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Standardization, System Design, and Implementation of Audio Content Digitization for Radio Nepal

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ABSTRACT

This thesis emphasizes the critical role of digitizing and archiving audio content to preserve cultural and historical heritage, focusing on Radio Nepal. It investigates the essential aspects of standardization, system design, and implementation for audio content digitization at Radio Nepal. Utilizing a systematic methodology, both primary and secondary data are collected and analyzed. Best practices and international standards for audio digitization and digital audio broadcasting guide the standardization process, rigorously verified through comparative analysis with national and global practices to ensure its applicability. An experimental setup is developed and executed to test the system in real-world scenarios. The thesis advocates for a robust and comprehensive approach to the standardization of analog-to-digital audio conversion processes, ensuring the preservation of Radio Nepal's audio content. Additionally, it provides a blueprint for future digitization efforts in similar contexts, ensuring the continuity of cultural and historical preservation.

Table of Contents

ABBREVIATIONS

A/D	Analog to Digital
AAC	Advanced Audio Coding
AMIC	Asian Media Information and Communication Centre
ARSC	Association for Recorded Sound Collections
BBC	British Broadcasting Corporation
BS	Broadcasting Satellite
CBR	Constant bit rate
CCROS	Card capacitor read-only store
CD	Compact Disc
CD-ROM	Compact Disc Read-Only Memory
CD-RW	Compact Disc Rewritable
CS	Communication Satellite
DAW	Digital Audio Workstation
FM	Frequency Modulation
HDD	Hard Disk Drive
IASA	The International Association of Sound and Audiovisual Archives
IASA-TC	International Association of Sound and Audiovisual Archives - Technical Committee
IAML	International Association of Music Libraries
IBM	International Business Machines
JICA	Japan International Cooperation Agency
Kbps	Kilobits per second
kHz	Kilohertz
ksps	Kilo Samples Per Second
KW	Kilo Watt
LPCM	Linear Pulse Code modulation
MD	MiniDisc
MIDI	Musical Instrument Digital Interface

MP3	MPEG Audio Layer 3
MPEG	Moving Picture Experts Group
MW	Mediumwave
NAA	National Archives of Australia
NCAA	National Cultural Audiovisual Archives Project
NOA	Nagy-Orsolya Audio
ORT	Open Reel Tape
OTT	Over The Top
PCM	Pulse-code modulation
RH	Relative Humidity
SSD	Solid-State Drive
SW	Shortwave
TRS	Tip, Ring, and Sleeve
TS	Tip-Sleeve
TV	Television
USB	Universal Serial Bus
XLR	External Line Return

LIST OF FIGURES

Figure Number **Figure** **Page No.**

LIST OF TABLES

Table Number **Table** **Page No.**

CHAPTER 1: INTRODUCTION

1.1 Background

The digitization of audio content and archiving has gained significant importance due to the rapid advancement of digital technology. Many organizations and institutions possess valuable collections of audio materials stored in different physical formats that need effective preservation and management in a digital format on modern storage systems. Digitizing the audio content will ensure that valuable cultural, historical, and artistic works are safeguarded against degradation and made available to a wider audience, including researchers, historians, and the general public.

In 1950, Democracy Radio was founded, marking the beginning of broadcasting in Nepal. Radio programs educating the public about the Rana regime were first broadcast by Political workers. Then Prajatantra Radio was founded in Biratnagar with the same radio equipment. However, Radio Nepal became the nation's first state-owned national radio broadcaster when it was formally founded in Singh Durbar on April 2, 1951 (B.S. 2007 Chaitra 20). Initially, the transmission covered 4 hours and 30 minutes through a 250-watt shortwave (SW) transmitter. Between 1950 and 1981, the power of SW transmission was increased by using two 5 K W and three 100 KW transmitters with three different carrier frequencies. Due to the unavailability of spare parts from 2012, the SW transmitter was later shut down. From 1968 to 1990, MW transmission was increased using six 10 KW and four 100 KW MW transmitters. In 1995 Radio Nepal established an FM transmitter of 1 KW power [1]. To reach interested listeners worldwide, Radio Nepal has entered the Internet since April 1997. Radio Nepal commenced program distribution through V-SAT on 26th August 1999 via its main hub station in Singha Durbar, Kathmandu. Future developments include coverage expansion by establishing new FM fill-in stations around the nation. Currently, Radio Nepal broadcasts programs from FM and MW bands with 3 MW and 33 FM relay stations situated in different places of Nepal to cover radio signals in urban as well as remote areas [2].

In the beginning, Radio Nepal relied on live broadcasts for its programs, including music and songs. However, with technological advancements, the station introduced turntable players to play Shellac and vinyl disks. In 1961, the Nepal Government founded Ratna Recording Sansthan, which paired with Radio Nepal to release records of Nepali national music [3]. Most of the recording was done in Nepal or India on old reel-to-reel tapes, then shipped off to Calcutta or Japan for pressing onto vinyl. The primary objective of this undertaking was to safeguard Nepali folk music and enhance the transmission quality of Radio Nepal.

The majority of Ratna Recording Sansthan's audio recordings are housed in the Radio Nepal Music Library, facilitating potential broadcasts. In 1968 (2024 BS), with aid from Britain, Radio Nepal set up a recording studio, making it possible to record high-quality analog music within the country. Radio Nepal is equipped with recording options such as Open Reel Tape (ORT) machines for creating master copies of recordings, and tape cartridges for playback and broadcast.

The Broadcasting Headquarters at Singha Durbar in Kathmandu has two broadcasting houses consisting of one drama studio, two music studios, one reporting studio, three continuity studios, one news studio, and seven program production studios. One of the music studios is equipped with a 24-track recording facility. The advancement in recording technology enabled Radio Nepal to pre-record programs, interviews, music, and other content, allowing for editing and enhancement before broadcasting. Recording technology helped Radio Nepal maintain consistent quality, schedule programs at specific times, and build an archive of past broadcasts. However, due to limited resources, not all broadcasts could be recorded, and most were presented live.

Radio Nepal initiated the digitization of its studio for news operations and program production following the completion of the JICA project in 2007/2008, aimed at strengthening its MW transmission network. At the moment, the regular broadcasts run twenty-four hours a day, including four hours of provincial broadcasts in the local languages of the provinces, from 2:10 pm to 6:15 pm. Radio Nepal broadcasts news bulletins in Nepali, English, and 24 other regional languages. It airs various programs, including talk shows, children's programs, awareness initiatives, informative segments, and current affairs programs.

Radio Nepal has played a significant role in disseminating information, and education, promoting culture and traditions, and connecting people across the country. It is crucial to digitize valuable audio contents stored in different physical storage media in Radio Nepal to ensure that valuable cultural, historical, and artistic works are safeguarded against degradation and made available to a wider audience, including researchers, historians, and the general public. This research work mainly focuses on Standardization, System Design, and Implementation of Audio Content Digitization for Radio Nepal.

1.2 Problem Statement

From 1951 to 1997, State-owned Radio Nepal was the sole radio station in Nepal. It possesses a substantial collection of valuable audio recordings that are not available to others, encompassing Nepal's history, culture, politics, social life, and entertainment (Drama and Songs). However, Radio Nepal still has the majority of these recordings in analog format, and the audio files that were digitally converted do not adhere to international standards for sound preservation. Despite Radio Nepal initiating studio digitization for news operations and program production in 2008, there remains a lack of standardization in audio formats for both newly recorded and digitized old analog content. This deficiency has resulted in Radio Nepal's failing to preserve high-quality digital content in its archives, representing a significant loss for the station and the nation.

Storing audio content in outdated mediums like vinyl records, cassette tapes, open reel tapes, and CDs presents risks of degradation over time due to factors such as temperature, humidity, and physical wear, leading to a loss of audio quality or permanent damage. Additionally, the availability of players for these old storage media is a significant concern, posing a threat to accessing the content. According to F. Bressan and S. Canazza, UNESCO claims that over half of the cultural patrimony of the world is at serious risk of vanishing, despite the attention that cultural heritage preservation has attracted, especially from the European Union, which has shown great awareness in financing a number of research projects in this field [4].

E. Micheloni, N. Pretto, and S. Canazza highlight in their work, A Step Toward AI Tools for Quality Control and Musicological Analysis of Digitized Analogue Recordings: Recognition of Audio Tape Equalizations, that historical analogue audio documents are deeply connected to their physical carriers. Since these carriers have a limited lifespan, digitization is crucial. The authors address the difficulties posed by these physical carriers during digitization and emphasize the need to preserve the original listening experience in digital formats. They argue that maintaining the link between the carrier and the content is vital for preserving the document's overall authenticity [5].

This thesis aims to bridge this gap by proposing a standardized approach to digitizing and preserving analog audio content, ensuring the safeguarding of Nepal's rich cultural and historical heritage.

1.3 Objectives of the Study

1.3.1 General Objective

To develop a system model for converting analog audio into a standardized digital format to ensure preservation and accessibility.

1.3.2 Specific Objectives

1. To identify and categorize analog and digital audio formats stored in various states at Radio Nepal.
2. To establish standardized parameters and best practices for the conversion process from analog to digital audio.

3. To implement and evaluate the proposed system model through practical experiments and case studies on audio digitization.

1.4 Significance of Study

1.4.1 Preservation of Analog Audio Heritage

The study addresses the critical need to preserve a vast collection of analog audio materials at Radio Nepal, including songs, dramas, speeches, and programs. These materials serve as valuable sources documenting Nepal's history, culture, politics, social life, and entertainment.

1.4.2 Ensuring the Future with Digitization

As analog playback equipment faces obsolescence, digitization becomes essential for ensuring long-term accessibility and usability. Digital formats are flexible and can easily be converted to new formats or playback devices as technology advances, thus protecting content from future technological changes.

1.4.3 Standardization and System Design are Necessary

The study highlights the significance of standardization, system design, and implementation in the audio content digitization process to achieve effective digitization. This involves determining the appropriate tools, processes, and quality assurance procedures to guarantee precise conversion of analog content into digital formats.

1.5 Limitations of Study

The limitations of the study are as follows:

1.5.1 Resource and Equipment Constraints

The experimental setup for converting every available storage medium into a digital format was limited by the study's resource and equipment constraints. As a result, the study concentrated on testing and gradually implementing the suggested digitization system.

1.5.2 Limited Large-Scale Testing

The full verification of the system's performance might have been restricted by the inability to perform extensive testing because of access restrictions.

1.6 Organization of the Report

This report is organized into five chapters.

Chapter 2: Literature Review presents an extensive review of relevant literature, offering insights into the existing body of knowledge within the field.

Chapter 3: Methodology focuses on practical aspects, detailing field observations for data collection, and defining the research design and methods. This chapter encompasses the systematic approach to system design, implementation, and testing of the experimental setup.

Chapter 4: Results and Discussion centers on the comprehensive analysis and discussion of the collected results, providing insights into the implications and interpretations derived from the data.

Chapter 5: Conclusion and Recommendation summarizes the research findings and offers constructive suggestions based on the outcomes of the study.

CHAPTER 2: LITERATURE REVIEW

The act of recording and preserving memories has been a natural desire of human nature since the beginning of our existence. Throughout history, people have made an effort to document and preserve their experiences. Initially, a lasting visual record was created using stone art graphics. The written word developed throughout societies as a way to preserve and share knowledge and record historical events. With the advancement of technology, audio recording became a vital tool for capturing speeches, events, and cultural factors such as music and oral traditions. Additionally, audio recordings played a crucial role in safeguarding languages, dialects, and unique vocalizations. As technology advanced, video and multimedia formats gained popularity, enabling better documentation of historical events and personal stories.

The combination of audio, visual, and interactive elements has facilitated a more immersive and comprehensive record of the past, capturing not only spoken words but also facial expressions, gestures, and visual context, providing a multi-dimensional insight into history. In contemporary times, the importance of audio recording and preservation has continued to grow exponentially, serving as a valuable resource for researchers, historians, and cultural enthusiasts alike. It offers authentic and intimate glimpses into the past, preserving our collective memory. Moreover, the digitization of audio recordings has revolutionized their accessibility and longevity, simplifying storage, sharing, and preservation efforts. Audio recording holds a unique position in capturing the essence of human expression and cultural heritage. With advancements in technology and effective preservation strategies, future generations can access this invaluable audio record of our shared human history. Consequently, the global attention on audio archives has intensified as organizations seek to safeguard and provide access to their audio collections, emphasizing the critical need for standardizing analog audio to digital audio conversion processes. According to N. Pretto, A. Russo, F. Bressan, V. Burini, A. Roda, and S. Canazza, the 1960s and 1970s marked the beginning of field recordings of dialectal speech, folk music, and other orally transmitted material such as legends, proverbs, and folk medicine formulas, which are often characterized by the lack of written records. The digitization of these collections plays a significant role both culturally and historically [6].

This literature review explores the development of audio recording. It explores the evolution of physical audio recording media storage. It also covers the factors that are involved in converting audio from analog to digital format, the devices used to digitize audio, digital audio standards, and global standards for audio content digitization.

2.1 History of Audio Recording

The evolution of audio recording technology has played a significant role in shaping the music industry. In 1877, Thomas Edison introduced the phonograph, a revolutionary invention utilizing wax cylinders, marking the beginning of sound recording and playback. Subsequently, in 1890, Emile Berliner changed the industry by introducing flat disc-shaped records, providing a more practical and portable alternative to cylinders. The adoption of shellac-based discs in 1895 further enhanced recorded music's storage and transport convenience[7].

The development of magnetic tape recording in Germany in 1928 marked a major advancement in audio recording technology. This 20th-century technological innovation provided high-quality sound and made audio editing in applications simple. By the 1950s, magnetic tape was widely used by recording studios and radio stations.[6]. The formal history of audio recording in Nepal traces back to the establishment of Ratna Recording within the premises of Radio Nepal in 1961, marking a significant milestone in the country's audio recording landscape [3].

2.2 Physical Storage Media for Audio Recording

Audio recording captures sound vibrations onto a storage medium, while sound reproduction converts stored variations back into sound waves. The way we record music and audio has changed a lot over time. It started with wax cylinders, shellac, and vinyl discs, which were not very portable. The compact cassettes make audio more portable and easier to use and edit. Later on, digital technology came along and revolutionized recording. Digital recording provided better sound quality, reduced noise, and made it easy to edit audio. Musicians and producers could use digital audio workstations to create and record music more effectively. With digital recording, preserving audio content became much better. The digital format allowed for high-quality audio without taking up too much storage space. A brief explanation of various audio storage media is given below:

2.2.1 Mechanical (Phonographic Discs) Recording

The earliest Berliner discs from the 1890s were made of vulcanized rubber and were produced from etched zinc masters. However, during the acoustic era (circa 1890s–1925), a composite material consisting of shellac, which includes resin secreted by the lac beetle and other substances, became the predominant material for mass-produced or stamped analog discs [7]. They amplified the sound using a vacuum tube to power a recording head. This technique encoded sound data into grooves on a surface material, typically used in phonograph records. Common materials for phonograph records included wax, shellac, or vinyl. The size and speed of the record as well as the amount of music stored on each side all affect how long a phonograph record plays back. Phonograph records were played back using a stylus or needle. A disc-recording unit is shown in Figure 2.1

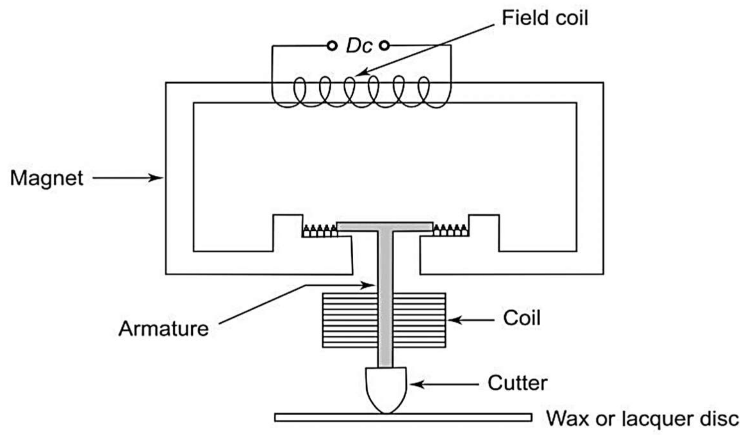

Figure 2.1: Disc-recording unit [8]

It consists of a powerful electromagnet giving a strong magnetic field between north and south poles when a DC is passed through the field coil. An armature of soft iron is placed between the two pole pieces. A coil is wound on the armature, and a cutter stylus is attached to the lower end of the armature. When an audio current (produced by a microphone and amplified by audio amplifiers) flows in the armature coil, it produces a varying magnetic field which is superimposed on the steady field of the electromagnet. This causes the armature to vibrate in the horizontal plane (i.e., lateral vibrations). These vibrations are by the variation of the audio current and are transferred to the cutting needle which is made of diamond [8].

When an audio signal passes through a coil wound on an armature and is placed in a magnetic field, the armature moves to and fro (motor action) by the audio signal. A cutting needle (called a cutter stylus) is fixed with the armature, and it also vibrates. The cutter moves from the edge to the center on a rotating disc made of wax or lacquer and hence cuts spiral grooves on the surface of the disc, which change their positions laterally by the audio signal. In the absence of sound, the grooves shall be uniformly spaced and move spirally ending at the center, as shown in Figure 2.2 (a). The audio signal makes the grooves shift laterally, and thus, the sound is recorded on the disc as shown in Figure 2.2 (b).

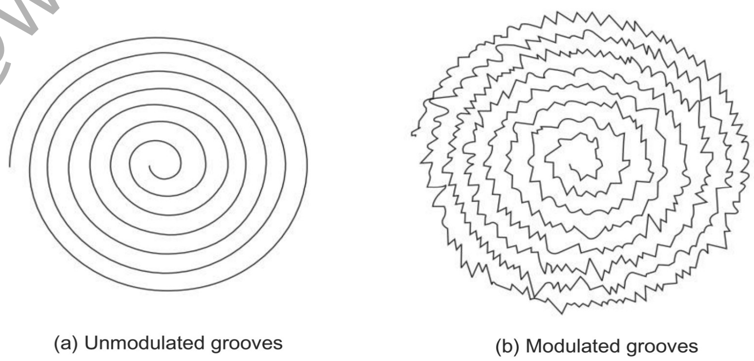

Figure 2.2: Mechanical Disc Recording [8]

2.2.2 Magnetic Recording

Magnetic recording of sound was first demonstrated as a viable technology in 1898 by Valdemar Poulsen, but it did not gain widespread use until the 1940s, following the development of electrical amplification and improvements in fidelity. During the 1930s, research and production of magnetic recording methods progressed independently in Germany and the United States. Once the conversion of sound waves into electric pulses and their encoding in the magnetic orientation of metal were practically demonstrated with wire recorders, further experimentation led to the development of magnetic tape, which allowed for capturing a wider range of sound at a higher fidelity [7]. By the 1950s, radio stations and recording studios had adopted magnetic tape, and consumers soon followed suit by purchasing reel-to-reel recorders and later, cassette tape decks. There were two main types of reel-to-reel tape recorders at the time: open reel and cassette. Open reel machines used large spools of tape that needed manual threading, primarily used in professional settings and live recordings. Conversely, cassette recorders utilized smaller tapes enclosed in plastic cases, making them compact and portable, ideal for personal use and home recordings. Despite their differences, both types were highly valued for their superior sound quality and durability[9].

Magnetic recording is based on the principle that certain materials (like iron oxide) when brought in a magnetic field, get magnetized and retain that magnetism permanently until altered. The various steps involved in magnetic recording are described below.

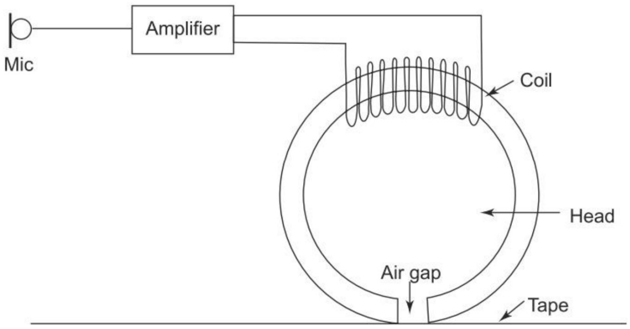

Figure 2.3: Magnetic recording [8]

Sound-pressure variations are converted into electrical variations (audio signals) by a microphone. The audio output of the microphone is amplified and fed to the coil of an electromagnet. The electromagnet (called the head) has a minute gap through which magnetic lines of force cannot pass easily due to the high reluctance of air. When a tape with a coating of a magnetic material (like iron oxide) is made to pass across the gap, the lines of force get an easy path through the iron oxide which is formed into elementary magnets. The magnetic strength of the electromagnet, and hence through the gap covered by the iron oxide of the tape depends on the audio current. Thus, the coating of iron oxide on the tape is magnetized by the audio current and hence, by the sound-pressure variations. The magnetism in the iron oxide can be retained for a long time. This means that sound has been recorded in the form of a varying magnetic field [8].

2.2.3 Hard Disk Recording

Hard Disk Drives (HDDs) are a crucial component of any computer, serving as non-volatile memory with large storage capacities, currently reaching up to 10 TB. Information is stored on these drives by magnetizing their working layer to create distinct areas with varying magnetic moment directions, representing binary data (0s and 1s). The data is recorded and read by a magnetic head. A typical HDD consists of a spindle on which one or more flat disks, known as platters, are mounted. These platters are made of non-magnetic materials, typically aluminum alloys or glass ceramics, and are coated with a thin magnetic layer (10-20 nm) and an outer protective carbon layer. In modern HDDs, the magnetic layer is composed of cobalt-based alloys. Data is recorded on concentric circles called tracks, which are numbered individually for each platter, starting from zero (the outermost track) to the last (innermost track). Each track is further divided into smaller data blocks called sectors, which are the smallest addressable units on the disk and are numbered starting from one [10].

The entire disk assembly rotates at a constant angular velocity (CAV) around its axis, driven by an electric motor. In modern HDDs, this motor is typically a small, flat unit directly connected to the spindle and controlled by a dedicated controller that stabilizes the rotation speed. Each working surface of the platters has its own read/write head. These heads are positioned by an arm that moves radially to access different tracks. In most modern HDDs, the arm pivots around an axis located outside the disk assembly, allowing the heads to move in a circular arc that aligns with the radius of the disk.

Data is recorded by altering the orientation of individual magnetic domains. Until the end of the 20th century, data was recorded longitudinally, with the domains oriented along the tracks either in the direction of or opposite to the rotation. To increase recording density, new techniques were developed, including transverse recording, where domains are oriented left or right across the track length, and perpendicular recording, where domains are oriented up or down into the depth of the magnetic layer. To optimize data access based on physical organization, the concept of an 'imaginary cylinder' is used, which groups tracks of the same diameter across all working surfaces. These cylinders correspond to the number and arrangement of tracks on each surface [10]

2.2.4 Optical Recording

Audio CDs were the first successful consumer digital audio format. Sony and Philips developed the Compact Disc Digital Audio (CD-DA) standard, also known as the Red Book standard. CDs adhering to the Red Book standard can store up to 79.8 minutes of audio. Digital audio information is represented in binary (1/0) and is encoded through microscopic indentations (pits) or the absence of them (lands) in the top polycarbonate layer of a CD. An optical stylus laser reads the variations in reflectivity between the pits and lands, and the playback system then reproduces the encoded digital audio. The Red Book standard also specifies the arrangement of data into sectors and the allocation of bytes for audio content, error detection, error correction, and additional features such as copy protection. CDs can also store data in various file types beyond the CD-DA standard, using different standards for encoding computer application information and other specialized data. Files on CDs have a 16-bit resolution, meaning each sample point has a 16-bit value, and a sampling rate of 44.1 kHz [7].

2.2.5 Solid State Recording

The invention of solid-state drives (SSDs) represented a major advancement in storage technology, owing to their compact size and efficiency. SSDs use flash storage technology, specifically NAND gates arranged in series, which provide greater storage density and cost-effectiveness compared to NOR gates. Each gate includes a control gate and a floating gate, the latter being insulated by a thin poly-oxide layer. When voltage is applied, electrons traverse the floating gate from source to drain, enabling the gate to hold a charge and store binary data. Multi-level cells (MLCs) are commonly employed in SSDs to store more bits per cell, although this can reduce individual cell reliability. However, SSD controllers with integrated error-correcting algorithms help maintain optimal performance.

Further enhancing SSD reliability and performance are advanced controller routines that manage data protection and efficiency during read/write operations. SSDs organize their storage into logical blocks, with each block consisting of pages that form 2D grids of NAND flash cells. As flash memory degrades over time with repeated writes, SSD controllers use wear-leveling mechanisms to evenly distribute write operations across cells, extending the lifespan of the drive. Additionally, the absence of moving parts in SSDs makes them more resilient to physical impacts, such as drops, compared to traditional hard disk drives (HDDs) [11].

2.3 Digitization of Audio Content

In a digital file, the analog sound wave is sampled every few microseconds, and a value is recorded at each point. These discrete points collectively represent the original continuous sound wave; the accuracy of this representation depends on the size of the recorded value and the number of samples taken. This method of digitally describing a sound wave is known as pulse code modulation (PCM) and forms the basis of most digital audio files, although newer methods are emerging in ultra-high-resolution projects. Digital audio was first introduced into professional sound recording around 1976, gradually replacing time-consuming tape editing, which had previously replaced disc mastering, and so forth. The advantage of digital recording is the ability to produce exact copies and eliminate sound artifacts that accumulate with each generation of analog copying [7]. Analog audio signals are converted into digital format using devices called analog-to-digital converters. Pulse Code Modulation (PCM) is the widely preferred method for this conversion because it ensures uniform sampling of audio amplitudes at regular intervals. Three main steps make up PCM encoding: quantization, encoding, and sampling. Each of these steps is controlled by the parameters listed below.

2.3.1 Sampling and Quantization Required for Audio Digitization

Since sounds are perceived by the human ear between 20 Hz and 20 kHz, the Nyquist Criteria recommends a minimum sampling frequency of 40 kHz, which is twice the maximum audible frequency. The sampling rate range that most modern audio interfaces operate in is 44.1 kHz to 192 kHz. This range is sufficient to capture frequencies up to approximately 22 kHz, which is in line with the standard for CDs. To reduce aliasing and guarantee a higher degree of audio reproduction fidelity, many interfaces, however, use sampling rates that are far higher than those of human hearing [12].

The human ear possesses a sensitivity range from 0 dB (representing silence) to approximately 120 dB (indicating painfully loud sound). The theoretical ability to discern volumes is just 1 dB apart, contributing to a dynamic range of about 120 dB, which is close to 20 bits. Dynamic range, denoting the difference in level between the loudest and quietest sounds perceived, can be estimated with the formula:

dynamic range ≈ number of bits x 6 dB

Consequently, the dynamic range for a 16-bit system is 96 dB, for 20-bit digital audio it is 120 dB, and for 24-bit digital audio, it extends to 144 dB [13].

In the context of digitization, Ragano discusses the quality of experience for digital audio archives, emphasizing the importance of maintaining high standards during the conversion process. Encoding to linear pulse-code modulation (PCM) with a minimum sample rate of 48 kHz is advised by IASA-TC 4. It recommends 24 bits at a 96 kHz sampling rate for various reasons, and this has become the industry standard for audio preservation reformatting. Organizations like Sound Directions use 24-bit, 96 kHz linear PCM encoding because of its broad support and sustainability [14].

2.3.2 Coding Required for Audio Digitization

The process of audio coding involves assigning a specific number of bits to each digital audio sample, with the final step being encoding in Pulse Code Modulation (PCM). However, PCM files are not commonly used due to playback compatibility issues with mainstream operating systems and their large file sizes. The bit rate of digital audio in pulse code modulation (PCM) is derived from the product of the sampling frequency, bit depth, and the number of channels [15].

File Size = sampling frequency* bit depth *no of channel* time in second

For instance, considering a scenario of two-channel stereo audio at a sampling frequency of 44.1 kHz and a bit depth of 16 bits, the bit rate for PCM at 44.1 kHz/16-bit is calculated as follows:

Bir rate= File size per second = 44,100 * 16 * 2
= 1,411,200 bits per second
= 1,411,200/1024 Kbps
=1.4 Mbps.

2.4 Current Practice of Digitizing Audio Content

The BBC describes the technical specifications for audio content in a published document. The table below lists the parameters, which include file type, digital bit depth, and sample rate.

Table 2.1: BBC Technical Specifications for Audio Digitization [16]

Specification	Details
General sound quality requirements	Content must be free from unintentional distortion, noise artifacts, and gross inter-channel phase differences. Speech must be intelligible.
Digital audio format1	Linear PCM
Mode	Stereo
File Type	.wav
Resolution (bit depth)	16 bits
Sample rate	48 ksps (kHz)
Bandwidth	Full (nominally 20Hz to 20kHz) or as required by program material and commissioning Network.

The Government of India's Ministry of Culture emphasizes the importance of digitization and compliance with metadata standards in preserving analog audio materials for future generations, in line with the goals of the National Cultural Audiovisual Archives Project (NCAA). The archival master file, which is created to the greatest standard for long-term preservation, should meet the requirements listed below:

1. Format: Broadcast Wave Format (BWF)
2. Encoding: Linear Pulse Code Modulation (LPCM)
3. Sampling Frequency: 96 KHz/48 KHz (depending upon the source material)

4. Bit Depth: 24-bit (the original digital material of 16-bit should be retained as-is)
5. Sound Field: Maintained as in the original recording

To ensure wider accessibility, access copies in the form of MP3 files with a bit rate of 128 kbps will be made available [17].

The preservation and public accessibility of Australian Government records holding witness to their history and identity is a fundamental duty of the National Archives of Australia (NAA). The National Archives uses the following guidelines, procedures, and tactics for digitizing audio:

Table 2.2: National Archives of Australia (NAA) Guidelines for Digitizing Audio [18]

Specification	**Details**	
Derivative	**Archival Master Digital surrogate**	**Derivative 1**
Format type	Analogue formats (for example Gramophone disc, ¼ inch tape, compact or micro cassette, and magnetic or optical motion picture film sound)	
Purpose	Preservation	Access
File type	BWF	mp3 (MPEG-2 Layer III)
Encoding	LPCM (Linear Pulse Code modulation)	
Sampling frequency	96 kHz	48kHz
Bit depth/rate	24 bit	192 kbit/s CBR
Audio channel	Same as original	Same as original

NOA (Nagy-Orsolya Audio) is a company that specializes in the digitization of audio content. It offers a range of services and solutions for preserving and managing audio archives, including the conversion of analog audio material into digital formats. NOA N7000c gives 24 bit analog to digital conversing with sample rates: Sample Rates: 44.1 / 48 / 88.2 / 96 / 176.4 / 192 kHz [19].

CHAPTER 3: METHODOLOGY

Audio re-recording is both costly and time-consuming. C.A. Paton emphasizes that for a re-recording project to be successful and efficient, it is crucial to base its plan on a thorough understanding of the issues to be addressed. This includes evaluating the strengths and weaknesses of available preservation options and identifying the types of personnel, equipment, and administrative support required for success [20].

The methodology employed in the thesis consists of systematic data collection from both primary (field observations) and secondary (scholarly publications) sources. Standardizing audio digitization formats under the direction of an extensive literature review was a crucial component. This standardization process was thoroughly verified against recognized national recording standards and international audio digitization practices. Employing knowledge gained from the observational phase, a strong system design was carefully developed to meet particular requirements and guarantee interoperability with the current infrastructure. To validate the success of the designed system, carefully designed experimental setups were executed. The methodology aimed to significantly improve the field of audio digitization by integrating observational data, literature review, comparative analysis, system design, and experimental validation.

3.1 Primary Data Collection

For this research, the primary data collection focuses on the audio storage devices and types of audio content available at Radio Nepal, as well as the devices required for audio digitization that are accessible at Radio Nepal. Additionally, it examines the standard digital audio formats used by digital music recording studios in Kathmandu.

To perform a thorough observation of the physical storage media used by Radio Nepal and audio content types on those diverse storage media, several in-depth field visits were undertaken in various tape library of the Radio Nepal. The purpose of this observation was to collect data on the various kinds of physical storage media, audio content types, and the registration logs associated with them in Radio Nepal, and other relevant information.

3.1.1 Observation of Physical Storage Media in Radio Nepal

Table 3.1: Observation of Physical Storage Media in Radio Nepal Audio Library

S.N.	Physical storage Media	Number	Remarks
1	Vinyl and Shellac Discs	2000	Collection, Playback, and Master Recording
2	Open Reel Tapes	16880	Master Recording
3	Tape Cartridge	15808	Slave Recording for Playback
4	Cassettes Tapes	586	Collection, Playback, and Master Recording
5	CD/MD Discs	6021	Collection and Playback
	Total	**41295**	

The observation shows that the type of Physical Storage Media stored in Radio Nepal is outdated formats and hard to find the players for these in the market.

3.1.2 Observation of Audio Content Types in Radio Nepal

The content categories that were observed in Radio Nepal Tape Library included the following:

1. Adhunik Geet
2. Baal Geet
3. Lok Geet
4. Rastrabhasha Geet (Fulbari)
5. Swodesh Gaan

6. Bhajan
7. Chalachitra Geet
8. Natak
9. Bhasan
10. Antarbarta
11. Sastriya Sangeet

The observations show that the type of content stored in Radio Nepal is mostly vocal content with less instrumental audio.

3.1.3 Observation of Resources Need for Audio Digitization

The selection of diverse audio storage players is crucial when converting audio content from different media into a standardized digital format. These devices are essential for reading audio storage media, and a balanced wire needs to be carefully connected to their audio output on the audio interface device. The Digital Audio Workstation (DAW) should then receive the interface's digital audio output through a data cable. In the end, digital audio that has been converted can be saved on digital storage media in a standard digital format.

The devices available and needed for this procedure are listed in the following section along with an explanation based on field observations made at Radio Nepal.

Table 3.2: Resources Available in Radio Nepal for Audio Digitization

S.N.	Name of Device	Descriptions
1.	XLR Cables	Balanced cables are widely used in the audio industry
2.	TS Cables	The tip-sleeve cable is used for mono, unbalanced signals.
3.	TRS Cables	The tip-ring-sleeve cable can be used for mono, balanced signals as well as stereo signals.

4.	USB data Cable	Universal Serial Bus is used for connecting digital audio
5.	Audio Interface	The device is used to convert sound from an analog form to a digital form (and back again). A/D resolution: 24-bit/192 kHz
6.	Shellac Disc Player	It generates an audio signal from the Shellac Disc
7.	Vinyl Disc player	It generates an audio signal from a Vinyl Disc
8.	ORT Player	It generates an audio signal from an Open Reel Tape
9.	Cassette Player	It generates an audio signal from a Cassette Tape
10.	DC/MD Player	It generates an audio signal from a Compact Disc
11.	Cartridge Tape Player	It generates an audio signal from the Cartridge Tape
12.	Headphones	It produces audio output to monitor audio and can hear more detail in the recording.
13.	Monitor Speaker	It produces audio output to monitor audio and can feel the sound with your body.
14.	Digital Audio Workstation (DAW)	Computer with music production software that allows the recording of audio on a computer, representing the audio graphically for monitoring its properties and saving audio in digital storage like Hard Disc Drive, Network Access Storage, etc. (Adobe Audition, Cubase, etc.)

The majority of the old audio players found during observation are extremely valuable for the preservation of historical audio content stored in old formats because they are no longer readily available on the market.

3.1.4 Observation of Audio standards used by music recording studios in Kathmandu

Table 3.3: Audio Standards Used by Music Recording Studios in Kathmandu

S.N	Name of Organization	Recording/ Master Copy Format	Distribution Format	Remarks
1	Prism Recording Studio, Babarmahal	24 bit/ 48kHz, WAV	As per demand	Recording Studio
2	A plus Recording studio, Anamnagar	24-bit/ 48kHz, WAV	As per demand	Recording Studio
3	Strings Recording Studio, Anamnagar	24-bit/ 48kHz, WAV	As per demand	Recording Studio
4	Prithak Recording Studio, Satungal	24-bit/ 48kHz, WAV	320 kbps MP3	Recording Studio
5	Sur Melody Recording Studio, Chhetrapati	24-bit/ 48kHz, WAV	320 kbps MP3	Recording Studio
6	Artomuse Recording Studio, Putalisadak	24 bit/ 48kHz, WAV	As per demand	Recording Studio

3.2 Secondary Data Collection

Extensive online research was done to collect information on the standards used by international archiving projects and broadcasting platforms to analyze the widely used digital audio standards globally. The audio Formats Suitable for Digitization and Digital Broadcasting are listed in the following section along with various digital audio parameters.

3.2.1 Audio Standards Used for Digitization by International Organizations

Table 3.4: Audio Standards Used for Digitization by International Organizations

Parameters/ Organizations	**BBC**	**NCAA**	**NAA**	**NOA**	**IASA**
Digital audio format1	Linear PCM	Linear PCM	Linear PCM	Linear PCM	Linear PCM
File Type	.wav	.wav	.wav	.wav	.wav
Resolution (bit depth)	16 bits	24-bit	24-bit	24-bit	24-bit
Sample rate	48 kHz	96/48 kHz	48 kHz	48 kHz	96/48 kHz

3.2.2 Audio Formats Suitable for Digital Broadcasting

Table 3.5: Audio Standards Used by Digital Broadcasting [21]

Type of Digital Broadcasting	**Sampling frequency**	**Audio coding**
Digital terrestrial TV broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
V-High multimedia broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
V-Low multimedia broadcasting	32 kHz or greater	MPEG-2 AAC
BS digital broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
Advanced BS digital broadcasting	48 kHz	MPEG-2 AAC

Narrow band CS digital broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
Wide band CS digital broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
Advanced narrow band CS digital broadcasting	32 kHz 44.1 kHz 48 kHz	MPEG-2 AAC
Advanced wide band CS digital broadcasting	48 kHz	MPEG-2 AAC

3.3 Digitization Standard for Radio Nepal

After reviewing the literature and considering national and international practices, it is recommended to use a 24-bit/48kHz standard for digitizing analog audio content for Radio Nepal, as it balances between file size and audio quality. This ensures sufficient range for recording (capable of capturing up to 24KHz audio frequency), producing, and processing audio (capable of supporting dynamic range up to 144dB). The suggested parameters for transforming analog audio content into a digital format are in Table 3.6.

Table 3.6: Audio Archiving and Preservation Specifications

Parameter	**Specification**
Format	Waveform Audio File Format (WAV)
Encoding	Linear Pulse Code Modulation (LPCM)
Sampling Frequency	48 kHz
Bit Depth	24-bit
Bitrate	1152 kbps (24-bit depth x48 kHz)

3.3.1 Validation of the Standardization

The proposed standardization of analog audio to digital conversion is validated by a thorough extensive literature review, digitization theory for audio, observation of audio content types stored in Radio Nepal, investigation of international digitization practices, and a global review of audio distribution and broadcasting practices available online. Furthermore, a detailed analysis of national recording practices was conducted via on-location visits to Kathmandu's music recording studios.

3.4 System Design

Preservation involves several distinct steps, among which content transfer and content description are crucial. Content transfer encompasses the preparation of the carrier, signal transfer, data processing, and archival processes. The primary goal of creating a preservation copy is to minimize information loss and prevent the introduction of distortions in the retained information [22].

Sound waves must first be captured, amplified, and filtered before being transformed into digital data using analog-to-digital converters (ADCs) to convert analog audio to digital. Analog audio players and microphones are essential tools for converting analog sound waves into electrical signals for ADC conversion. ADCs and multiple input channels are common features of audio interfaces, sometimes referred to as sound cards, which serve as a bridge between digital recording systems and analog sources. Digital audio workstations are software tools made specifically for digital audio editing and recording (DAWs). Balanced cables and connectors are also essential for achieving high-quality audio recording and playback on computers.

A customized system for digitizing audio content was developed based on well-informed theoretical knowledge, resource evaluation, and a thorough needs assessment. This system was specifically designed to handle a variety of analog audio archives on different storage media, guaranteeing compliance with established digital audio standards. A workflow diagram, as shown in the following figure, contains a comprehensive representation of the system that has been designed.

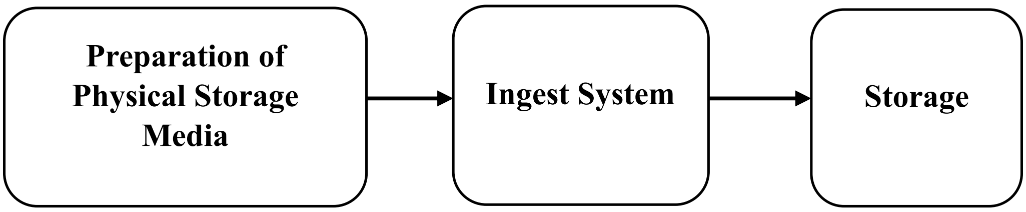

Figure 3.1: System Design

In the proposed system design, careful attention is considered to establishing connections between each section using balanced cables. These cables are engineered with three total conductors for a single channel, comprising two inner conductors responsible for carrying the positive and negative signals, alongside an outer conducting sheath, often referred to as the 'shield,' crafted from twisted wire, metal foil, or conductive plastic. Such precise construction ensures optimal signal transmission and minimizes interference, thereby enhancing the overall quality and reliability of the connections established within the experimental setup in this research.

In the field of audio technology, XLR (X Series, Latch, and Rubber) cables emerge as prominent balanced cables widely employed in the audio industry. Characterized by a three-pin configuration consisting of Ground (sheath), Positive (hot), and Negative (cold), XLR cables play a crucial role in ensuring efficient signal transmission. Similarly, TRS (Tip, Ring, and Sleeve) cables also serve as balanced cables and find extensive use across various audio applications. TRS connectors exhibit versatility, available in different jack sizes, including the commonly utilized 1/4-inch (6.35 mm) size, alongside 1/8-inch (3.5 mm) and 3/32-inch (2.5mm) variations.

3.4.1 Preparation of Physical Storage Media

Physical storage media preparation includes a thorough inspection of audio storage media, physical restoration techniques as needed, and item tagging. If issues are found before the digitization process begins, cleaning and repairing the storage media is crucial. If physical restoration is not carried out before digitization, there may be information missing from the final recorded file because the player may not be able to read damaged portions of the storage media. To avoid any damage to the storage media player or any of its parts, which may restrict the recording of any files, it is essential to remember the significance of cleaning and repairing any damaged storage media before playing.

Damage to any player would constitute a significant loss because of the age of these audio storage media and the lack of compatible players on the market. It is important to handle and preserve audio storage media carefully because it may become unplayable in certain situations. Due to its ability to provide info on issues such as database specifications, storage needs, and digitization requirements, this aspect becomes extremely important. It also makes sure that the degradation of open reel tapes, vinyl, and tapes is minimized, giving time for the contents to be ingested and digitized. If this procedure is not followed right away, recorded audio may be permanently lost.

3.4.2 Ingest System

Moving content from physical storage media to the Ingest System is part of the ingestion process. To create and evaluate an experimental setup for digitizing analog audio content, this thesis focuses a great deal of attention on this stage. The main goal is to transfer analog audio files into a standard digital audio format so they can be preserved for a long time. Furthermore, the objective is to move the valuable audio content to new media, substituting more modern digital storage options with classic formats like CDs, Open Reel Tape, Shellac Discs, Vinyl Discs, and Cassette tapes while preserving the audio's original qualities.

This systematic procedure converts analog audio material into a digital format, ensuring its long-term storage and accessibility while also guaranteeing its preservation. The design of the generalized Ingest System, which transforms analog audio storage media into digital audio, is as figure 3.2

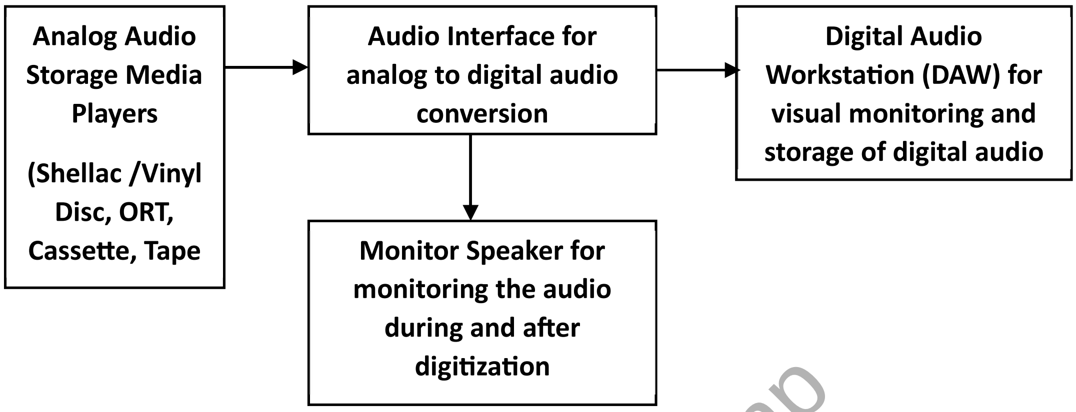

Figure 3.2: System Design for Converting Analog Audio into Digital Audio

The Ingest System designed to move digital audio from traditional digital storage media to present digital storage as in figure 3.3.

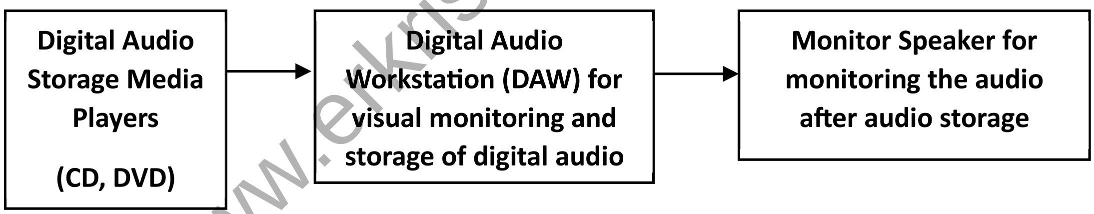

Figure 3.3: System Design for Transferring Digital Audio in Current Digital Storage Media

The standard methods that must be followed to ingest audio storage media are outlined in the following processes:

3.4.2.1 Audio Storage Media Players:

An essential part of digital audio playback and audio playback technology are the audio players. These are made to fit certain kinds of audio storage media, like CDs, cassettes, reels, Shellac Discs, and Vinyl Discs. Their significance stems from their capacity to preserve and enable the playback of audio recordings that are stored on these various types of media. To ensure the best possible playback quality and compatibility, each player is outfitted with unique technological features that are specific to the qualities of the media it supports.

During playback, Audio Players provide an audio line output that should be connected to the audio interface's line input via a balanced conductor. The audio should be carefully monitored with the headphones or monitor speaker for the appropriate level and minimum distortion which may depend on the player and the audio source.

3.4.2.2 Audio Interface:

Audio interfaces play a crucial role in audio conversion from analog to digital, in providing inputs and outputs for a range of audio devices, including speakers, microphones, instruments, and DAWs. Audio interfaces have a major impact on sound quality in three main ways during these operations: first, during the analog-to-digital conversion (ADC) process; second, through the quality of their pre-amplifiers (pre-amps); and third, by the noise they produce. Analog sound is sampled and measured as part of the ADC process. Inadequate sampling rates can cause aliasing problems, which in turn affect sound quality.

Furthermore, the bit depth used in ADC may lead to quantization distortion; higher bit depths generally lead to lower distortion levels. Furthermore, dynamic range is a crucial metric for evaluating the effect of interface-generated noise on processed sound, emphasizing the need for interfaces with higher dynamic ranges to maintain sound quality. To ensure the highest level of accuracy in audio production activities, audio interfaces are essential components that must be carefully selected.

3.4.2.3 Digital Audio Workstation (DAW):

A digital audio workstation (DAW) is music production software that allows users to record audio on a computer with various operating systems. It is used for audio recording, audio editing, mixing, and mastering, among other functions. A digital audio workstation functions by converting analog audio which arrives via an external audio interface into a digital sequence that can be processed on a computer. This audio information appears visually on a computer screen either as sonic waveforms or as music notation on a staff. which can then be manipulated by interacting with visual sound data on the screen.

Digital audio workstations offer a wide array of functionality like recording and editing audio, playing virtual instruments, experimenting with audio effects, Mix and mastering audio tracks. Many types of digital audio workstations exist in today's retail market. For example, Steinberg Cubase is an all-purpose DAW known for its audio recording capabilities and MIDI-based virtual instruments. It handles Virtual Studio Technology (VST) plugins and runs on Mac and Windows machines. Audacity is a free open-source audio editing program. It has far fewer capabilities than paid DAWs, but it functions on many platforms including Windows, Mac, Linux, and Unix-style systems.

3.4.2.4 Monitor Speaker

Monitor speakers are essential for precise audio monitoring and critical listening in the context of digital audio workstations (DAWs) during the stages of production, mixing, and mastering. Audio producers can detect minute details and make well-informed choices about audio balance, tonal accuracy, and spatial imaging thanks to the painstaking engineering that goes into these specialized speakers, which are designed to provide accurate and transparent sound reproduction across the whole frequency spectrum. DAW monitor speakers are designed to provide users with an accurate and neutral representation of their audio projects by having flat frequency response curves, low distortion, and broad spread patterns. The effectiveness and suitability of monitor speakers in a given environment are also greatly impacted by factors like driver size, cabinet design, amplifier power, and room acoustics. As a result, choosing the right monitor speakers that meet the unique needs of a DAW setup is essential to getting the best audio quality and preserving the audio production workflow.

3.4.3 Storage

The audio storage media and their digitized versions were systematically archived with clear metadata for easy post-digitization tracking. Initial metadata was systematically generated for each physically ingested storage medium and its digitized file. All audio storage media were centralized in a secure room, subject to entry/exit permissions. The storage facility was maintained at an average temperature of 21 degrees Celsius with a humidity level of 21% RH, ensuring minimal variations within 4 degrees Celsius for temperature and 10% RH for humidity.

Additional storage recommendations include keeping the area where tapes were stored clean and free of ash, food, corrosive gasses, dirt, dust, and smoke. It is important to keep tapes out of direct sunlight and away from moisture. All of these steps help to maintain the audio storage media in a safe, regulated environment and to handle it effectively.

3.5 Experimental Setup

To implement the designed system, an on-site experimental setup was established at Radio Nepal, utilizing the existing infrastructure and resources by the designed system workflows.

This stage included setting up digital workstations, audio players, and audio interfaces, as well as monitoring speakers or headphones. In addition, a balanced wire was used to connect the audio player and audio interface, a data cable was used to connect the digital audio output of the audio interface to the DAW, software configurations were put into place, and the digitization process was completely integrated into the workflow that is recommended for digitizing audio content.

3.5.1 Experimental Setup for ORT Tape Digitization System

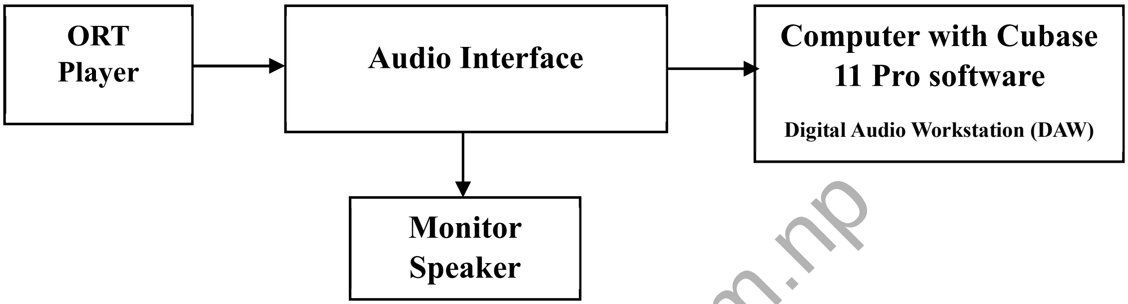

Figure3.4: Block diagram of ORT Digitization System

In this experimental setup, a DENON DN-3301REG ORT player was utilized to play the master copy from the ORT storage medium at Radio Nepal (Tape No T15637). The master copy of Narayan Gopal's Aadhunik Geet contained four versions of the same song; only the last version, which is regarded as the final master recording, was converted. To comply with the established standard, an audio interface capable of supporting 24-bit/48KHz, the Scarlett 2i2 [3rd Gen], was utilized to enable the conversion of analog audio to digital.

To evaluate the audio quality, a JBL 3MkII Monitor Speaker was used for audio monitoring. The digital audio conversion and recording procedures were completed on a Digital Audio Workstation (DAW), a computer equipped with the Windows 10 Operating system and Cubase 11 Pro software. The digital audio files that were produced were saved in the 24-bit/48-kHz WAV format and kept on the HDD of the DAW's digital storage media. The photographs of the experimental setup are in Annex 1 and Annex 2.

3.5.2 Experimental Setup for Cassette Tapes Digitization System

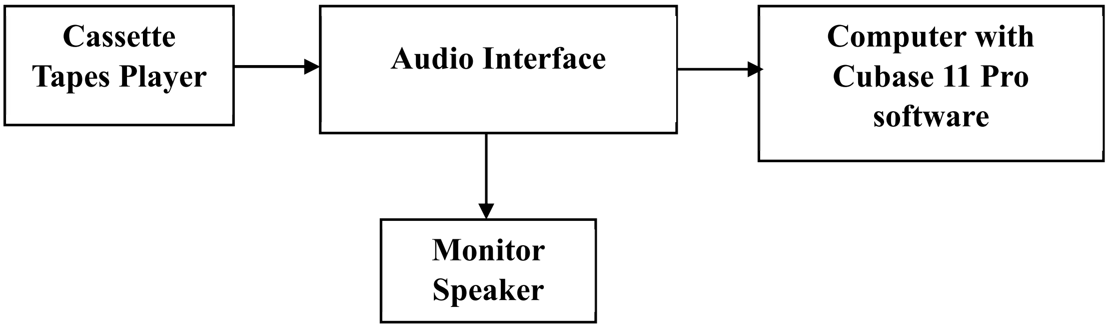

Figure 3.5: Block diagram of Cassette Tape Ingest System

The master copy of the cassette tape stored at Radio Nepal (tape no. 155) was played in this experimental setup using a TASCAM 322 cassette tape player. The Cassette Tape containing the "Ghatana ra Bichar" program was recorded on 2050-02-05 BS, with a duration of approximately half an hour. However, for the experiment, only a 2-minute audio segment was converted.

To comply with the required standard, an audio interface (Scarlett 2i2 [3rd Gen]) supporting 24-bit/48KHz was used to convert analog audio to digital. To monitor the audio, the Alctron headphones were used. Using a Digital Audio Workstation (DAW), a Windows 11 computer running Cubase software, the digital audio conversion and recording processes were carried out. The 24-bit/48-kHz WAV format of the final digital audio files was saved, and they were kept on the DAW's HDD for digital storage. The photograph of the experimental setup is in Annex 3.

3.5.3 Experimental Setup for CD/MD Discs

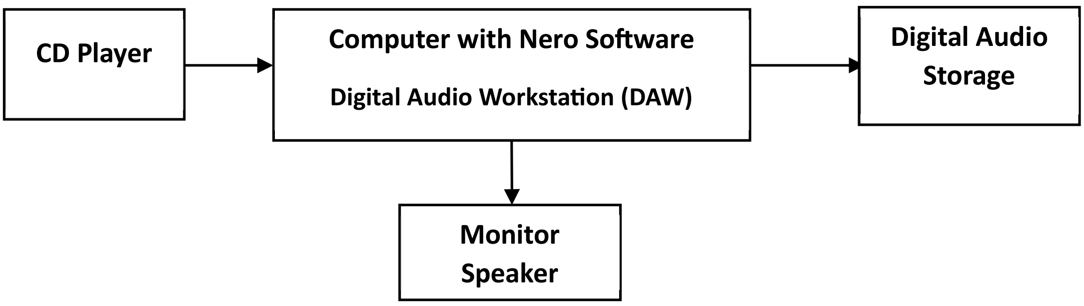

Figure 3.6: Block diagram of Experimental Setup for CD/MD Discs

In this configuration, a CD/DVD player embedded in the Dell OptiPlex 3010 was utilized to read the CD storage media available at Radio Nepal (CD No 723 - 'Karna Das ko Aadha Sapana'). As the audio stored on the compact disk is already in a digital format with CD quality (16-bit/44.1kHz), “Nero Burning ROM” software installed on the Digital Audio Workstation (DAW), a computer with the Windows 10 operating system, was employed to import the digital audio from the CD, enabling storage on the current digital storage media.

The imported digital audio was preserved in its original format of 16-bit/44.1kHz specification, aligning with the quality in which it was initially recorded on the CD. In this setup, saving a 24-bit file instead of a 16-bit file would merely add 8 bits of zeros to each sample, increasing the file size without enhancing the audio quality. Therefore, for archival purposes, maintaining the digital audio in its original format as it was recorded is preferred. The photograph of the experimental setup is in Annex 4.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 The result of the experimental setup

The digitized audio output from various audio storage media was stored in the storage available in DAW with Hard Disk. The digitized audio specifications detail and its metadata were created in an Excel file as given below and stored in the same storage in DAW. After digitization the properly tagged physical storage media were stored in a clean room with AC turned on at 21ºC with the proper tagging. The detailed Digital Audio Output Analysis is given in Table 4.1.

Table 4.1: Experimental Setup output of Digital audio

Ingest Media	**ORT Tape**	**Cassette Tape**	**Compact Disc**
Media Content ID	Tape No 15637	Cassette No. 155	CD No. 723
Digital Audio File Name	From ORT Mayalu aaune aash bokera	From Cassette ghatana ra bichar	Track 2- Vatiyera Chutnu
Digital Audio Format	WAV	WAV	WAV
Audio Channel	Mono	Mono	Stereo
Bit Depth	24	24	16
Sampling Frequency (kHz)	48	48	44.1
Output audio Duration	0:06:21	0:02:00	0:05:49
Theoretical file size (MB)	52.3	15.65	58.7
Output File Size (MB)	52.4	15.7	58.7
Audio Category	Adhunik Geet	Ghatana Ra Bichar Program	Pop Geet

4.1.1 Ingest Media and Metadata

The digitized audio output was categorized based on the media from which it originated; those were 1. Open Reel Tape, 2. Cassette, and 3. Compact Disc. Each piece of media was assigned a unique identifier, and metadata detailing the title, artist, and genre were recorded for contextualization.

4.1.2 Audio Specifications

Technical specifications of the digitized audio files were analyzed, encompassing parameters like audio channel configuration for ORT and cassette were mono as it was recorded originally and that of CD was stereo, bit depth for ORT and cassette were kept 24 bit and for CD it was kept at 16 bit as it is CD standard, and sampling frequency for ORT and Cassette were kept at 48kHz and for CD it was kept at 44.1kHz as CD quality. These specifications are crucial in ensuring the fidelity and accuracy of the digitized audio content, aligning closely with the original analog source.

4.1.3 Theoretical File Size Calculation

Theoretical file sizes were calculated based on established principles of audio encoding and digital signal processing. The theoretical file sizes for experimental setups were calculated as follows:

Calculation of File Sizes

1. Experimental Setup Output for Open Reel Tape (ORT)

For 48 kHz/24-bit mono audio with a duration of 6:21 minutes:

File size in bits = sampling frequency x bit-depth x number of channels x duration in second

$$= 48{,}000 \times 24 \times 1 \times (6 \times 60 + 21) \text{ bits}$$
$$= 438{,}912{,}000 \text{ bits}$$

File Size in MB = File size in bits /(8x1024 x1024)

= 438,912,000/(8*1024*1024) MB

= 52.3 MB

2. Experimental Setup Output for Cassette Tape

For 48 kHz/24-bit mono audio with a duration of 1:54 minutes:

File size in bits = sampling frequency x bit depth x number of channels x duration in seconds

= 48,000×24×1×(1×60+54) bits

= 1,152,000x114 bits

File Size in MB = File size in bits /(8x1024 x1024)

= 131,328,000 /(8*1024*1024) MB

= 15.65 MB

3. Experimental Setup Output for Compact Disc

For 44.1 kHz/16-bit stereo audio with a duration of 5:49 minutes:

File size in bits = sampling frequency x bit depth x number of channels x duration in seconds

= 44,100 x 16 x 2 x (5 x 60 + 49) bits

= 44,100 x 16 x 2 x 349 bits

= 492,508,800 bits

File Size in MB = File size in bits /(8x1024 x1024)

= 492,508,800/(8*1024*1024)

= 58.7 MB

4.1.4 Output Duration and File Size

The duration and file size of the digitized audio files were examined to gauge the length of the audio content and the storage space required for preservation. These measures provided valuable facts about the exact file sizes for standard audio formats under experimental configurations, ensuring the validation of the digitization process.

4.2 Discussion

The study identified that Radio Nepal utilizes various storage media, but many are poorly maintained, resulting in limited functioning players for analog storage. Current digitization practices entail using 16-bit WAV formats for ORT Tapes and MP3 format at 128kbps for Cassette tapes, cartridges, and CDs. The absence of clear archiving guidelines poses a risk of losing valuable materials. Preserving analog audio content is vital, aligning with international practices and technical recommendations. Observation revealed that Open Reel Tapes (ORT) are the primary medium for keeping master copies at Radio Nepal, with some recordings stored on shellac and vinyl discs. Slave copies for Radio Nepal come from Tape cartridges. However, cassette tapes and CDs were later included in the master copy collection. In 2008, Radio Nepal transitioned to digital playback and recording equipment without a recognized standard format for digital recording, impacting the recording format's compliance with global standards.

To tackle these issues, a standardized format for analog-to-digital conversion was devised, considering international standards and technological principles. A comprehensive system for audio content digitization was crafted and tested on ORT Tapes, Cassette tapes, and Compact Disks. The experimental setup digitized a portion of tracks from ORT Tapes and cassette tapes in 24-bit/48-kHz WAV format, resulting in file sizes of 52 and 20 MB, respectively. These standard digital audio formats cover a frequency range exceeding human hearing (up to 24kHz) and a dynamic range of up to 144dB. Additionally, digital audio was imported from CDs in its original format of 16-bit/44.1kHz, preserving the quality of the initial recordings. Maintaining digital audio in its original format is preferred for archival purposes to ensure data integrity. Digitization enhances the longevity and quality of audio content, facilitating easier access for researchers, historians, and the general public. The proposed system design and standardization can serve as the national standard for audio digitization, aiding in preserving Nepal's cultural heritage. Radio Nepal should also digitize various analog audio stored within the country to safeguard the nation's history.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, this thesis has made significant strides in the digitization efforts of Radio Nepal, with the most notable achievement being the systematic creation of a comprehensive digitization framework designed to manage and digitize a wide range of analog audio content. Through an in-depth investigation into digital audio formats and the types of audio content stored at Radio Nepal, the ideal standard format for the station's archival needs has been identified as 24-bit/48kHz WAV. The choice of a 48kHz sample rate ensures the digitized audio captures frequencies up to 24kHz, surpassing the range of human hearing. Additionally, the 24-bit depth provides a dynamic range of up to 144dB, offering superior au¬dio quality compared to CD quality (44.1kHz, 16-bit, and 96dB dynamic range). Opting for the LPCM WAV format guarantees that the audio is preserved in its highest quality, remains accessible across various platforms, and can be effectively managed and utilized in the future.

Grounded in global standards and tailored for practical applications, this selected format ensures seamless interoperability and long-term sustainability. This work not only safeguards the integrity of the digital content but also positions Radio Nepal to leverage its audio assets for broader distribution and potential revenue across over-the-top (OTT) platforms.

In summary, this thesis marks a critical turning point in Radio Nepal's digital transformation, securing the organization's significance and influence for future generations while enabling it to seize opportunities and address challenges presented by the rapidly evolving digital audio landscape with excellence and foresight.

5.2 Recommendations

To ensure the preservation and accessibility of historic audio content, it is crucial to follow specific guidelines during the digitization process. These guidelines help maintain the integrity and quality of the audio while also ensuring compatibility with current and future technologies. The following recommendations provide a framework for best practices in the digitization and preservation of analog audio recordings.

1. Analog audio storage containing historic content should be preserved both before and after digitization and placed in a controlled environment with proper temperature and humidity to ensure longevity.

2. The vantage audio players should also be preserved to ensure the future accessibility of valuable historic audio recordings.

3. Digitized audio should be compatible with new technologies to ensure accessibility in the future so it is recommended to use open, proprietary lossless formats such as WAV to maintain high quality and broad compatibility.

4. The archived digital audio content stored in lossless format has a higher bitrate which is generally unpractical for audio distribution so for digital audio distribution the format and bitrate of digital audio can be adjusted to meet the requirements of digital audio distribution platforms. For instance, lossy formats such as MP3 with bitrates ranging from 128kbps to 192kbps are commonly used for online distribution.

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ANNEX

Figure A.1: Experimental Setup for ORT Digitization System

Figure A.2: Working on ORT Digitization System

Figure A.3: Experimental Setup for Cassette Tape Digitization System

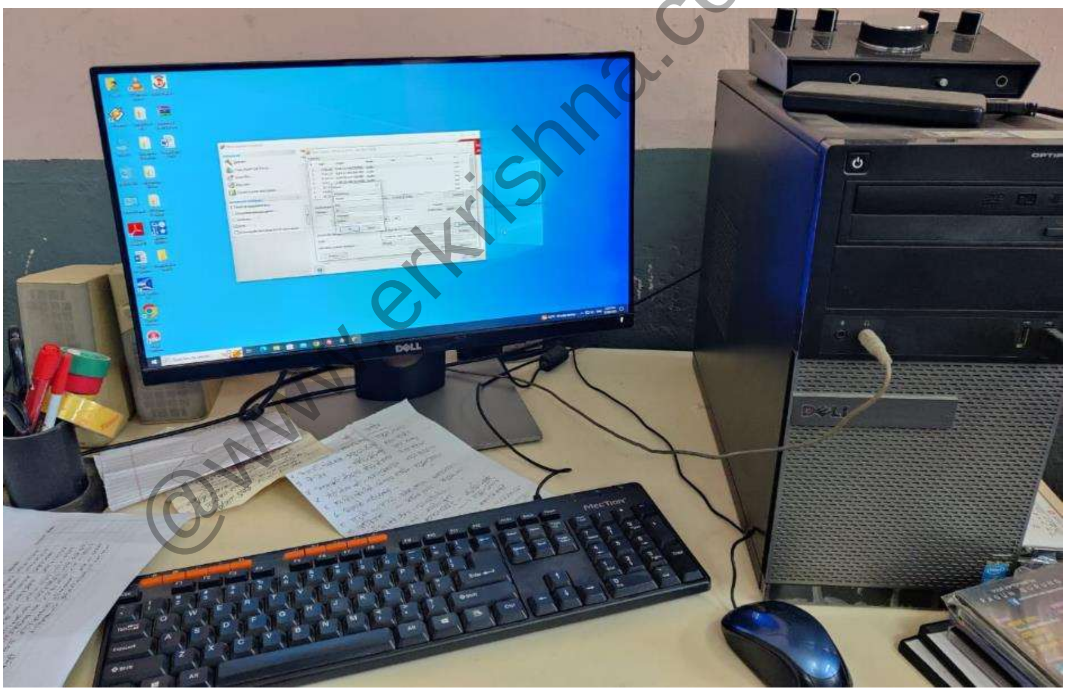

Figure A.4: Experimental Setup for CD

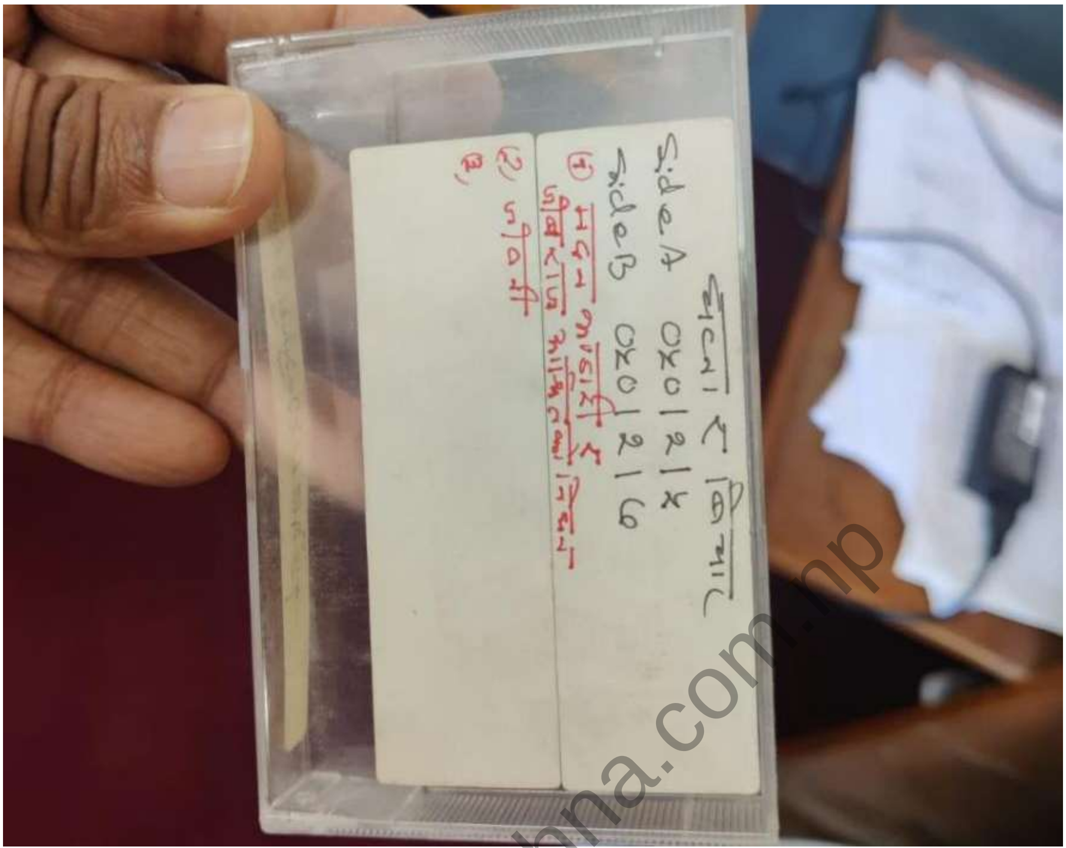

Figure A.5: Cassete label

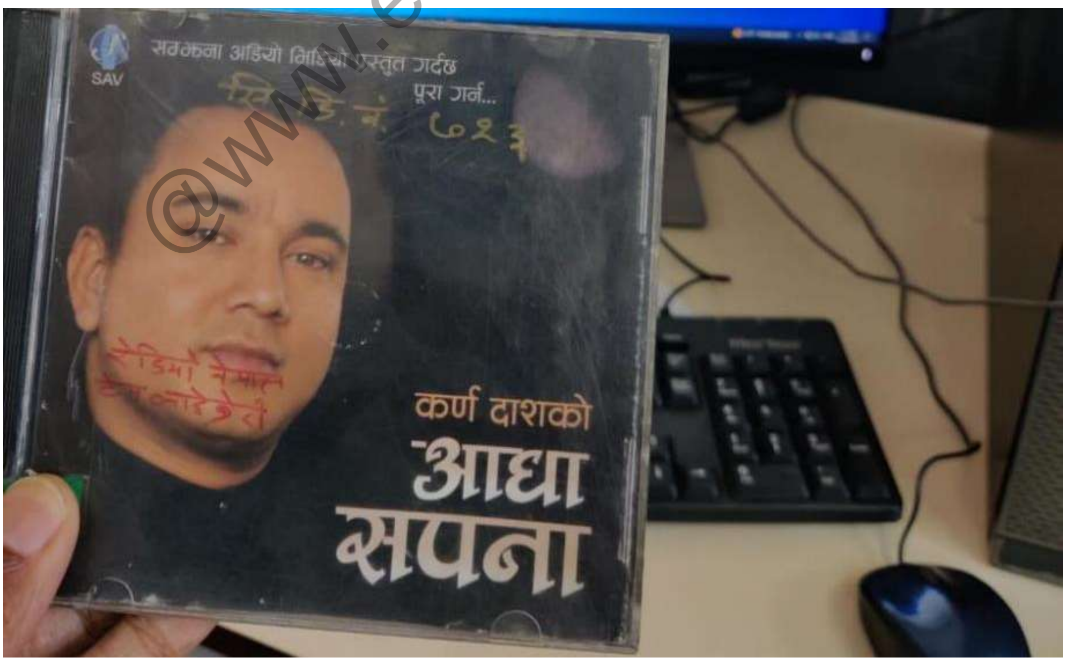

Figure A.6: Cover of CD

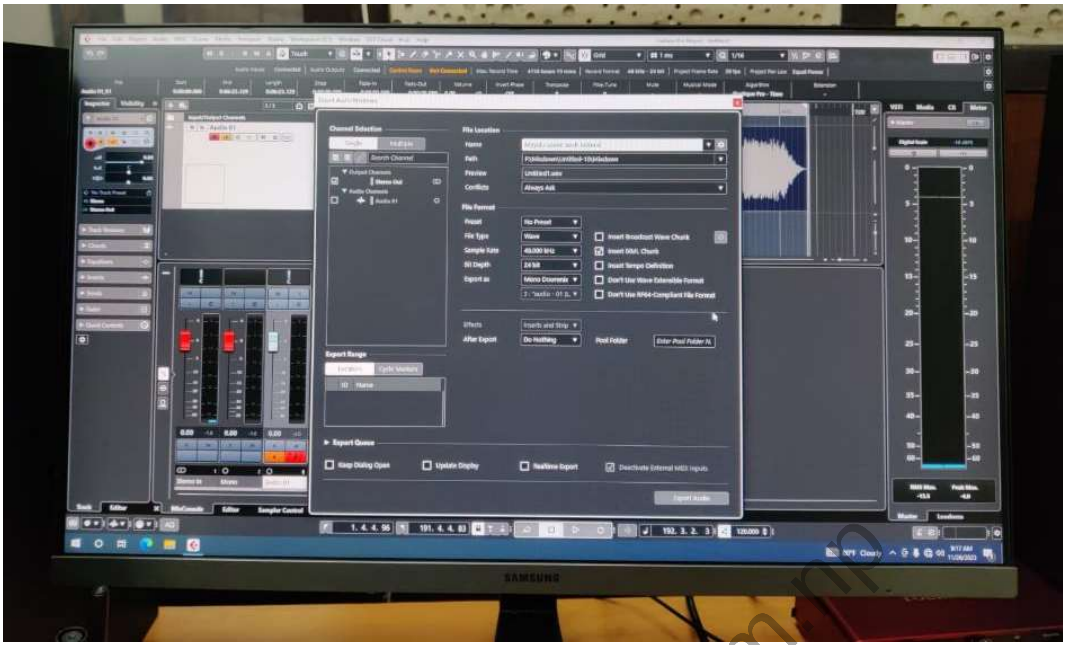

Figure A.7: User interface of Cubase 11 Pro

Figure A.8: Open Reel Tape

Figure A.9: Vynil and Shallec Discs stored in Radio Nepal

Figure A.10: Compact Discs stored in Radio Nepal

Figure A.11: Open Reel Tape player

Figure A.12: Strings Recording Studio Visit for data collection

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उपरोक्त सम्बन्धमा तहांको मिति: 29 October, 2023 को यस समितिलाई प्राप्त पत्रानुसार त्यस संस्थामा M. Sc. in Information System Engineering विषयमा अध्ययनरत विद्यार्थी कृष्ण कुमार श्रेष्ठलाई यस समितिबाट Standardization System Design, and Implementation of Audio Content Digitization सम्बन्धमा अध्ययन, अनुन्धान तथा प्रयोगात्मक परिक्षण गर्न अनुमति प्रदान गरी सहयोग गरी दिन हुन भनि उल्लेख भई आएकोमा यस समितिबाट निजलाई उक्त कार्यकालागि अनुमति प्रदान गरिएको व्यहोरा मिति: २०८०।०७।१५ को निर्णयानुसार जानकारी गराउदछु ।

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बोधार्थ

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