumentalists in such a way that the audience doesn't even realize it. While such a system might not be capable of achieving due to lack of equipment, funding or knowledge, this should always be the goal while designing a system.

**The Space**

It’s very important to understand the space in which the show is taking place because that will greatly dictate what sound reinforcement equipment is required. First the size and shape of the performance hall needs to be examined. The size will help determine the ideal speaker array and placement in the space.

For Alden’s Great Hall, it has been shown that using a 3-speaker array flown just down stage from the audience is an optimal configuration. The speakers previously used in this rig are two EAW NT-59 speakers and one EAW NT-56. The speakers are arrayed such that the NT-59 speakers provide reinforcement for the hall seating while the NT-56 is used for the balcony reinforcement.

The acoustic properties of the hall are also an important to thing about while specifying speakers. The NT-series by EAW was desired for flat response, meaning that speakers in this series very accurately amplify all frequencies very evenly. In larger spaces, the NT-series might not be the ideal choice since they are best for short to medium throws.

**The Pit**

The location of the pit orchestra can change many aspects of the sound reinforcement of a show. For example, if the orchestra is located in the traditional pit location directly in front of the audience, then the speaker array needs to be slightly down stage of that. Having a pit in front of the stage also means that microphone placement in that area can be very difficult as there is a high chance of those microphones amplifying undesired noise (the orchestra).

If the orchestra is located all the way upstage as it occasionally is, it is now important to think about amplifying the pit. The main speakers will now be responsible for amplifying at least some of the orchestra. This means that a main speaker system with lower response will be required. Specifically this means that there may be a need to add a subwoofer to the system, as instruments have the ability to reach frequencies outside the range of the human voice.
There is now a concern with adding enough speakers to the system to make sure that the orchestra, especially the conductor, can hear the actors, and likewise, the actors hear the orchestra. Typically, the orchestra would be able to use either speaker monitors or in-ear monitors, but the actors on stage will most likely be using monitors placed throughout the stage. This complex setup will be addressed again as more of the production staff is consulted with as there are many requirements that a setup like this must meet.

**Equipment**

Equipment availability is a very important part of a musical. While the concept for the sound reinforcement may call for 10 speakers, 2 mixers, and 40 microphones, without the funding or access to that type of equipment, no matter how good the plan is, it will have been for nothing. It is important while planning the sound for a large musical, to always be in contact with the producers to ensure that there is enough funding to rent the desired equipment or that there is a way to get it donated.

Currently, Lens and Lights has a lot of good equipment available for rental. Lens and Lights primarily does sound reinforcement for concerts so their equipment, while good, might not be the best choice sometimes for musicals. If there is no other choice for affordable equipment available Lens and Lights equipment will be great, but for some speakers especially, there are better options out there. Since Lens and Lights services the entire community, there is sometimes a shortage of equipment so it is very important to put in rentals with them as early as possible. Since some equipment will almost always be rented, such as a 40 channel mixer and XLR cable, it is a safe bet to put in requests for equipment like that the moment the musical is announced, even if it is a year ahead of time.

A good source for speakers is directly from EAW, who are based in Whitinsville, MA. There have been good relations between them and WPI in recent years as many WPI alumni are now employees there. The NT-series system discussed previously was has been borrowed from EAW in previous years. There is no faculty or staff member who work directly on musicals at WPI and have a repertoire with EAW, so it will be the responsibility of the production staff, specifically sound engineer, to establish a relationship to request use of the speakers for a show.

Besides rentals, it is important to think about the equipment that is owned by VOX and figure out how best to use it. The 24 wireless microphones are clearly a very important part of that inventory. Once roles have been announced, it is important to get a script and begin figuring out how many principle
actors there are to see how many people will be getting wireless microphones. It is usually good practice to leave a few of the microphones unused when planning. This will allow for the potential to give a cast member a wireless microphone if an unexpected part arises that needs the excellent amplification that the wireless microphones provide.

Preparations

Understanding the audience configuration
To properly amplify a show, it is important to not only understand the show and the actors, but it is also necessary to understand where the audience will be. It is important to understand where the audience will be seated while planning the setup of the sound equipment for a show so that it is possible to place the speakers in a way to give the audience clear and proper sounding amplification of the actors and orchestra.

Depending on the show and the hall, it may be required to use different speakers and position them in different locations. For a traditional show in Alden’s Great Hall, it can be assumed that there will be raked audience seating setup on the floor as well as audience occupying the balcony seating. A configuration used multiple times before involves flying 3 EAW speakers. One EAW NT-59 is position in the center of the array pointing directly at the balcony and two EAW NT-56s will be used as fills to cover the left and right banks of the raked hall seating. If the audience configuration changes, then it is necessary to identify this as soon as possible and make modifications to the speaker setup as needed. An example of a change could be if seating is pushed up very close to the stage. In this case, a three-speaker flown array will most likely not cover those audience members who are seating very close to the front of the stage and it may be necessary to setup a couple small speakers on the front of the stage to fill in the required amplification.

Understanding the set design/layout
There may also need to be modifications in the speaker layout based on the set design for the show. If a set is particularly tall or requires equipment to be placed where speakers are should be, it is necessary to begin preparations to move the speakers or inform the set designer and producers of the problem. Beginning planning for speaker placement as early as possible will help to reduce stress during tech week and the weeks leading up to it.
Planning the rig
As the preliminary concerns already discussed are addressed and understood, the design of the rig can begin. The sound rig includes the following item: speakers (including necessary truss and rigging equipment), microphones, mixers, snakes, processors, CD players and laptops. Depending on a specific show, there may be more or less equipment required for the rig. As the stage and audience spaces are looked at, it is important to remember that uniform sound reproduction is desired.

At this stage in the planning, it is time to begin also decided where to place front of house (FOH). Front of house refers to the location that the main mixer and board operator will be located during the show. Traditionally, front of house is centered in the house, one half to three quarters of the way back and is slightly elevated from the rest of the audience. This distance from stage is commonly used because it provides a good distance for the board operator to be able to see most of the acting space all at once. A speaker setup without delay clusters usually optimized their sound for halfway up the audience to give the best sound to the most audience. Sound front of house is slightly elevated from the audience so that the board operator can see the stage over the heads of audience members who may be standing during the show. Some board operators do not like to do this and remain at the height of the audience so they can hear exactly what the audience hears. The exact location of front of house and whether or not to elevate it slightly above the audience is a decision that needs to be made by the sound designer/engineer.

Whatever the final decision for the location of front of house, speaker placements and selection of other equipment, it is important that this planning begin as early as possible. If time permits, there should be a tentative rig designed 3-4 months before the show. More information will become available as the show gets closer and the rig should be able to be modified to fit within the constraints.

Planning special microphone/speaker layouts
Since it is not usually possible or practical to provide every actor who appears on stage with a personal microphone, stage microphones will probably be required. There are two main types of stage microphones typically used in a theater. They are boundary microphones and overhead microphones.

Boundary microphones are microphones placed on the ground and used primarily to pick up vocals. They have a microphones have their elements mounted on the end of a long cable with a gooseneck to help position them once hanging. They are also commonly known as choir microphones and are excellent for amplifying choirs. They can also amplify actors who might be doing a lot of moving or
dancing on stage but are projecting their voices in a relatively consistent direction. Since they are flown and not positioned on the ground, they do not pick up footsteps or other movement.

Depending on the blocking of a show, boundary and overhead microphones can be very helpful amplifying actors who do not have large solo parts. There are many instances where an actor may have a few lines that need to be amplified but it is not feasible to put a wireless microphone on them. In these situations, stage microphones can come in handy to amplify them. While a stage microphone will not sound as clear and crisp as a microphone worn by an actor, it provides adequate amplification in most situations.

Another situation that may require on-stage microphones is to amplify the orchestra. If, for example, the orchestra is located in upstage for a show, there is a need to amplify them so that the audience can hear them. In a situation such as this, research needs to be done into the instruments present in the orchestra. After the instruments have been identified, a list of microphones needs to be created which will allow for uniform amplification of the entire orchestra. Unfortunately it is impossible for this document to detail appropriate microphones for all potential orchestral instruments, so additional research would be required of amplifying of the pit orchestra is required.

**Monitors**

Traditional musical theater positions the orchestra in front of the actors and orients the conductor so that he can see both his musicians and the actors on stage. One reason for this is so that he may cue both groups of individuals for entrances and for timing. There are occasions which directors choose to change the positioning of the orchestra which sometimes can restrict or remove the conductors’ ability to see or been seen by the actors and, in turn, cue them. In situations such as these, there may be a need for monitors to be placed on stage or with the orchestra. If required, these monitors will allow the conductor and musicians and actors to hear each other to help with cuing. Sometimes a video feed is also used to added assistance with cuing and timing.

Another instance that might require monitors would be if there is going to be a loud dance or movement on stage during accompaniment pieces in the show. Actors rely on the orchestra for timing and pitch, so it is very important that they are able to hear what the orchestra is doing. If a show calls for tap dancing, it is especially important for the actor to be able to hear the orchestra to stay on beat.
When running monitors for a show, it is important to think about the many components involved in them. For one, speakers need to be specified and rented. Amplifiers will also be required if the speakers are not internally amplified. A mixer will also need to be specified to be responsible of the mixing of the necessary channels down to a mix that will help the intended recipient. While this mixer may be the same as the main house one, sometimes this is not feasibly. All necessary cables also need to be accounted for prior to setup.

**Setting up rentals**
A very important part of preparations is the equipment rental. At the time of the creation of this paper, VOX, the musical theater club at WPI, only owns 24 wireless microphones, a handful of compressors, four headphone monitoring systems and other miscellaneous accessories. As a result, the majority of the equipment required to amplify a show, must be rented or borrowed. The sound engineer or designer (whoever is in charge of planning and setting up the sound equipment) should contact the Lens and Lights Club vice president to arrange a rental. Lens and Lights is recommended as a primary rental source due to its inexpensive rental prices. Lens and Lights does not have all the equipment that may be required for the show, but getting as much equipment as possible from them will save money for the production.

The earlier the rental gets confirmed the better for a show like this. Since the musical production usually goes up around the time of Parent’s Weekend, there are usually demands across campus for use of Lens and Lights equipment. Getting in touch with the Lens and Lights vice president as early as possible will make sure the necessary equipment gets reserved for the musical so that outside rental companies do not need to be used.

A very important part of creating a rental is making sure that there is extra equipment rented for unexpected requirements. This is particularly important when renting XLR (microphone) cable and snakes. It is very hard to properly estimate cabling lengths for large shows, but there are some good tricks to estimating. Running out of cables can also be disastrous with the tight schedule WPI musical productions usually follow, so it is very important to make sure there is a proper buffer of cable when setting up.

When estimating cables it is important to make sure that a layout for the speakers, microphones and front of house have been established. Without these established, there is no accurate way to estimate
cable requirements for a show. Once a layout has been created, make measurements to figure out rough distances from sources to destinations, always rounding up 5-10 feet. An example of this technique would be estimating microphone cable required for all onstage microphones. It has been measured that there are three microphones spaced every 10 feet across the front of the stage and the backstage snake head is 20 feet away from the closest microphone. Assume that the typical microphone cable length is 25 feet. Therefore, the first two microphones need two cables each, and the third needs 3 cables. For this setup, it would also be wise to add an additional two cables for unexpected problems to the other, totally ten 25 foot cables.

**Recruiting help, if necessary**
Setting up a sound rig for a performance is usually not something that can be done by just one individual. Speakers and mixers usually require multiple people to lift, testing system operation usually needs at least two people and it’s generally nice to have help during rehearsals and shows, should something go wrong.

For shows with extensive on-stage microphones or complicated speaker setups (such as shows where multiple monitor feeds are required), it may be appropriate to recruit help with running the show. When choosing this person, their technical know-how and experience should be examined, as well as their dependability record. Since the show will probably consist of 1-2 weeks of intense rehearsal just before show opens, make sure the individual picked to assist running the show has time to dedicate to all relevant technical rehearsals so they can learn their cues.

While having some help running the show can prove invaluable, it is not required and many people have run much more complex shows without assistance. A huge benefit to having an assistant is that if something goes wrong during the show, the assistance can attend to it while the show continues without distraction.

**Gathering sound effects**
Some shows require the use of sound effects to be played during the performance. There is also sometimes a desire to have background music played before the show, during intermission and after the show, or any combination of the three. If the director requests sound effects or music for the show, it is the responsibility of the sound designer/engineer. The easiest and most common place to get sound effects is the internet. While there are many sound effect library CDs, these can be quite expensive and
given the frequency with which sound effects are requested for performances, they are not very affordable.

When looking for a specific genre of music or type of sound effect, keep in mind that the campus population is a great resource. People come to WPI from all around the world and backgrounds and might be knowledgeable about a music genre or theme required for the show. Attempt to do research around campus to find out if there is an interest group or person who has knowledge in the genre needed.

If it proves difficult or financially unfeasible to find sound effects online, there is also the possibility of recreate the desired sound and recording it on campus. The recording studio in the basement of Alden could prove to be a useful resource for creating the perfect sound effect, customized for the show.

**Construction**

**Executing the plan**
While planning out the sound rig and arranging the rental are very important to successfully preparing for a show, without planning the physical setup, a setup can see delays and major issues if it is not executed properly. The audio systems used for musicals are usually very large and complex and require components coming from many sources. Because of this, it is very important to plan out exactly how and when items will be delivered, setup and tested prior to their use. Always make sure to confirm rentals a few weeks ahead of the rental date to make sure nothing has popped up on the rental house’s schedule that might create a problem for them to deliver the expected equipment. Since there is usually a shortage of technical rehearsals, it is imperative that the audio system is operational as much as possible to allow for the most about of time to practice with the actors, the space and the equipment.

Planning how exactly to setup the system can also be an interpersonal one. If a crew has been established for the show, it is important to make sure that everyone has work to do during the setup times to optimize these times. Failure to do this may result in frustration of the crew, a lack of confidence in the rig’s planning and a potential delay in getting everything setup and running.

**Modifying setup as needed**
While there has been a lot of time spent up until this point on the planning of the rig, it is important to remember that nothing is set in stone. If there are last minute production or logistic changes made on
the show, it is important to be able to quickly and efficiently modify the sound rig to take these changes into account.

A musical production is so large and complicated that the possibility of a major change coming down the line late in the game is very likely. Instead of getting upset at the person who issued the change, remember that these types of things are inevitable and make sure to keep a positive outlook and make the necessary changes to the sound rig to make it compliant with whatever has changed. Failure to do so will only anger everyone involved and cause unnecessary stress on an already very stressed production team.

**Execution**

**Tuning the system**

Once the system is setup and tested to be functional, it is time to “tune” the system. Tuning the system has many meanings, but for this paper it refers to equalizing the speakers for the hall. An ideal output frequency response for a system in this application is to have a flat response from approximately 200 Hz to 4 kHz. This is roughly the range of the human voice. If the orchestra is also being amplified through the speakers, then this range needs to be increased on both ends.

Using the equalizers on the main speakers, a real time analyzer (RTA) and a pink noise generator, it is possible to tweak the equalizers until the system is very accurately reproducing even amplitude of all frequencies. Once this value is set, it should not be touched unless there are large changes made to the hall.

**Adapting to actors**

Even with all the planning in the world, it is impossible to plan for individual actor’s exact requirements with regards to microphone selection, placement, gain and equalization. Once microphone packs have been assigned to the actors, begin to take notes on actor's vocal volumes, vocal ranges, nervous mannerisms, etc. Certain actors may require their wireless packs be gained down, some may require modification to the location of their microphone and some may require a different microphone element (lower sensitivity for louder individuals), just to name a few potential modifications that must be made. Even though some microphone placements and solutions may not be the most comfortable for them, it
is important to remember that without amplification, they run the risk of not being heard and the audience missing the meaning of their actions while on stage.

**Taking good notes/mastering cues**
As the show progresses, the number of cues to follow will increase as well. Each musical number will more than likely include many actor entrances and exits. Because of the sheer number of actor exits and entrances and the importance of having no cues missed, keeping good notes and a cue list written in the script is very important.

It is near impossible to be able to remember all of the cues needed for a musical. The easiest way to keep track of what to do during the show is to take notes in the margins of the script. Make sure that pencil is used so that cues will be easy to change, if needed.

After each technical rehearsal, it is a good idea to meet with the director, technical director, or stage manager to go over any problems or concerns that came to light during that rehearsal. By constantly informing the rest of the production stuff of the concerns with regards to sound, the sound will be able to sound much more natural, and be better rehearsed.

**Follow Up**

**Reflecting on how the show went**
Once the show has closed, equipment has been struck, rentals returned and normal sleep patterns have resumed, it is important to sit down and think about the production. The weeks following a show are the best time to reflect and jot down notes about how to improve shows for future years. Taking notes about how the show went is both important for returning and exiting production staff. While returning staff will directly benefit from the notes taken at this time, newcomers to the production staff will greatly benefit from the notes that exiting staff can leave behind.

Since WPI musical productions employ students and not paid staff, there is a very short turnaround time for people. Without diligent documentation and notes, it is very easy for useful information and knowledge to be lost between the generations that pass through.

**Identifying short comings**
Along with the obvious mention of successful components or techniques used for sound during a show, it is also important to detail shortfalls or mistakes that were made. For example, if the wrong
equipment was chosen to amplify the orchestra, or a particular placement of a microphone caused more trouble and good, make sure it is documented so that future generations of sound designers and engineers will be able to avoid them.

**Troubleshooting**

**Microphone placements**
The acoustic properties of Alden’s Great Hall can sometimes cause some trouble when attempting to mix a live show. All of the tuning and equipment setup techniques discussed previously in this document should help with reducing the potential for feedback, but feedback is always a large concern when using stage microphones.

When placing microphones on stage, always make sure to understand the microphone’s pickup pattern and position the microphone such that its pickup pattern is not within range of the speakers. Doing this will greatly increase the chance of getting feedback when trying to use that specific microphone. There will be circumstances where this is unavoidable, but understanding the pickup patterns of all microphones being used (including those worn by actors) will help manage the feedback problems that may arise from such a large system.

While the microphones worn by the actors allow for very good isolation, it is still important to make sure they are properly setup on each actor. Since every actor is different, it is important to individually adjust the microphones for each actor. This can include placement of the microphone element on the face, gain control and also changing the sensitivity of the microphone. Some actors have louder voices than the standard head-worn microphone can handle and as such require their microphone to be replaced by one with lower sensitivity. It is important to not give a softer-spoken individual with a low sensitivity microphone or it will be very difficult to amplify that actor.

**System**
When trouble strikes with a piece or what appears to be the entire sound system, it is important to try and remain calm and attempt to keep a high-level view of the system at all times. While many times it will be easy to isolate and trouble shoot a problem, there will be times where it feels as though no matter what remedy is attempted, the problem persists. These are the types of situations where keeping a level head and thinking about the entire system will be a great resource. Continually trying
one remedy and continually getting the same negative result is a common action when frustrated or stressed. With the system layout in mind, it is possible to modify other components in the system chain to either remedy the solution or change the problem in an attempt to narrow it down. While some people believe that any problem is a bad problem, when debugging a large system, this is not always true. If it is possible to create predictable and controlled problems in a system, then the problem has been well isolated and a solution should be easy to figure out relatively quickly.

Obviously there will be many problems that will be encountered on a system as large as the sound system for a major theater production but through knowledge of the equipment and system layout, it is possible to solve any problem.

**Conclusion**
The art of designing, implemented and executing a successful sound system for a musical production is a very complicated and involved process which requires experience and determination. The process of getting from an idea to a fully functional system takes a lot of planning and compromise in order to get a system that is both of high quality and fits within the cost structure of the production. If each step of the process outlined in the document is followed, the sound designer and engineer should have a very easy time understanding and managing all components of a sound system for this application.