AN ELECTRIC UPRIGHT BASS

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ABSTRACT

Electric upright basses are stringed musical instruments that combine elements of the acoustic double bass and the electric bass guitar. The vertically-oriented interface they present resembles that of the double bass. They rely, however, on electronics to amplify their sound instead of the hollow wooden body of the acoustic. The current interest in electric upright basses (EUBs) seems to be driven primarily by jazz and pop musicians looking back to the tradition of upright bass playing but insisting on the advantages that modern musical instrument technology has to offer.

This project is the design of an electric upright bass through the application of the industrial design process. The history of bass design, EUB design precedents, the interface between the instrument and the player, material and technological considerations and manufacturing processes are addressed. The environmental sustainability of the design and human factors concerns are presented.

The primary focus of the project is the appropriateness of the form and function of the design. A prototype, constructed for this project, will demonstrate the decisions made in the design process and will serve as a basis for a discussion of these decisions. It will also help identify areas within the design that can be improved on or developed further.

Keywords

Electric upright bass, Acoustic upright bass, Double bass, Pick-ups, Components, Interface, Tone, Musical instrument technology, Industrial design, Materials, Sustainability

Beauty will result from the form and correspondence of the whole, with respect to the several parts, of the parts with regard to each other, and of these again to the whole; that the structure may appear an entire and complete body, wherein each member agrees with the other, and all necessary to compose what you intend to form.

Andrea Palladio
First Book of Architecture
Venice, 1570

TABLE OF CONTENTS

INTRODUCTION

PART I: BACKGROUND

1.0: Sound and Music

2.0: A Brief History of Stringed Instruments

3.0: Upright Bass Systems: Components & Functions

4.0: Player/Instrument Interface

5.0: Existing Electric Upright Basses

PART2: DESIGN

6.0: Design of an Electric Upright Bass

7.0: Proposed Design

8.0: Prototype

9.0: Conclusions

Appendix

LIST OF FIGURES

INTRODUCTION

The development of electric stringed musical instruments began around the middle of the twentieth century. Advances in electronic technology made it possible to amplify the sound produced by instruments that were notoriously hard to hear within the overall sound of orchestras and dance bands. The electric guitar and the electric bass guitar are the most successful examples of designs that began as solutions to this problem. These instruments have gained worldwide acceptance and play an important role in today's music industry. The electric upright bass did not receive the early attention that the electric guitar and electric bass guitar did, but today's musicians are expressing renewed interest in the creative possibilities and the practicality offered by the electric upright bass (EUB) and its family members, the electric violin, viola and cello.

Musicians who play acoustic stringed musical instruments control the volume and tone produced by their instruments through playing techniques. Electric stringed musical instruments allow players to extend their control of volume and tone through electronic technology. Technology expands the range of creative options available to the musician. Volume, treble and bass tone, reverberation, equalization and distortion are examples of common sound controls available to musicians playing electric stringed instruments. The recent development of MIDI (Musical Instrument Digital Interface) technology extends the possibilities even further.

In most traditional stringed musical instruments, the strings produce the signal and the hollow body of the instrument produces the volume and the tone. In electric stringed musical instruments, the strings produce the signal and the electronics produce the volume and tone. This eliminates the need for a hollow body, thereby opening up a wide range of design possibilities for the instrument.

OBJECTIVES

The main objectives of this project are to design an electric upright bass and to construct a working prototype model of the instrument. The design of this instrument should combine a consideration of traditional playing techniques and the capabilities that electronic technology offers. The design should reflect a sensitivity to the needs of the musician as well as the possibilities offered by electronic technology and current manufacturing processes. The prototype is intended to demonstrate the application of industrial design processes and activities to musical instrument design and to serve as a basis for further design development.

The design of the instrument will take into account the history of bass design and the design of electric stringed musical instruments. This project will view the musician/instrument/technology interface as a system and will consider the requirements of each component of this system in the design of the instrument.

This project will focus on industrial design processes and activities in the design of an electric stringed musical instrument. These include materials and technologies, aesthetics and human factors considerations. The project will investigate all electric upright bass design precedents available and will summarize these findings in a comparative format. The project will also include an evaluation of the proposed design and will make recommendations for further design development.

This document is structured in two parts. The first part will address all relevant background issues such as the properties of sound and music, musical instrument design history, the instrument as a system, the player/instrument interface, and existing electric upright bass designs. The second part will detail the design of the proposed instrument and will illustrate the prototype construction process.

TERMS

A brief description of some of the terms used frequently in this document will provide the reader with a clearer understanding of the project. Relevant musical terms, acoustic and electric musical instruments and some of their components are defined below.

In **electric stringed musical instruments**, the term "electric" refers to the incorporation of an electronic component in the design of these instruments. Electric stringed instruments have small, built-in microphones which pick up the instruments' sounds and translate them into electronic signals. These signals are then amplified and broadcast through a speaker. Today, we use the term **electronic** to denote the processing of low-voltage electrical signals. Yet, the term "electric", originally coined in the 1920s, is still used today to describe these musical instruments. These include the electric guitar, electric bass guitar, electric violin, viola and cello and the electric upright bass.

Acoustic stringed musical instruments refers to traditional Western instruments whose sound is produced by their strings being caused to vibrate by bowing, plucking or hammering. These include the piano, harpsichord, harp, guitar, violin, viola, cello and double bass. The term will be used exclusively in this document to describe the bowed instruments: the violin, viola, cello and double bass, except as otherwise noted.

The **acoustic bass** is the largest and lowest-sounding member of the acoustic stringed instrument family. It traditionally has four strings but some may have a fifth. The standard string scale, or free string length, on a full size acoustic bass is forty-four inches. The standard string scale on a three-quarter size acoustic bass varies from forty-one to forty-two and a half inches. An instrument's string scale may vary from these standards. The instrument is played in the vertical position by **bowing (arco)** or **plucking (pizzicato)** its strings. The acoustic bass has a large hollow body, traditionally made of wood, which amplifies the sound of the vibrating strings. This instrument is also known as the bass violin, the upright bass, the string bass, the contre-bass and the double bass (the cello is considered to be the single bass). An **electric upright bass** is a design variation of the acoustic bass that employs electronics to produce its sound. It should not be confused with the electric bass guitar.

Pick-ups are small microphones which, when mounted on or near an instrument's strings, produce a low-voltage electrical signal in unison with the vibration of the strings. This signal is transmitted to an **amplifier** which amplifies the signal and sends it to a speaker. These processes are described in further detail in section 2.4 of this document. There are a number of different types of pick-ups. These include dynamic, magnetic, condenser, and piezoelectric or contact pick-ups.

A BRIEF HISTORY OF THE ELECTRIC UPRIGHT BASS

The acoustic bass violin has been a component of western music for centuries. The design of these instruments has evolved from the three gut-string version of the 1500s to the four and five steel-string designs of today. The range of notes that can be produced on these instruments has been expanded to meet the needs of contemporary arrangers and composers. Fine old basses are considered rare and treasured artefacts. There are still some luthiers producing good quality acoustic basses, which range in price from $8,000 to $35,000US.

Acoustic basses were often drowned out by the sound of modern orchestras and dance bands. The amplifiable electric bass guitar seemed to provide a solution to this problem. The curious new instrument first appeared publicly in Lionel Hampton's jazz orchestra in the 1950s. By this time, advances in electronics and manufacturing technology were making it possible for instrument makers to produce electric guitars and bass guitars in relatively large numbers and offer them for sale at affordable prices. By the mid-1960s, the electric bass guitar had become an accepted bass instrument in popular music.

As time passed and tastes changed, the popular music genres of rock-and-roll, rhythm-and-blues and soul became progressively louder and more defined by the sounds that electric instruments could produce. The acoustic bass carried on its traditional role in classical music but was relegated more and more to quieter forms of popular music such as jazz and country-and-western. The term "upright bass" was applied to the acoustic bass to differentiate it from the horizontally-played electric bass guitar, which had become the more visible of the two bass instruments.

Today, the acoustic bass is still the only stringed bass allowed in the performance of traditional classical music. Within popular music, however, performances on the electric bass guitar far outnumber those on the acoustic bass. When compared, acoustic basses are expensive, fragile and difficult to handle. They are not very loud and are not readily amplifiable. Electric bass guitars are more affordable, considerably easier to play and transport, and provide the musician with all the additional possibilities that music technology has to offer. Acoustic basses are usually only heard now when the distinctive acoustic bass sound is required by the music or desired by the musician.

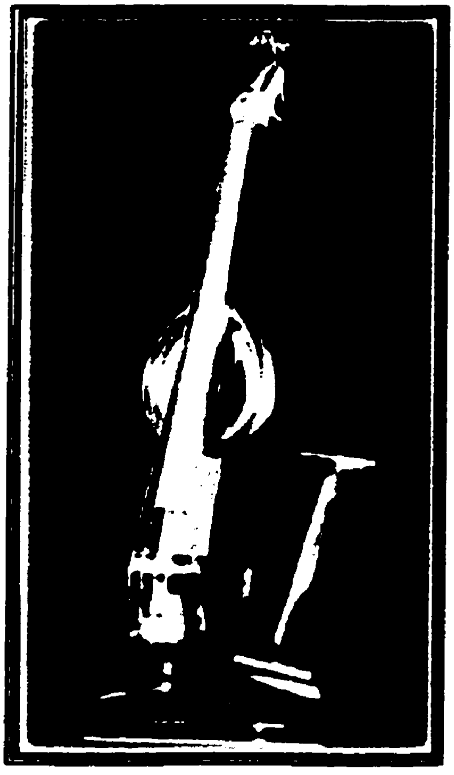

Figure 1.
The first EUB (1924).

Concurrent with these developments there has been ongoing experimentation with electric upright bass design. Lloyd Loar, an engineer with the Gibson Guitar Company, designed the first electric upright bass in 1924 (**Figure 1**).

Serious sound problems, due to the rather primitive state of the pick-ups and amplifiers of the time, rendered this design unsuitable for commercial production. By the 1930s, companies such as Regal, Rickenbacker, Gibson and Vega were developing a variety of electrical stringed instruments. In 1936, George Beauchamp designed the Rickenbacker basses, using gut strings with metal material applied to the strings near the magnetic pick-ups. These instruments and all other electric upright basses of the time were made using standard acoustic bass necks attached to simple body structures.

The Second World War interrupted the development of electric upright bass design. In 1951, Leo Fender introduced the Fender Bass, a short-scale, fretted, electric bass guitar. Its affordability, elegant design and easy playability made it the bass instrument of choice by the early 1960s.

The sound produced by the bass guitar, however, was different than the sound of an acoustic bass. Its tone was not as low and, as the instrument could not be played with a bow (arco), it could not produce long, sustained notes. Certain musical pieces required these types of sounds. Plucking (pizzicato) technique varied between the two types of instruments as well. The bass guitar, held horizontally, was often played with a plectrum (pick). Also, the bass guitar had a fretted neck whereas the acoustic bass was traditionally fretless. Musicians who had trained on the acoustic bass wanted an instrument that sounded like an acoustic bass and played like an acoustic bass but they wanted it to be amplifiable and easy to transport like a bass guitar.

Attempts to modernize the acoustic bass were made throughout the 1950s. In 1958, Ed and Rudy Dopera introduced the Zorko Bass. As Martin Clevinger writes in his [1]Evolution of the Electric Double Bass, the Zorko Bass "featured a hollow fiberglass body, a slightly scaled-down head and fingerboard. The Zorko fiberglass hollow body, with its bolt-on maple neck was later modified and became the Ampeg Baby Bass. The Ampeg Baby Bass was widely marketed in the USA during the 1960s. It featured an improved aluminum bridge pick-up system compatible with non-ferrous or traditional gut strings. The Ampeg's heavier body was made of a thermoplastic called UVEX. This plastic is unstable as its melting temperature is very low. The Ampegs give off a somewhat foul odour due to continual off-gassing by the UVEX material. Many Ampeg basses show warping of the body due to exposure to heat inside parked cars on hot days. Hundreds of Ampegs were produced in the 1960s. A

[1] in "The Evolution of the Electric Double Bass." by Martin Clevinger, 1997.

bass called the Azola Baby Bass is now being produced by Steve Azola. This bass draws on the Ampeg and Zorko tradition and is somewhere in between the two in construction. It features up-to-date pick-ups and electronics. Azola has recently been constructing a reissue of the Ampeg Baby Bass for the St. Louis Music Company."

The Framus Corporation of Germany manufactured an electric upright bass in Europe in the 1950s. The instrument had a solid wood body with a glued neck joint, a very different approach than the hollow body Dopera-influenced designs. This bass featured individual string height adjusters, custom finishes and a chrome-plated magnetic pick-up integrated into a chromed bridge cover assembly. It was difficult to balance during playing and produced tones similar to those of an electric bass guitar. Nonetheless, many recent electric upright bass designs are similar to the solid wood Framus concept. Another earlier instrument was the New Futurama Electric Bass, marketed by Selms in London, England around 1960. It was much like the Framus instrument in its construction.

In the 1960s, a few makers played with the idea of merging the electric bass guitar and the upright bass. The mid-60s Mini-Bass resembled the Ampeg Baby Bass with long, sloping shoulders. It offered bass guitar design features such as two magnetic induction pick-ups coupled to the strings, and knobs and switches located on its front, following the curve of the upper left bout. This instrument had a "mod" look intended to appeal to young musicians involved in the Beatle haircut and Carnaby Street fashion craze of the day. Its body resembled the shape of an electric guitar body.

The Blitz Bass was designed by John Dawson in California in the 1970s. It was originally put together for a North American Music Merchant's (NAMM) exhibition. The annual NAMM exhibitions are the world's largest music merchandise displays, showcasing new products and musical instrument design innovations. The Blitz Bass became popular with some jazz bassists who recorded and toured with the instrument but very few were made and it was never put into full production.

By the 1970s, the electric bass guitar was dominating the bass role in the music industry. Most bass music was being played by bassists who had either given up acoustic playing techniques or had never learned them. Bass guitars were a safe bet for most manufacturers as they were popular and easily mass-produced. Fretless bass guitars had been available for a few years by the late 1970s and several influential rock and jazz musicians, like Jack Bruce and Jaco Pastorius, began playing the unique-sounding instruments in front of large audiences and on their recordings. This marked the beginning of renewed interest in the fretless bass sound.

Henk Van Zalinge introduced the Z Bass in Holland in 1978. It was a slim, shoulderless upright bass with a hollow body and a piezoelectric bridge pick-up. This instrument received a lot of attention and appeared in Playboy magazine's Christmas wish list that year. The pop musician, Sting, popularized the instrument on tour with his band, the Police, in the 1980s. Van Zalinge opened a factory that eventually produced about 265 Z Basses.

A number of manufacturers were producing full-scale length electric upright basses by the early 1980s. Notable among these were the Merchant Vertical Bass, the Gunn Bass in Canada, the Dobro, the Oregon Bass, the Hofner JB-59 and the Clevinger basses (**Figure 2**). Martin Clevinger designed a line of electric upright basses, still in production today, which greatly increased the instrument's profile in the 1980s.

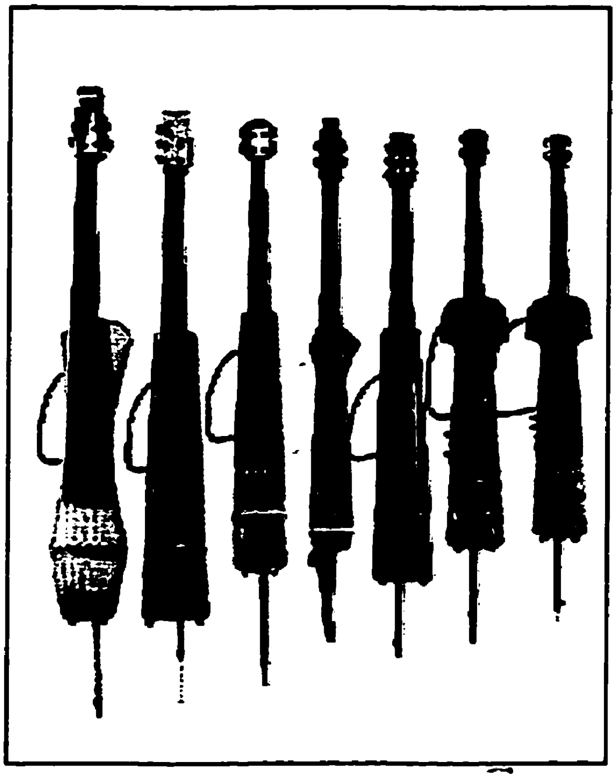

Figure 2.
The Clevinger line of EUBs.

Changing musical tastes in the 1990s have given rise to increased interest in "alternative" forms of music such as world beat (eg: African and Latin music) and have created a resurgence in popularity of music forms such as jazz and swing. The growth in popularity of electric upright basses has kept pace as the instrument is seen as an "alternative" to the mainstay bass guitar. There are currently more than twenty electric upright bass designs commercially available in North America and Europe. These instruments are all fabricated out of wood. A few incorporate some composite materials in their construction. Most of these are intended to be balanced upright while playing or can be locked upright in a stand. Some design innovations have been made, such as the concave back of the neck on the NS Design NSDB-CR4; an American design which recently went into full production in the Czech Republic. Some manufacturers have designed and incorporated their own pick-up systems into their instruments but most use outsourced pick-ups and electronics. These instruments are catalogued in a comparative format in the appendix of this document.

THE MUSICIAN

Simply put, the musician is someone who makes music. Music is the organization of sound into a rhythmic form for the expression of emotion. It is communicated, by voice or on instrument, through the artistic combination of tone and pitch into harmonies and melodies occuring over metered periods of time. The musician is the person responsible for the organization and production of the desired sounds. The musician is the communicator.

THE INSTRUMENT

The musician requires an instrument to produce the desired sounds on. The instrument must provide the kind of tones and the range of pitches required by the musician to perform a particular piece of music. The instrument must be able to be played with a reasonable degree of ease and comfort. The instrument must provide the musician with auditory feedback and the ability to control the tone and volume of the instrument's output.

MUSICIANS AND INSTRUMENTS AS SYSTEMS

Musicians and their instruments form systems. A system is a complex, co-ordinated arrangement of things or parts, for working together or performing a particular function. The actions the musician performs on the instrument causing it to vibrate are the system's input. The sound produced by the instrument when played is the system's output.

The input of the musician/instrument system begins with the musician performing a task that causes the instrument's strings to vibrate. These tasks are performed by the musician's hands. As well, a tool may be used to perform the task; for example, a bow, mallets, or a plectrum. The fingers and tools become the system's input devices. The input in acoustic instrument systems and electric instrument systems is essentially the same.

The performance of the musician's task causes the dynamic mechanism or mechanisms of the instrument to vibrate. In acoustic instruments, the resulting vibrations are transmitted into the air as sound waves, which is the initial output of an acoustic instrument system. In electric instruments, the resulting vibrations are translated into low-voltage electric signals, which become the initial output of an electric instrument system. The initial output in both types of systems is manipulated by the system's output devices. The different output devices employed by the two systems are the principal elements that distinguish them from each other.

The musician's role in the musician/instrument system is to input the data into the system and to control the system's output. The role of the instrument in the system is to accurately translate the data into sound of a discernible volume. The musician/instrument interface is further examined in section 4.0 of this document.

PART 1: BACKGROUND

1.0: SOUND AND MUSIC

1.1: SOUND

1.1.1: The Physical Properties of Sound

We perceive sound when vibrations travelling through the air strike our eardrums. Vibrations occur when an elastic material is caused to oscillate. These oscillations are transmitted through the molecules of the surrounding air in intermitting areas of rarefaction and compression. One vibration in the air is comprised of one area of high pressure and one area of low pressure, called one wave or one cycle.

The frequency of a sound wave is the number of vibrations that occur per second. The frequency of a sound wave increases as the number of vibrations per second increases. As the frequency of a sound wave increases, the pitch of the sound becomes higher.

The amplitude, or strength, of a vibration determines the intensity, or volume, of the sound. As the amplitude increases, the sound becomes louder.

1.1.2: Tone, Tonality and Intonation

We usually designate complex, irregular vibrations as noise. Regular vibrations are heard as tones of a specific pitch. There are terms we use to describe the characteristics and properties of tones. These are:

Timbre: the distinctive quality of a sound
Intensity: the degree of loudness or volume of a sound
Duration: the length of time over which a sound occurs
Pitch: the relative sense of a sound being high or low

[2]George T. Jones writes in his book on music theory, "These are the principal properties that interest the musician, although some other aspects will have significance in the area of the performance: for example, how the tone is attacked or released, how one tone is connected with

[2] George Thaddeus Jones, Music Theory, pp.3-4.

another, and how a combination of tones produces a sense of density or texture."

Tones are individual sounds. Tonality is defined as a system of tones that displays an organizational affinity to a critical centre tone, or tonic. This centre tone is also called the keynote. Tonality is a primary consideration in the organization of tones into music.

Intonation is the modulation or inflexion of a tone to express emotion. It is the expressive accentuation of a tone or combination of tones to cause a desired effect.

1.2: MUSIC

1.2.1: Music Defined

We generally define music as organized sound. It is the arrangement of tones and pitches, in composition or performance, occurring over a period of time. Music may be considered to have two fundamental components: rhythm and melody.

[3]Jones writes that "rhythm refers to the length or duration of tones. These relative lengths, expressed by note symbols, must be measured accurately, one against another. In order to know the exact length of a tone, one must establish a regular pulsation, which is called the beat, against which lengths can be measured. The basic beat is what we express when we tap our foot, march, or dance to music. This background pulsation may be fast or slow, but it must be regular, so that it measures off equal increments of time. It is somewhat analogous to the increments of distance represented by the markings on a ruler or yardstick. The speed at which we beat time is called the tempo; this is variable from very fast to very slow."

Melody is the orderly arrangement of pitches presented in time. It is usually the agreeable succession of sounds, especially of simple tones in the same key. This arrangement of pitches takes place within the framework of the rhythm. There are notable exceptions to these rules. Atonal and arhythmic music are often explored in experimental and contemporary classical musical forms.

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[3] George Thaddeus Jones, Music Theory, pp.13.

In musical notation, music is graphically represented by conventional symbols placed along two axes. The horizontal, left-to-right axis, represents the measured passage of time and the organization of tone lengths and their relation to each other within the time framework. The vertical, up-and-down axis, represents the pitches of the notes and the order they appear in successively within the time framework.

We all feel that we recognize music when we hear it. We all have musical preferences, whether for certain pieces of music, certain types of music or for certain musical sounds. Our musical tastes are largely influenced by the social, cultural, political and technological circumstances surrounding our lives. Music is abundant. We are inundated by it. We use it to accompany our most sacred rituals and to support our crassest enterprises. We use it to soothe and to arouse. We use it to evoke our ideals of beauty and to describe our darkest visions. Music is a language that we may not all speak, but that we all understand.

In his book, [4]Thinking About Music, Lewis Rowell provides a chart, reproduced below as Table 1, to illustrate some of the many ways we can define music. Readers are invited to select combinations of words that best define their own definitions of music. He cautions that he does not intend this chart to be exhaustive or all-inclusive.

SUBJECT	VERB	OBJECT
	means	a feeling
	expresses	emotion
	represents	a mood
Music or a Musical Event →	evokes →	an image
	imitates	a thing
	signifies	nothing
	symbolizes	a process
	resembles	human qualities
	points to	another event
	refers to	a type of motion

Table 1.
Definitions of music (from Rowell, 1983).

[4] Lewis Rowell, Thinking About Music, 1983.

1.2.2: The Cognition of Music

Children have long been known to develop an early appreciation for music. In their first year of life, children pay attention to auditory stimuli with a harmonic structure. It seems they learn music much the same way they learn language: with one note, exponentially acquiring new ones.

When people hear music, whether melodic and beautiful or discordant and cacophonic, their brains are sending and receiving precise neurological signals of the auditory encounter. Recently, Anne Blood, a researcher at McGill University in Montreal, conducted scientific studies on music's emotional impact on the brain. Blood targeted the emotional response to music by studying ten adults from ages 19 to 43 as they listened to music that either had a harmonic tone or clashed. Her experiment used a single melody and added on six versions that varied from very pleasant-sounding to jarring and abrasive. She and her team measured blood flow in the brain during these experiences in hope of identifying differences. They found that the abrasive sounds triggered blood flow activity in an area of the brain called the parahippocampal gyrus, an area in the temporal lobe that has a function in processing sensory memory. When the sounds were pleasant, they observed increased activity in the lower part of the frontal lobe. These responses were observed primarily in the right side of the brain.

These brain areas are different from the regions activated when musicians read a score or are asked to identify mistakes in musical pieces. In 1995, Lawrence Parsons and his colleagues at the University of Texas Health Sciences Centre, conducted studies to determine which areas of the brain are active when specific musical tasks are undertaken. Eight right-handed conductors volunteered to be his study subjects. They were asked to identify errors in melody, harmony or rhythm in a Bach chorale. They were told to merely note the errors, but not to make any motor responses such as writing the mistakes down. Each task produced different brain activity patterns. Melody activated the right and left hemispheres in the temporal areas of the brain. Harmony and rhythm triggered more activity in the left hemisphere. Each of the tasks also produced activity in an area of the left side of the brain that is linked to the visual processing of words.

1.3: MUSICAL INSTRUMENTS

1.3.1: How Musical Instruments Produce Sound

Acoustic musical instruments are mechanical devices that produce, amplify, resonate and in other ways, control vibrations. Electric stringed musical instruments produce vibrations the way their acoustic cousins do but the amplification, resonance and tone of these vibrations is controlled electronically. Electronic instruments, such as synthesizers and samplers, generate their sounds electronically and require no vibrating components.

Some acoustic musical instruments are named for the materials they are constructed from: woodwinds, brass. Some are named for the mechanisms that produce their vibrations: strings. The most accurate way to categorize common acoustical instruments is according to the mechanisms that produce their vibrations. These are vibrating bars, membranes or plates, vibrating air columns and vibrating strings.

Vibrating bars, membranes or plates are components of percussion instruments, so called because they are played by striking them with hammers, sticks or mallets. Striking the bars, membranes or plates causes them to vibrate which vibrates the surrounding air resulting in sound. There is a wide variety of these instruments and the sounds they produce are as diverse as the materials from which they are made. They can be divided into two main categories: instruments with definite pitch such as bells, chimes, marimbas and xylophones, and instruments of indeterminate pitch such as cymbals, drums, triangles and tambourines.

Vibrating air columns are components of wind instruments. These are the brass and woodwind instruments. The initial vibration in brass instruments is the musician's lips, which vibrate inside a cupped mouthpiece. The brass instruments are the trumpet, French horn, trombone and tuba.

The woodwind instruments are divided into three categories according to their initial source of vibration. The edge tone instruments; the flute and piccolo, receive their initial vibrations from the player blowing across an opening in a tube. The splitting of the blown air against the edge of the opening creates a vibration that is transmitted and amplified by the air column in the tube. In the single reed instruments; the clarinet and saxophone, and the double reed instruments; the oboe, English horn and bassoon, the initial vibration is caused when the player blows air into a tube through a reed and a mouthpiece, or between two reeds, respectively. The reed or reeds vibrate and the vibration is picked up by the air column in the tube.

The pitch of a vibrating air column is determined by its length. Wind instruments control pitch through mechanisms that decrease or increase the length of the tube. In the woodwinds, the overall length of the tube is shortened by the player opening holes in the tube that have been covered by the player's fingers or by stops, or keys. The brass instruments use valves to add additional lengths of tubing. In the trombone, the length of the tube is controlled by the slide.

There are three categories of instruments with vibrating strings. In each, the strings are caused to vibrate by different means. The bowed string instruments include the violin, the viola, the cello and the bass. The struck string instruments are the piano, the cimbalon and the clavichord. The plucked string instruments are the harp, the guitar, the lute, the banjo, the mandolin and the harpsichord. Regardless of how they are vibrated, the strings of these instruments all respond the same way acoustically.

The fundamental, or basic pitch, of a string is the pitch produced by the vibration of its entire length. **Figure 3** below, reproduced from Jones's Music Theory, illustrates the action of a vibrating string.

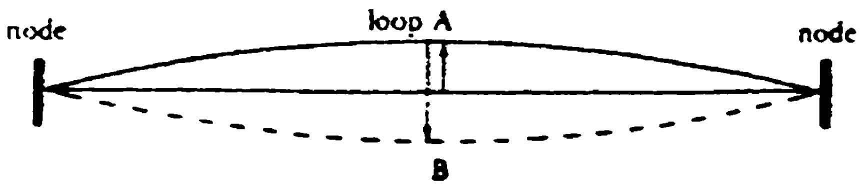


Figure 3.
The action of a vibrating string.

[5]Jones explains that "If it (a string) is moved out of its position by being struck, plucked or bowed, the elasticity of the string and its momentum will carry it to point B, a distance past the point of rest approximately equal to the original displacement (A). If it is then left free to vibrate, it will eventually be brought again to a state of rest by the friction of the medium, in this case air. The degree of displacement, which is the amplitude, determines the loudness of the sound. One entire cycle, from

[5] George Thaddeus Jones, Music Theory, pp. 4.

point of rest to A, then to B, and back to point of rest, is considered one vibration or wave; the ends of the strings are the nodes of the wave, the centre point is called the loop. While many things affect the pitch produced by a string--the material out of which it is made, its thickness, and its tension--its pitch is primarily determined by the string length. The vibration of the entire length of the string produces the fundamental, or basic pitch we assign to this string length. However, being flexible the string vibrates also in parts of halves, thirds, quarters, and so on, and each of these segments produces a sound. These sounds are called partials, or overtones. This composite sound accompanies the fundamental and is called the overtone series."

Figure 4 below, reproduced from Jones, illustrates the composite vibration of a string in whole length, halves, thirds and quarters; the fundamental pitch and its overtone series.

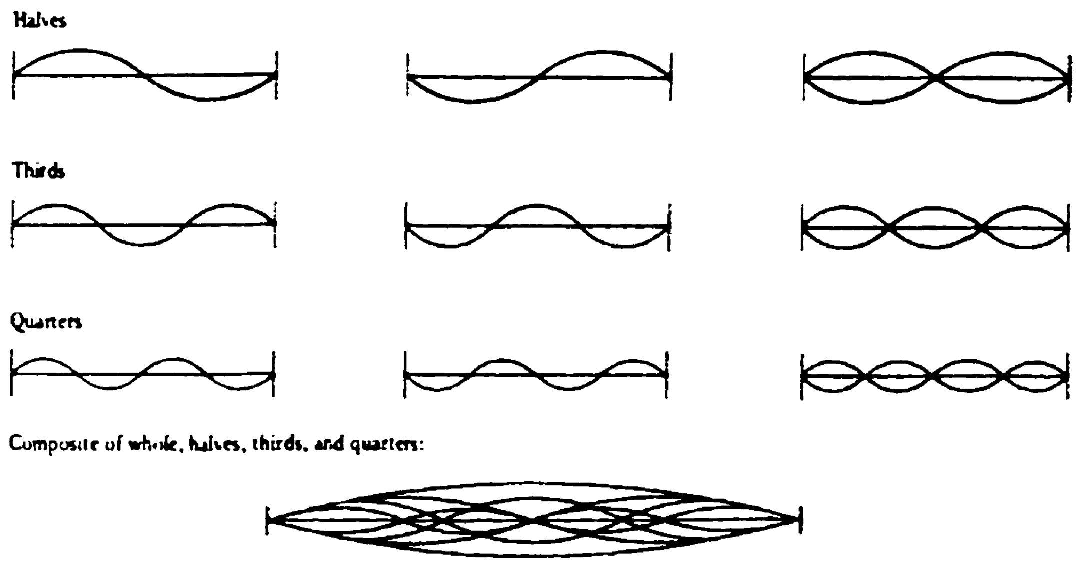


Figure 4.
Fundamental and overtone series of a string's vibrations.

1.3.2: The Quality of an Instrument's Sound

The overall sound produced by different types of instruments is determined by a number of factors. These include the nature of the vibrating mechanisms, the material that the instrument is made from, and the structure and shape of the instrument. The recognizable vibrations that instruments produce allow us to determine the sound of one type of instrument from another. It is how we discern the sound of a flute from the sound of a piano, for example. Within the range of sounds produced by a type of instrument, there are many subtler differences in sound that distinguish one specific instrument of that type from another. These subtler differences determine the quality of an instrument's sound.

These differences are not always hard to detect. One instrument's sound may not be as clear, or resonate as well as another's. Or an instrument may not be able to produce the volume of sound that another can. These differences, assuming a reasonable similarity of design, can be attributed to the inherent acoustic characteristics of different types of materials that go into the construction of an instrument. The quality of an instrument's construction also determines its acoustic abilities. Instruments that are poorly constructed, or are made from substandard materials usually produce poorer quality sound and are considered inferior instruments.

Some differences are not so easily detected and are usually only discernible to a trained ear. The differences between an acceptable, a good, and an exceptional sounding musical instrument may be lost on the common listener, but to people with extensive knowledge of the sound of instruments, these differences are critically important. Nuances of sound in an instrument's tone, clarity and resonance allow players to rate its quality, from bad to good. Some instruments attain legendary status for their quality of sound. Violins built by Nicolo Amati (1596-1684) and his pupil, Antonio Stradivari (1644-1737) are possibly the best examples of this.

There are differences in the quality of sound produced by electric stringed instruments as well, though these differences are less significant than they are in acoustic instruments. Electric instruments are components of larger systems, which include the pick-ups, amplifiers and other elements. Every element of one of these systems has an effect on the overall sound produced by the system, and the combination of all these effects determines the quality of the system's sound.

There are still discussions about the relative merits of one electric instrument over another, similar one. The focus of these discussions is usually the materials and construction that have gone into an instrument and, maybe even more importantly, the electronics and accessories an instrument has; for example, the type, quality and number of pick-ups used in the instrument.

Electric guitar players argue endlessly about which instrument is better: the Fender Stratocaster or the Gibson Les Paul. The Gibson is made of heavier, denser wood and resonates a little more than the Fender. This resonance is transmitted back into the instrument's strings, producing subtle overtones that give the instrument, it is believed, a "warmer" sound.

The choice of pick-ups is an important consideration for electric stringed instrument players. There are a variety of pick-ups available for stringed instruments but most players prefer humbucking pick-ups. Humbucking pick-ups are double-coil magnetic pick-ups that eliminate stray electrical waves from fluorescent lights, automobile spark plug systems, radio stations and other sources by putting two interfering signals together out-of-phase. Pick-ups are discussed in further detail in section 2.4 of this document.

1.4: SUMMARY

Sound is produced when an elastic material vibrates and its vibrations are transmitted into the surrounding air. Each vibration consists of an area of high pressure and an area of low pressure. The number of vibrations per second is the frequency of a sound. As the number of vibrations per second increases, the pitch becomes higher. The strength, or amplitude, of a sound determines its volume. Complex, irregular vibrations produce noise while regular vibrations produce tones of a discernible pitch.

Music is the organization of sounds within a time framework. Music can take many forms, and is usually performed to express an idea or an emotion. In this regard, music can be seen as a form of language. Musicians are the people who speak this language, but we all comprehend it to some degree.

Music produces specific physiological responses in people. Listening to and thinking about music causes activity to occur in the listener's brain. Blood flow activity increases in different areas of the brain according to the kind of music listened to: pleasing or disturbing. Elements of music: melody, harmony and rhythm, also produce different responses in the listener's brain.

Musical instruments are mechanisms that produce and control vibrations. Instruments can be categorized according to the means by which they produce these vibrations. Acoustic instruments employ vibrating strings, vibrating air columns and vibrating bars, plates or membranes. Electric instruments produce vibrations the same way acoustic instruments do, but are components of larger systems with other elements that also affect their sound.

The quality of an acoustic instrument's sound is determined by its materials and the degree of craftsmanship that went into its making. Nuances in an instrument's tone, clarity and resonance set it apart from other instruments of the same type. The craftsmanship and materials that go into an electric instrument also help determine its quality of sound, but this is also dependent on the other elements of the system that the instrument is a part of, such as the electronics.

2.0: A BRIEF HISTORY of STRINGED INSTRUMENTS

2.1: EARLY ACOUSTIC STRINGED INSTRUMENTS

There are many different kinds of stringed instruments. While it might make for interesting reading, it is, unfortunately, beyond the scope of this document to provide an overview of the history of all stringed instruments. The focus of this section, therefore, will be the stringed musical instruments that are played with a bow, as the history of these instruments is deemed the most relevant to the main objective of this project: the design of an electric upright bass.

It has been suggested that all our modern musical instruments are descendants of primitive artefacts. Dried, hollowed-out bones may have been used as the first flutes. Dried gourds could have been used as rattles and shakers. A skin or membrane stretched across the mouth of a simple pot would have made an excellent drum. The string of a hunting bow may have been the earliest plucked instrument.

The structure and design of early stringed instruments had certain, basic elements in common. They consisted of animal gut strings stretched across a hollow, wooden body and along a slightly rounded neck that protruded from the body. When vibrated, the strings produced sounds that reverberated and were amplified inside the hollow body. The pitch of a string was changed by the player shortening its vibrating length by pinching the string down onto the neck. The strings were vibrated by bowing, plucking or striking.

Paintings from the Middle Ages, 476-1000 A.D., reveal early evidence of two distinct types of stringed instruments in western culture. One type was held between the legs when played (da gamba). The other was supported on the shoulder or arm (da braccio).

2.1.1: The Viol

A nine-string viol is described in the very first treatise on musical instruments; Sebastian Virdung's Musica getutscht, of 1511. Martin Agricola's Musica instrumentalis deudsch, 1529, describes five and a six-string viols. The Regolo Rubertino, published by Silvestro Ganassi in 1542, describes and illustrates the viol and provides instructions on how it is to be played.

True viols are always held between the knees while being played. The instrument has a flat back and sloping shoulders. Its fingerboard is fretted, like the fingerboard of a guitar. Early viols had five, six or seven strings, but six-stringed instruments were most common. It is played with a bow, which is held in an underhand grip, allowing the player to adjust the tension of the bow hair with the middle finger.

Both Ganassi and Agricola refer to the treble viol, the tenor viol and the bass viol as being the most important sizes of the instrument. There are, in all, eight types of viol which vary in size and in how they are tuned. They are, from smallest to largest:

1) The **Pardessus de Viole** is tuned a fourth above the treble viol and is often missing the lowest string. This viol developed in France in the early 1700s and was a popular amateur instrument.
2) The **treble viol** is the smallest of the common viols and its six strings are tuned D, G, C, E, A, D. It takes the higher voices in consort (group) music.
3) The **alto viol** is a small tenor viol tuned one tone lower than the treble.
4) The **tenor viol** takes the middle voices in consort music and is usually tuned G, C, F, A, D, G.
5) The **lyra viol** is midway in size between the tenor and bass viols.
6) The **bass viol** is often referred to as the viola da gamba. It takes the deeper voices in consort music but came into its own as a solo instrument in the Baroque era (1600-1750 A. D.). It is usually tuned D, G, C, E, A, D, but may have a seventh string.
7) The **great bass viol** is tuned like a seven-string bass viol without the top D, or with the C tuned to B.
8) The **violone** is tuned an octave below the bass viol. **The violone is the predecessor of the modern double bass.**

Figure 5.
Viol, circa 1600AD.

The viol was a popular domestic instrument in the 17th and 18th centuries. A proper education included lessons on how to play the instrument in a group, or consort, of viols. This was particularly true in England and France, where the viol was favoured over the violin.

By the time the bass viol emerged as a solo instrument in the mid-1600s, the overall popularity of the viol had begun to decline. Even so, music written specifically for the viol was still being produced in Germany as late as 1750. **Figure 5** shows a viol built by the Venetian maker, Antonio Ciciliano, around 1600 A.D.

2.1.2: The Violin

Violins began to appear in Italy in the early 16th century. Violins were played on the arm (da braccio) as opposed to viols, which were held between the knees (da gamba). The first known maker was Andreas Amati (1505-1580), who founded a famous school in Cremona. His grandson, Nicolo Amati (1596-1684), is one of the most renowned violin makers in history. His students, Andreas Guarneri and Antonio Stradivari, are celebrated violin makers, or luthiers, in their own right. The earliest surviving violins come from areas near Milan in northern Italy, and from Venice. These were the principal violin making regions during the 16th and 17th centuries. **Figure 6** shows a violin attributed to Nicolo Amati, circa 1650. The violin is tuned G, D, A, E.

Figure 6.
Amati violin, circa 1650.

The violin originally had three strings but four-stringed instruments were common by the mid-1500s. In his book, [6]Robert Dearling describes the construction of a violin, which has changed little since the 16th century.

"The front (or belly), the back and the middle section (or ribs) are made as separate pieces from a soft wood, such as spruce. The bottom, top and corners of the rib section are reinforced by blocks. The belly is pierced by two sound holes shaped like a cursive 'f', and a bass bar is attached to its underside, running parallel to the lower strings, its position determined by one foot of the bridge which supports the strings. Underneath the opposite foot of the bridge is the soundpost, which runs vertically towards the back of the instrument. At one end of the neck, which is made separately of a harder wood, is the scroll, containing the tuning pegs. The strings run from these across the fingerboard, placed

[6] Robert Dearling. The Encyclopedia of Musical Instruments, pp.51.

on top of the neck, over the bridge to the tail piece which is looped around the end button. The start of the fingerboard is marked by the nut. The inlaid decoration around the edges of the belly and back is known as *purfling*."

The violin and its larger family members, the viola and cello, grew in popularity across Europe, practically displacing the viol and its associated instruments. The French king, Louis XIII, established a string orchestra featuring violins in his court in 1626. The practice was carried on by his successor, the influential Louis XIV, and was adopted in the English court of Charles II. The violin's expressiveness and versatility made it attractive to composers of chamber and orchestral music in the early Baroque era.

2.1.3: The Viola

The viola was established as the alto or tenor member of the violin family by the end of the 16th century. To be as acoustically perfect as the violin, the viola needed to be half as long again. This made the instrument practically unplayable on the shoulder. Compromises in size were made, resulting in instruments ranging in length from 38 to 45 centimetres (15-18 inches). The absence of a standard size impeded the early emergence of the viola as a solo instrument as compared with the cello or the violin. The viola is tuned C, D, G, A; a fifth below the violin.

The name viola is Italian for viol, and this has resulted in some confusion. In the 16th and 17th centuries, it was known as the viola da braccio, to designate the family of instruments that it belonged to.

2.1.4: The Cello

The cello is actually called the violoncello. Violoncello literally translates as 'little violone.' The violone is the double bass. The cello was initially known as the 'basso di viola da braccio,' indicating that it was the bass instrument in the arm-held violin family, even though early cellos were held between the knees like a viol. The term, bass violin, was used in England for most of the 17th century to describe the cello. In France, it was the basse de violon.

A three-stringed version of the cello is first described in Agricola's Musica instrumentalis deudsch (1529). A fourth string was eventually added. The earliest four-stringed cellos were originally tuned B flat, F, C, G, but this was changed to the modern tuning, C, G, D, A, as early as 1530. The cello is tuned in fifths like the violin and viola but its larger size requires a different fingering pattern. In the 1720s, the left hand position on the instrument was flattened somewhat, allowing players to use their left thumb as a bar across the strings, like the 'capo dastro' on the guitar. Around this time, the size of the instrument was standardized at about 75 centimetres (30 inches). This development is attributed to Antonio Stradivari. By the early 19th century, the cello was no longer held between the knees but rested on the floor, supported by an end pin. The bow used to play the cello was also modified around this time, making it thicker and shorter than the bows used to play the violin or the viola.

2.1.5: The Double Bass

The double bass is the only member of the modern stringed instrument family that is directly descended from the family of viols. Some double bass viols have survived from the early 16th century. Most of these have six strings and may or may not have the fretted neck of the viol. They appear in a variety of shapes, sizes and tunings. The four-stringed instrument became popular in Germany, Austria and France in the 18th century. These models were tuned in fifths, an octave below the cello. Figure 7 shows a double bass built around 1840. Note the sloping shoulders that distinguish it as a member of the viol family. Some modern instruments have rounded shoulders, like a violin.

Figure 7.
Double bass, circa 1840.

The double bass is tuned in fourths like a viol, rather than in fifths like a violin. This is largely due to the distances the left hand has to travel on the fingerboard (the span). Four-stringed instruments are tuned E, A, D, G, but some modern basses have a fifth string, tuned to C or B. 20th century composers have taken the low C string on the double bass for granted. A fifth string, tuned to low C, is preferred to simply tuning the E string down.

Most double basses retain the viol's flat back, especially those models with the viol's trademark sloping shoulders. There are significant differences in the sizes of double basses. The larger instruments stand a meter-and-a-half tall (60 inches) and the smallest are 120-125 centimetres (48-50 inches) tall. The string scale (the free string length) on a full-size double bass is 112 centimetres (44 inches). The string scale on a three-quarter size double bass is 103-108 centimetres (41-42 1/2 inches). The three-quarter size double bass is most popular today because it is easier to play and transport. Also, the large, solid pieces of good quality wood that luthiers favour in the construction of the front (belly) and back of an instrument are increasingly hard to come by. The size of available wood often dictates the eventual size of an instrument.

Bass bows have always been shorter and thicker than other bows. Shorter bow hairs bend less than longer ones, allowing the player to apply greater downward pressure onto the strings. This is necessary because bass strings are larger and require more effort to vibrate than the strings of other instruments. Doubles basses have traditionally been played with the underhand bowing technique but many players today favour the overhand technique used in bowing the violin, viola and cello.

2.2: MODERN ACOUSTIC STRINGED INSTRUMENTS

The design of acoustic stringed musical instruments played with a bow; the violin, viola, cello and double bass, has changed very little over the years. Their sizes and shapes may vary slightly from one to the next within a category of instrument, but this is largely due to the fact that each instrument is crafted by hand and is not subject to the strict mechanical processes we apply to the production of standardized products.

Craft is still a vital element of musical instrument production. Craft can be defined as a low-volume method of production in which the end result is not predetermined. There is an element of risk in craft: the risk that a product may not turn out entirely as intended or desired. Materials and the human manipulation of materials are the basic components of craft and the quality of both that go into the construction of a product largely determine the quality of the product's outcome. This method of production gives each instrument a similar overall appearance, yet retains, in its details, a quality of individuality. The individuality of an instrument, in its appearance, feel or sound, is what draws a musician to an instrument, or causes him or her to reject it.

Modern stringed instruments are made the way they have always been made, although power tools have replaced some traditional hand tools in this process. The shape and size of instruments and the materials used in their construction are fairly standard today, although many instruments are built to the specifications of their intended users.

Modern violins have slightly longer necks, their strings are made of nylon instead of gut, and the hairs on the bow are tighter. These design changes provide the modern violin with a more powerful sound. Modern violas, like the violin, are stronger in tone and better suited to play more demanding parts. The replacement of the gut strings and the development of an improved bowing technique make the modern cello more powerful and richer-sounding than its ancestor. The modern double bass has an overall stronger tone but has changed little otherwise. The C string is less common than it once was.

Classical music consists of parts written for specific instruments and these demands are largely responsible for the ongoing production of these instruments. As classical music enjoys its current upswing in popularity, new students require new instruments. Luthiers are as busy as they have ever been, although there may be fewer of them. There are no recognized centres of musical instrument production as there once were but certain countries are acquiring reputations for excellence in instrument making. The best double basses made today come from Germany. China has established itself as the top violin-producing nation in the world.

Stringed instruments have all but been replaced by the ubiquitous guitar in popular music today. Yet even here, stringed instruments are making a comeback of sorts. The violin is a common instrument in folk music and in country-and-western music. The use of the violin in jazz music was pioneered by artists like Stephane Grappelli (1908-1998). The double bass is a mainstay of jazz music and is becoming more popular in rock music as well.

2.3: EARLY ELECTRIC STRINGED INSTRUMENTS

2.3.1: Early Performing and Recording Requirements

Dance bands and orchestras were popular forms of entertainment in the early 20th century. These bands often resembled symphony orchestras in their array of instruments: piano, brass, woodwinds, strings and percussion. Whatever their exact make up, they usually included at least one acoustic guitar and one double bass. These two instruments do not produce a great deal of volume on their own and were often drowned out by the sound of a full orchestra. This problem presented itself in live performance, as well as in the recording studio. People started looking into ways to amplify the bass and guitar.

2.3.2: Amplifying Acoustic Instruments

Acoustic guitarists and bass players at first played directly into microphones, which translated their sounds into electrical signals that were sent to an amplifier, amplified and broadcast over a speaker. This method is sometimes still used today. Modern microphones work on the same basic principles they did in the 1920s. Vibrations in the air cause an air-sensing diaphragm in the microphone to move. The movements of the diaphragm are converted into an electrical signal which can be transmitted to an amplifier for amplification. The problems with this method are 1) that the instrument cannot be turned even slightly away from the microphone without reducing volume, and 2) that sensitive microphones can pick up unwanted sounds within their proximity. Microphones could not be placed inside an instrument's hollow body because the sound inside an instrument is different than the sound outside an instrument and it is the outside sound we are familiar with.

In the early 1920s, people tried taking microphones apart and mounting their air-sensing diaphragms directly onto the vibrating surfaces of instruments. The vibration of the instrument's body became the source for amplification. These types of pick-ups became known as contact pick-ups, because they have a vibration-sensing element "in contact" with a vibrating surface. These early experiments did not work particularly well because microphone design had not been perfected and there were numerous problems with the components.

2.3.3: Early Electric Guitars and Basses

In 1924, Lloyd Loar, an engineer with the Gibson Guitar Company, designed an improved contact pick-up. The vibration sensing elements were dollar-sized copper disks in a bakelite case. The guitar he used to test his pick-up on was possibly the first ever electric guitar. The same year, he built an odd-looking upright bass that used his new pick-up. This is generally acknowledged as the first ever electric upright bass. Unfortunately, his pick-up was prone to picking up static electricity and absorbing moisture, which caused it to behave erratically. None of these designs went into full production.

In 1931, George Beauchamp and Paul Barth designed a solid aluminum guitar for the Rickenbacker Guitar Company, incorporating the first documented design of a magnetic pick-up (patented in 1937). The first magnetic pick-ups far outperformed the early contact pick-ups. Magnetic pick-ups differ from contact pick-ups in that there is no physical coupling between the pick-up and the source. The different types of pick-ups and how they work are discussed in section 2.4 of this document.

In 1932, the Dopera brothers, founders of the Dobro Guitar Company, and guitarist Art Simpson, collaborated on an acoustic guitar with magnetic pick-ups built into it. This "hollow-body electric" is generally considered to be the first commercially-available electric guitar. Later the same year, Dobro began making one-piece cast aluminum electric Hawaiian guitars.

Another Dobro venture was Valco. This Chicago-based company claimed to make the world's first modern electric guitar. Founded by Louie Dopera, Al Frost and Victor Smith, it was the successor to the National and Dobro companies.

The Gibson Guitar Company began to make electric Hawaiian guitars and electric banjos in 1934. In 1937, they introduced a hollow-body electric guitar that caught on with the public. The Gibson ES-150 guitar with the Charlie Christian pick-up was the first electric guitar to win both the respect of musicians and the approval of audiences.

Dobro and Gibson's electric Hawaiian guitars were solid-body designs. Paul Bigsby, an independent inventor and musician, built the first solid-body Spanish-style guitar in 1947, incorporating his own magnetic pick-ups. This instrument ushered in the era of the modern electric guitar.

In 1948, the Fender Company introduced the world's first mass-produced, Spanish-style, solid-body electric guitar. The Broadcaster had a six-magnet magnetic pick-up; one magnet per string. For legal reasons, the company changed the name of the guitar to the Telecaster. Over fifty years later, the Telecaster and its progeny, the Stratocaster, are still two of the top-selling guitars in the world. By the early 1950s, Fender was mass-producing electric bass guitars as well.

2.4: PICK-UPS AND AMPLIFIERS

To gain a thorough understanding of the development of electric instruments, it is helpful to learn about pick-ups and amplifiers, what kinds there are and how they work. Pick-ups and amplifiers, along with the instrument, are the main components of an electric instrument system. The characteristics of each component in this system affect the sound produced. The pick-ups and amplifiers are the electronic components in the system. Most research and development work done in the music industry today is in the area of electronics. It is beyond the scope of this paper to provide an overview of all the electronic features available to the musician but it is helpful in understanding electric instrument history to know the basics: what types of pick-ups and amplifiers there are and how they work.

2.4.1: Early Development in Pick-Ups

The earliest types of pick-ups were contact pick-ups. Actually, these were modified microphone parts; air-sensing diaphragms that were attached directly to the vibrating surfaces of musical instruments. These first appeared in the early 1920s.

George Beauchamp and Paul Barth designed the first magnetic pick-up in 1931 for the Rickenbacker Guitar Company. The first magnetic pick-ups were simple bar magnets wound with copper wire. Beauchamp and Barth's design used a tungsten steel magnet. Rickenbacker did not pursue the development of this pick-up because of the high cost of tungsten steel.

The Broadcaster, the world's first mass-produced electric guitar, introduced by the Fender Company in 1948, used a magnetic pick-up with six, cylindrical alnico magnets, wound with copper wire. One magnet was dedicated to each string of the instrument.

In 1952, The Gibson Guitar Company introduced an electric guitar designed by Les Paul, a renowned guitarist. The Les Paul guitars had single coil magnetic pick-ups, nicknamed "soap bar" pick-ups because of their shape. In 1956, these were replaced by humbucking pick-ups. These are the most widely used type of pick-up today. Les Paul guitars, largely unchanged since 1952, are still one of the top sellers in the music industry.

2.4.2: Types of Pick-Ups and How They Work

The basic function of a musical instrument pick-up is to convert a vibration into a corresponding electrical signal. There are two basic types of pick-ups: contact pick-ups and electromagnetic pick-ups. These types can be divided into further subcategories. Contact pick-ups can be condenser, dynamic or piezoelectric. Electromagnetic pick-ups can be single coil or double coil. There are low-impedance, mid-impedance and high-impedance single and double coil pick-ups. Contact pick-ups produce sound very much like the natural acoustic sound of an instrument.

Electromagnetic pick-ups produce an "electric" sound, like the sound of an electric guitar.

2.4.2a: Contact Pick-Ups

Contact pick-ups have a vibration-sensing element "in contact" with a vibration source. The vibration-sensing element is sensitive to air pressure and moves back and forth in unison with the waves of air pressure striking it. The vibration-sensing element is connected to an electronic device that converts this motion into an electrical signal. This signal then drives a loudspeaker back and forth in direct relationship to the original vibration. The three main types of contact pick-ups are condenser pick-ups, dynamic pick-ups and piezoelectric pick-ups.

The term condenser is applied to the phenomenon of two separated surfaces holding an electric charge. **Condenser pick-ups** employ two thin conductive plates separated by a small gap. When the pick-up is vibrated, the plates vibrate, causing a change in the distance between them. As the gap closes, electrical resistance is reduced and the current can flow more easily between the plates. The increased current flows in one direction. When the gap increases, electrical resistance increases and the current flow is reduced. The reduced current flows in the opposite direction. The resulting pulse of electrical current matches the pulse of the sound waves striking the vibrating element. The conductive plates only regulate the flow of the current. No current is actually produced by the plates. The current charge in the plates is supplied by a power source or may be permanently induced into the plates. An induced charge retained by the plates is known as an electret charge. The charge on the plates bounces back and forth when the plates vibrate, producing an alternating current corresponding to the original sound waves. **Figure 8** illustrates the main components of a condenser pick-up.

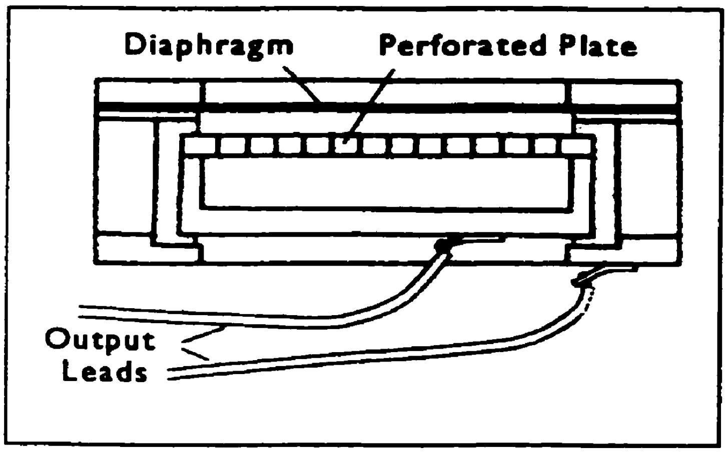


Figure 8.
Condenser pick-up diagram.

Condenser pick-ups work by regulating the flow of a current. **Dynamic** pick-ups actually create a current. Dynamic pick-ups are based on an old electrical principle: when a wire is quickly passed through a field of alternating magnetic currents, the wire will display a flow of electrical current through it. In dynamic pick-ups, an air-sensing diaphragm is connected to a cylindrical sleeve wound with thin copper wire. The wound sleeve fits around a cylindrical magnet. When air vibrations move the diaphragm, the sleeve moves up and down over the magnet. This back and forth motion causes a current to be created in the wire winding. This current mirrors the vibrations moving the diaphragm. It can then be directed to an amplifier, amplified and broadcast through a speaker. Figure 9 shows the components of a dynamic pick-up.

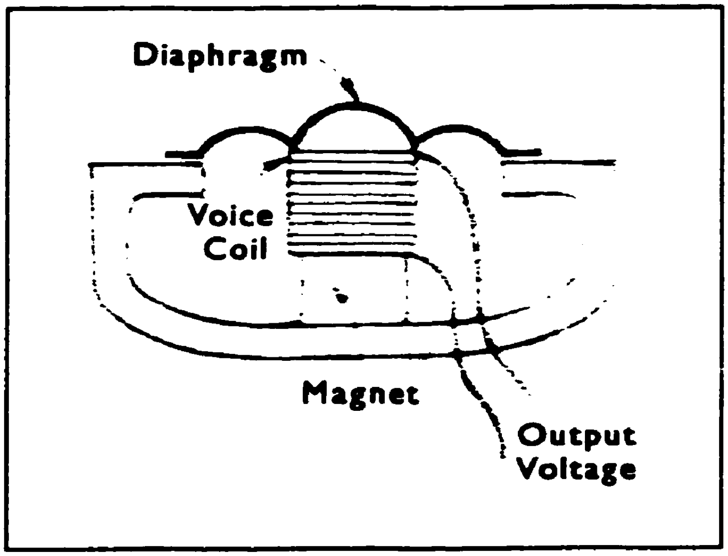


Figure 9.
Dynamic pick-up diagram.

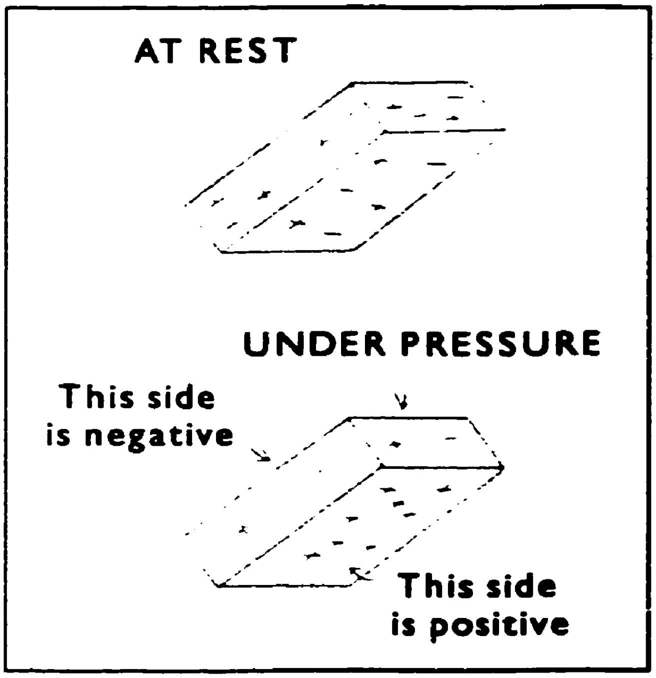


Figure 10.
Piezo crystals.

Piezoelectric pick-ups get their name from piezoelectricity. Piezoelectricity is the electrical charge induced in a crystalline substance through the application of pressure. Piezo is derived from a Greek word meaning "to press." The surfaces of a crystal contain evenly balanced and distributed positive and negative electrical charges. When the crystal is pressed in one direction, the electrical charges move from one surface to another, resulting in a greater number of positive charges on that side. When the crystal is pressed in the opposite direction, the current reverses and the positive charges move to the other side. A piezo crystal used as a vibration sensor will experience a change in current with each vibration pulse. The resulting current pulse exactly mirrors the vibration pulse. Piezoelectric pick-ups work best in areas of significant change in pressure and stress. In stringed instruments, these areas are the ones put under pressure by the tightened strings: the bridge and saddle. The electrical current output of piezoelectric pick-ups is very small and a pre-amplifier is usually required to produce adequate sound volume. Figure 10 shows the charges in a piezo crystal at rest and a piezo crystal under pressure.

2.4.2b: Electromagnetic Pick-Ups

Magnetic pick-ups and dynamic pick-ups both use electromagnetic forces, but a magnetic pick-up is not physically joined to a vibrating element like a dynamic pick-up is. In a dynamic pick-up, vibrating air causes a vibration-sensing mechanism to actually move. In a magnetic pick-up, magnetic motion is picked up, not air motion.

When an iron string vibrates over a magnet that is wound with thin copper wire, an electric current flows through the wire winding. The magnetically conductive iron string pushes and pulls the magnetic flux field of the magnet. When the string moves down toward the magnet, the current flows in one direction. When the string moves away from the magnet, the current flows in the opposite direction. The resulting alternating current directly corresponds to the vibrations of the string. This is the basic function of a magnetic pick-up.

Most commercially available magnets are man-made. A strong electrical current applied to a suitable material pulls its magnetizing forces in one direction, polarizing the material. Most magnets used to be made of iron but it has been replaced by other materials that retain a magnetic charge better. The properties of alnico, an aluminum, nickel, cobalt alloy, make it well-suited for magnetization. Alnico magnets are available in different alloy formulas and each formula has slightly different magnetic qualities. When used in a magnetic pick-up, an alnico 8 magnet will deliver a stronger treble response than an alnico 5 magnet. Ceramic magnets deliver even higher treble responses than alnico magnets. Ceramic magnets are replacing alnico magnets in pick-ups because they are more sensitive and cost less to manufacture.

Each magnet in a pick-up will have its own pole piece. The pole piece protrudes from one end of a magnet, its pole, and functions as an emanating point for the magnet's flux field, "aiming" it at the vibrating string. The pole pieces may be flat bars or adjustable screws or may be concealed inside the pick-up's casing. Even if a pick-up's magnets are not visible, every magnet in the pick-up will have a pole piece.

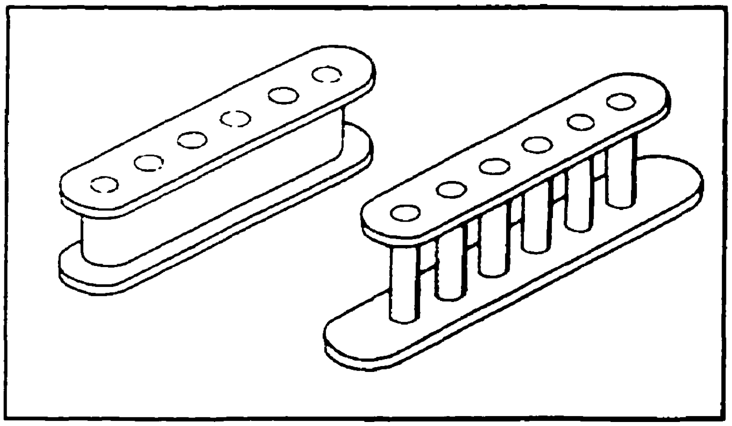


Figure 11.
Magnetic pick-up bobbins.

A typical six-string electric guitar **single coil magnetic pick-up** will contain six magnets in a bobbin, spaced the same distance apart the strings are, wrapped 6,500 times with 42 gauge copper wire. A single coil bass guitar pick-up will have four or five magnets, depending on the number of strings on the instrument. **Figure 11** shows two examples of pick-up bobbins, without magnets or windings. The more windings of wire there are around the magnets, the more the magnetic pulsations will be sensed. More windings increase amperage. Amperage is the quantity of an electrical current, measured in amperes. More windings mean more electrical current. The closer the windings are to the magnets, the more sensitive the wire coil will be. This is because the magnetic field of effect does not extend very far from a magnet. For these two reasons, very thin wire is used in the wire coils. It allows for a large number of windings close to the magnets without making the entire assembly too large. 6,500 windings of 42 gauge diameter wire is common on most single-coil pick-ups, though this varies between manufacturers. Copper wire is used because copper is an excellent conductor of electricity. The wire must conduct electricity like one long strand of wire, but thin copper wire is very brittle and unprotected coils are prone to breaking and shorting out.

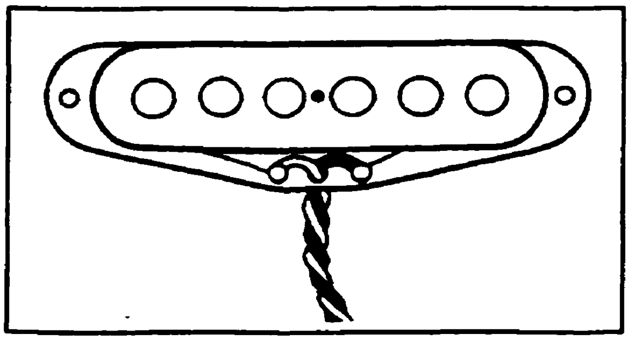


Figure 12.
Single coil pick-up.

Lacquer was once used as a protective coating on coils but it tended to crack and chip off. Today, a synthetic insulator is applied to protect the wire coils on a pick-up. **Figure 12** shows a single coil pick-up.

Single coil magnetic pick-ups work very well but present a problem because they tend to pick-up stray electrical signals such as those from fluorescent lights and radio stations. These unwanted signals are picked up and amplified along with the instrument's sound, producing a noticeable background hum. In 1956, Seth Lover, an engineer at Gibson, designed a hum-cancelling **double coil magnetic pick-up**. This design became known as the humbucking pick-up. **Figure 13** shows a double coil humbucking pick-up. A humbucking pick-up has two coils, wired together out-of-phase. This is the way it works. The magnets of one coil are positioned in opposite polarity to the other coil. This is to say that the tops of the magnets in one coil are magnetically north, the tops of the magnets in the other coil are magnetically south. When activated, the flow of electricity through these two coils is identical but opposite: out-of-phase. When the wave form of one current is at its peak, the wave form of the other current is at its lowest. When these two out-of-phase wave forms are combined, you would expect them to cancel each other out. Instead, only the hum is cancelled. In short, any signal (hum) seen by the coils is cancelled. Any signal (string vibrations) seen by the magnetic poles is accepted. **Figure 14** illustrates how a humbucking pick-up combines wave forms.

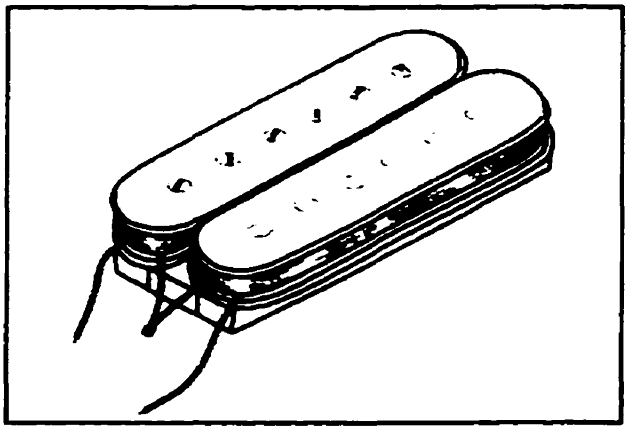


Figure 13.
Dual coil humbucking pick-up.

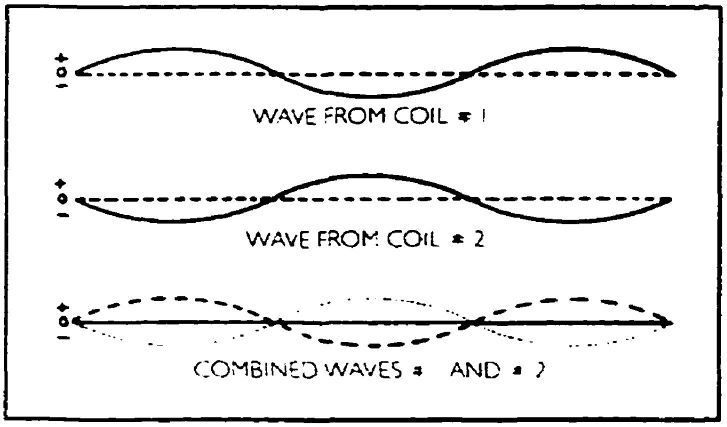


Figure 14.
How a humbucking pick-up combines wave forms.

A pick-up's electrical impedance has to match the impedance of the amplifier its signal is going to be sent to. Most pick-ups and amps today are low impedance. [7]Donald Brosnac provides an excellent explanation of impedance and its importance in his book, Guitar Electronics for Musicians. "Impedance is the resistance to alternating currents (resistance is the restriction of current flow) and the output of a pick-up is an alternating current. The measure of a pick-up's impedance is important because it reveals the tonal quality of a pick-up.

Impedance is determined by the constraining influence of a magnet's field on a coil. If the magnet is put in sideways instead of vertical, the magnetic field will form around a coil differently, and this will affect impedance. One problem with impedance is that as frequencies rise, trebles are impaired. This impedance/resistance problem is most evident in humbucking pick-ups since they use two coil bobbins. Humbucking pick-ups have more windings than single coil pick-ups and the added windings increase the impedance and resistance.

Generally, the minimum amount of windings are those windings which produce a needed impedance figure that is compatible with the amp being used. Since d.c. (direct current) resistance figures of pick-ups are fairly well correlated to the impedance (alternating current resistance) of most pick-ups, we can use resistance as an informative guide to a pick-up's behaviour. It certainly doesn't hurt that d.c. resistance is a lot easier to measure. Few people have the necessary equipment to measure a.c. resistance. Pick-ups with a resistance of 6,000 to 12,000 ohms are generally considered high impedance, whereas 1,500 to 4,000 ohms is generally referred to as mid-impedance. Pick-ups around 2,000 ohms could be plugged into a low impedance or a high impedance amplifier, but they are not quite at home in either because they are neither low nor high. Below 1,000 ohms is generally low impedance. For information about the impedance of a particular amplifier, check with the manufacturer."

The distance a string travels when it vibrates is greatest in the exact middle of the string. This travel distance decreases from maximum at the string's centre to minimum at either end (the nut or bridge). The location of the pick-ups on the strings of an instrument will affect the tone and the overall volume. Bass tones are reduced when the pick-up is moved closer to the bridge. Pick-ups further away from the bridge will produce a fuller, less treble sound. Some pick-ups are placed on an angle so the treble side of the pick-up is closer to the bridge than the bass side. Most electric stringed instruments have two or more pick-ups located at

[7] Donald Brosnac, Guitar Electronics for Musicians, pp. 16-17.

different positions on the strings to detect the different sound qualities of the strings at those locations. The player can select pick-ups by using a switch or can combine their effects into a blended sound.

2.4.3: Amplifiers

The function of an amplifier (amp) is to amplify the electrical signal from a pick-up and broadcast it over a speaker. To obtain the best possible sound, an amplifier's impedance should match the impedance of the pick-up(s) being used on the instrument.

The first amplifiers used vacuum tubes to amplify electrical signals. Vacuum tubes have a high impedance. Pick-ups built for use with high impedance vacuum tube amplifiers were also designed to be high impedance. Up until about 1970, nearly all amplifiers used vacuum tubes and so, accordingly, most electric instruments were high impedance units.

Leo Fender, founder of Fender Guitars, is largely responsible for the development of guitar and bass amplifiers. His early tube amp designs had a unique "electric" sound that was very popular. Fender still makes tube amps today that are similar to his early designs.

After 1970, manufacturers started using transistors in amplifiers in place of vacuum tubes. Solid state (transistor) electronics are basically low impedance and most electric instruments made after 1970 use matching low impedance pick-ups.

There are two main types of amplifiers: guitar amps and bass amps, although amplifiers for other instruments are available. Each amplifier is designed for the frequency range of the instrument it is to amplify. This is why bass guitars do not sound very good when played through a guitar amp and vice versa. Amplifiers are usually self-contained units that may or may not include a speaker or set of speakers in a cabinet. Speaker cabinets are sometimes separate units, especially bass cabinets, because larger speakers are required to handle low bass frequencies. All amplifiers include a power switch, a power source with an electrical cord, one or more phono jacks for plugging in the instrument, and basic volume and tone controls. Many offer added features and special effects. Examples of common additional amplifier features are reverberation: an echo effect, and EQ (equalization): limiting the band width of certain frequencies within the sound.

2.4.4: Speakers

Speakers are another important component of an electrical instrument system, and are usually considered, because of the need for electrical compatibility, a subcomponent of the amplifier. The sound produced by the speaker is the sound that we hear in the end. Speakers and speaker cabinets come in many shapes and designs. Smaller speakers generally give higher, crisper tones. Larger speakers tend to give solid, lower tones. Home stereo speakers cannot take the demands placed on them by electric instruments. Bass instrument systems require larger speakers and speaker magnets to handle the low frequencies generated by the instrument.

2.5: MODERN ELECTRIC STRINGED INSTRUMENTS

There is an overwhelming amount of electronic technology available to musicians today. To take advantage of most of this, a string player needs an electric instrument; that is, an instrument with pick-ups to convert the vibration of its strings into an electrical signal. Manufacturers have been making electric guitars and bass guitars for decades but the "electrification" of other stringed instruments has taken longer to occur. The development and commercial production of electric violins, violas, cellos and basses has only been underway since about 1980.

2.5.1: Electric Guitars and Bass Guitars

Electric guitars and bass guitars have not changed a great deal outwardly since the 1950s. Improvements have been made in their electronics but they basically still look, feel and work like they always have. Many experiments have been put forward but these have been largely unsuccessful. Some instruments are now available in new materials, like carbon fibre, and some strings are now being made of new composite materials.

One of the most successful recent design innovations in electric guitars is the Steinberger Guitar. Ned Steinberger, an industrial designer, moved the tuning machines away from the end of the guitar neck and placed them at the bridge end, effectively doing away with the peg head (the structure at the end of the guitar neck that holds the tuning pegs or tuning machines). He also did away with most of the solid wood body, which has more to do with tradition than the production of sound. These changes dramatically improved the balance of the instrument (the peg head end of most electric guitars tends to want to drop when worn on a strap over the shoulder and must be supported by the player's fingering hand). He also designed a bass guitar on the same principles (Figure 15). The bass and guitar are both made from a graphite/carbon composite material. Both instruments proved highly popular with the public and Steinberger eventually sold his designs to the Gibson Guitar Company. Today, he markets a line of his own instruments, including one of the most successful upright electric basses.

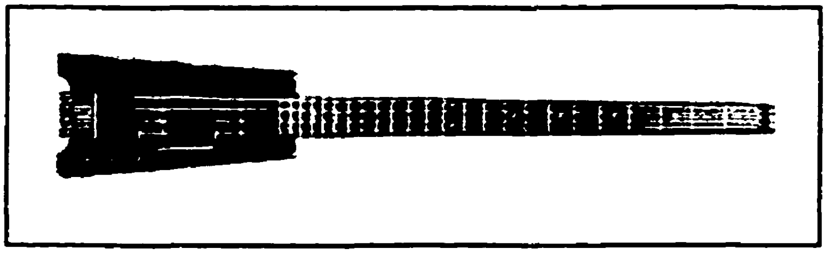


Figure 15
Steinberger electric bass guitar.

The most significant development in electric bass guitar design has taken place only recently. The electric bass guitar has traditionally been a four-stringed instrument but five-stringed basses have surged in popularity lately and are just as common now as the four-string version. Six and seven-stringed basses are also commercially available. **Figure 16** shows an example of a five-stringed electric bass guitar.

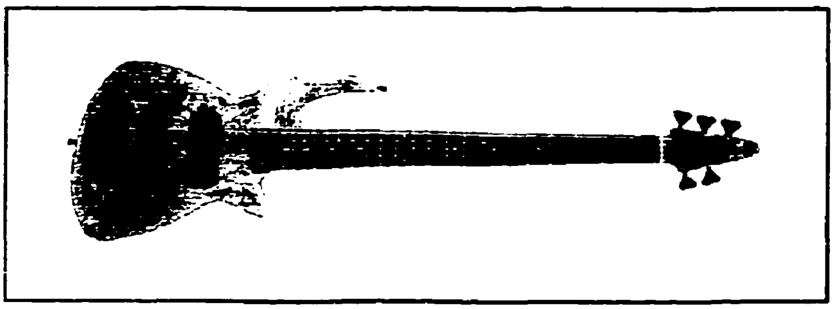


Figure 16.
5-string electric bass guitar.

2.5.2: Electric Violins, Violas and Cellos

Acoustic violins, violas and cellos have had pick-ups clipped, glued and taped onto them for years. In the last fifteen years, some manufacturers have developed strictly electric versions of these instruments. The characteristics of electric violins, violas and cellos are that they have pick-ups built right into their construction. Hollow bodies are unnecessary on these instruments and most of them, while retaining the basic shape of the instrument and the relative position of the player to the strings, have reduced or redesigned the body.

The elimination of the need for a hollow body to amplify their sound opens up a world of design possibilities for these instruments. **Figure 17** below shows a Zeta electric violin, **Figure 18** shows a Jensen electric viola and Figure 19 shows a Jensen electric cello. These designs illustrate the kinds of changes in formal elements that manufacturers are giving these new instruments.

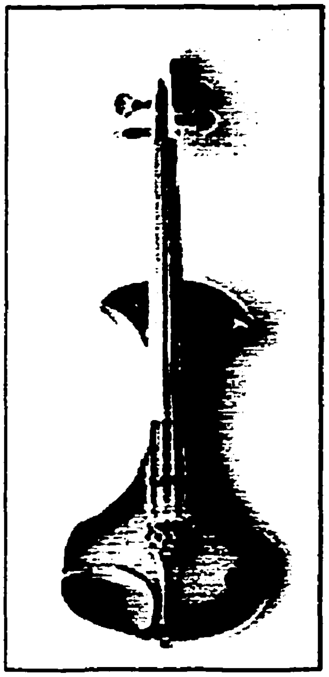


Figure 17.
Zeta electric violin.

The Zeta electric violin still resembles an acoustic violin but the Jensen viola and cello are visually very abstract. The string lengths and their positioning, and the shape and size of the necks on these instruments are the same as on acoustic instruments. In this way, a musician trained on an acoustic instrument is able to pick up and play its electric cousin with a minimum amount of difficulty. Some electric violins, violas and cellos have also been adapted for MIDI applications.

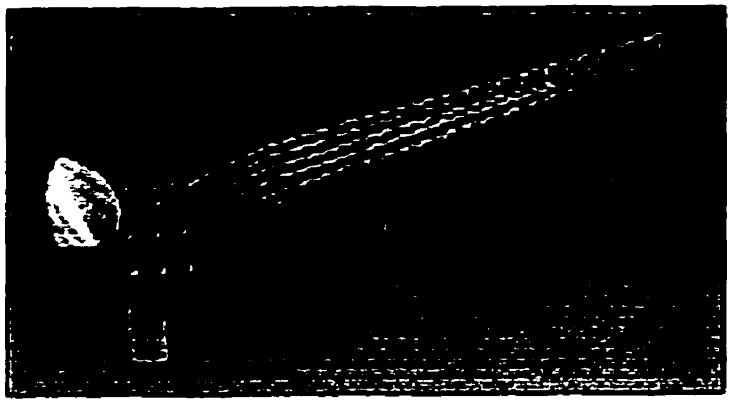


Figure 18.
Jensen electric viola.

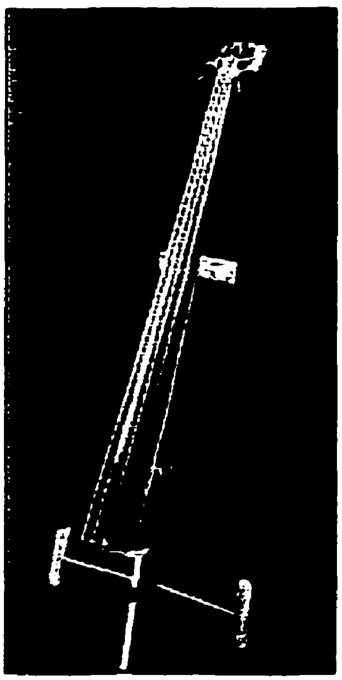


Figure 19.
Jensen electric cello.

2.5.3: Electric Upright Basses

Of all the stringed instruments that have been electrified, besides the guitar and bass guitar, the upright bass has received probably the most attention. This is due to the prevalent use of a bass instrument in popular music. Most popular music does not contain parts for violins, violas or cellos, but a bass is deemed essential. Acoustic bass players looking for the creative possibilities offered by an electric instrument, or bass guitar players looking for an alternative to the common bass guitar, have created a demand for electric upright basses. The design solutions put forward vary considerably. Most have eliminated or reduced the hollow body of the acoustic instrument. Many retain the string length and positioning, and the neck shape and size of an acoustic bass, while others offer shortened string scales and neck shapes and sizes designed to facilitate a musician trained on a bass guitar converting to an upright instrument. Some electric upright basses have also been adapted for MIDI applications.

Most electric upright basses are fretless, unlike most electric bass guitars, because of associations between upright basses and their sound. We expect a fretless sound to come from an upright bass instrument, acoustic or electric. There are a variety of solid and semi-acoustic (reduced hollow body) models of electric upright basses and, for the most part, they are all made out of wood. Not every electric upright bass can be played both arco (bowing) and pizzicato (plucking). One assumes that because the bass is usually only played with a bow in classical music, and because classical music largely restricts itself to acoustic instruments, that bowing capability on an electric upright bass is not essential. Nonetheless, many manufacturers have made determined efforts to make their instruments playable by both methods. Reviews and product profiles in trade publications indicate that while most electric upright basses can reproduce a good pizzicato acoustic bass sound, most are not capable of reproducing a good arco acoustic bass sound. Some manufacturers, like NS Design and Messenger, have designed and produced their own pick-ups to address this problem. The Messenger electric upright bass appears in **Figure 20.**

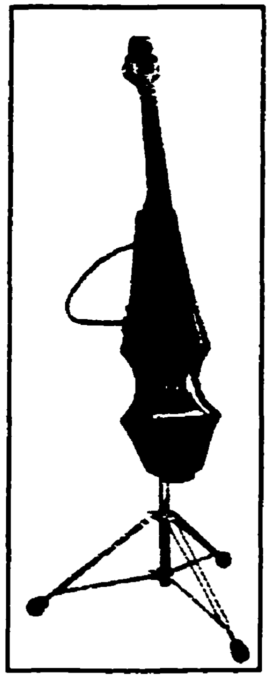


Figure 20. Messenger electric upright bass.

There are a number of different types of pick-ups used on electric upright basses. Some manufacturers have designed and built their own. Contact pick-ups seem to provide the best results. Many electric upright basses have piezoelectric pick-ups under one foot of the bridge. When the instrument's strings are tightened they push the bridge down onto the instrument, pressing the crystal element in the pick-up. Piezoelectric pick-ups provide a natural, acoustic sound. One manufacturer, Barbieri, makes a bridge with piezos built right in, located in the grooves at the top of the bridge where the strings sit. Each groove has two piezos; one at the bottom of the groove and one at the side of the groove. The bottom piezo is meant to react when the string is played pizzicato and vibrates up and down. The side piezo is meant to react when the string is played arco and vibrates from side to side. Barbieri pick-ups are the most highly regarded upright bass pick-ups, and they are also the most expensive. The NS Design electric upright bass uses specially-designed magnetic pick-ups, embedded in the instrument under the strings. Surprisingly, these are reported to deliver a very natural, acoustic sound.

Modern electric upright bass designs seem to reflect the current trend in electric bass guitars towards having more than four strings. Many electric upright basses are available in four, five and six string models. Most electric upright basses are designed to be balanced upright while being played, or can be connected to a stand. Most take advantage of commercially available music stands. Not to be confused with sheet music stands, these music stands are heavy-duty, tubular, telescoping metal structures with three or four collapsible legs, that hold microphones, drums, amplifiers and other musical equipment. They are usually chrome-plated. No manufacturer produces a stand specifically designed for their instruments. Commercially available music stands undoubtedly work very well but often clash aesthetically with the instruments they support.

2.6: ELECTRIC STRINGED INSTRUMENTS and MIDI

2.6.1: An Explanation of MIDI

MIDI is an acronym for Musical Instrument Digital Interface. MIDI began in the 1980s as an agreement among electronic musical instrument manufacturers to standardize the hardware and software connections on their equipment. With MIDI, different brands of electronic instruments and other components can be linked together in whatever configuration the consumer chooses. MIDI is digital technology and every component in a MIDI configuration requires a microprocessor. Typical components in a MIDI system include data banks of musical voices or voice-generating engines, sequencers to provide a pattern or structure for the sound produced, and a controller, usually a musical keyboard.

2.6.2: Controlling MIDI With Stringed Instruments

As they cannot produce any sound on their own, stringed instruments can only function as controllers in MIDI systems. A musician plays a stringed instrument by vibrating its strings. The strings vibrate at a frequency that produces a discernible pitch. Pick-ups convert this frequency into an electrical analog signal which can be converted into digital information by a MIDI microprocessor. This is known as pitch-to-MIDI conversion. The converted digital information can then be sent to other MIDI components where it can access voice banks or trigger other tasks to be performed. A stringed instrument, when played through a MIDI system, can be made to sound like anything imaginable. Any sound that can be digitized and stored in a computer can be accessed and controlled by the instrument in the system.

The trouble with stringed instruments as controllers comes in the pitch-to-MIDI conversion process. Because of the rapidly changing frequencies in music (data), pitch-to-MIDI conversion requires a very powerful microprocessor (data processor). String pitches are particularly demanding to convert, as a string experiences a constant change in frequency as it vibrates from attack, through decay, to rest. The more variations in frequency there are, the more computing power required. Microprocessors powerful enough to convert string pitches to MIDI are becoming increasingly affordable and MIDI technology itself has improved. Today it is possible to convert most stringed instruments into MIDI controllers. It was not always so. One early stringed instrument controller was the Roland Electric Guitar Synthesizer. Its microprocessor was powerful enough to convert clean, sustained guitar string signals into MIDI but it became confused when there was too much going on. This guitar had a brace that ran from the body to the peg head, bracing the neck so it could not be bent in the normal course of playing, which would further complicate the frequencies being sent to the microprocessor.

Today, many instruments; percussion, strings, even wind instruments, have MIDI-controlling capabilities. Outwardly, they do not look different from other instruments except for their electrical connections, which are larger to accommodate multi-conductor cables. Clevinger recently introduced a MIDI-equipped six string electric upright bass. This bass features a specially designed RMC Polyphonic Pizz Arco bridge. When connected to its Axon AX-100 MIDI Interface, it can communicate with any MIDI sound module. The Zeta Quartet Series of instruments features MIDI-equipped violins, violas and cellos.

2.7: SUMMARY

Two distinct types of stringed instruments emerged out of the Middle Ages in Europe (476-1000 A.D.). One type was held between the legs while playing (da gamba) and the other was supported on the arm (da braccio). These instruments were known as viols. Viols were built in a variety of sizes, the larger instruments producing deeper sounds. They were made of wood, had hollow bodies, fretted necks, usually six strings and were played with a bow. Viols remain popular well into the 17th century.

The violin and its associated instruments, the viola and cello, appeared in the 16th century and eventually overtook the viol in popularity. Amati, Guarneri and Stradivari are celebrated 17th century Italian violin makers. Early violins had three strings but a fourth string was added as the instrument developed. String orchestras featuring the violin and its relatives were established in the 17th century French and English courts. Only the largest instrument, the double bass, remained directly descended, in terms of design, from the family of viols.

The design of modern acoustic stringed instruments has changed little in the last several hundred years. Some materials and manufacturing processes have been updated but stringed instruments are still largely crafted by hand. Classical music remains popular today and the demand for acoustic instruments is steady. Bowed instruments do not play a large role in modern popular music.

The acoustic guitar and double bass in early 20th century dance bands and orchestras were often drowned out by the rest of the group. Efforts were made to find ways to amplify the sounds of these instruments. People built devices that could convert the vibrations of an instrument's strings or body into an electrical signal. These devices were called pick-ups. The electrical signal could be amplified and broadcast over a loudspeaker. Ongoing development resulted in improvements to pick-ups and a number of different types became available. People experimented with building pick-ups right into instruments and, following some refinement, manufacturers began mass-producing electric guitars and bass guitars. These instruments became phenomenally popular with musicians and audiences.

Electric instrument development is tied to the development of pick-ups and amplifiers. The instrument, its pick-ups, and the amp it is played through are the main elements in an electric instrument system. The earliest pick-ups were contact pick-ups, so named because they are in physical contact with the vibrating surface of an instrument. Contact pick-ups have air-sensing diaphragms which move in direct relation to the vibrations of the instrument. This movement creates an electrical current in the device which can be transmitted to an amplifier. Magnetic pick-ups appeared in the 1930s. These kinds of pick-ups detect magnetic motion, not air motion. Contact pick-ups provide a natural, acoustic sound. Magnetic pick-ups provide an "electric" sound, familiar in electric guitars and bass guitars.

Modern electric stringed instruments work on the same basic principles as their forerunners, although there is an amazing amount of technology available now that can be plugged into the electric instrument system between its pick-ups and its amplifier. While the electric guitar and the electric bass guitar have received most of the attention, there has been development, particularly within the last twenty years, of electric violins, violas, cellos and upright basses. Of these instruments, the upright bass has generated the most interest, as the bass is a very common instrument in popular music and a greater number of people know how to play it.

Electric stringed instruments do not require a hollow body to amplify sound and this has opened up a wide area of design possibilities for these instruments. Most existing electric instrument designs have reduced or eliminated the hollow body altogether. Although most of these instruments are made of wood, some new materials, such as carbon/graphite composites, are being used. Most of these instruments retain the string length, string positioning, neck size and shape, and playing techniques as their acoustic counterparts, making it easy for acoustic-trained players to switch over. 5-string electric bass guitars and upright electric basses are becoming increasingly popular.

Advances in digital technology lead to the development of electronic musical instruments (synthesizers, sequencers, samplers). Manufacturers of these instruments agreed to standardize their connections so consumers could mix and match various components in their systems. This standard protocol is known as MIDI (Musical Instrument Digital Interface). Pitch-to-MIDI (analog/digital conversion) technology has made it possible to convert stringed instrument vibrations into MIDI signals, thereby allowing the instrument to function as a MIDI controller. MIDI controllers can access digital sound modules, like musical voice data banks, and can perform other tasks. MIDI-equipped violins, violas, cellos and upright basses are all currently available.

3.0: UPRIGHT BASS SYSTEMS: Components & Functions

The acoustic upright bass is the principal informing design precedent for all electric upright bass designs. All electric upright basses demonstrate the same basic functional characteristics as the acoustic upright. Electric upright basses are meant to combine all that is good about the acoustic upright with the advantages that modern technology offers. However, any electric instrument that ventures too far from fundamental upright bass design parameters ceases to be an electric upright bass and becomes something else.

Most musicians want an electric upright bass to sound something, if not exactly, like an acoustic bass. They also want the experience of playing an electric upright bass to be similar to the experience of playing an acoustic upright, if not better. To these ends, it follows that a thorough understanding of the acoustic upright bass is required to inform the design of an electric upright bass.

When considering the design of a new electric upright bass, it will be helpful to understand how the upright bass, acoustic or electric, works as a system, what the components of this system are, and what their functions are within the system. This section will:
1) compare and contrast an acoustic upright bass system and an electric upright bass system.
2) identify and describe the components and workings of the principal design precedent: the acoustic upright bass.
3) identify the components and functions required in the formulation of an electric upright bass system.

3.1: THE UPRIGHT BASS AS A SYSTEM

We should consider the upright bass as a system. An upright bass system is comprised of components that perform various functions. These components and their functions differ somewhat, depending on whether the instrument is acoustic or electric. The upright bass system also includes the musician. This section will address the musician's role in the system but will focus mainly on the instruments, their components and the functions they perform. The role and requirements of the musician are discussed in Section 4 of this document.

A system is generally defined as a co-ordinated arrangement; an organized combination; or an organization method. A system is an organized combination of things or parts, working together to perform a particular function. An upright bass system is an organized combination of components, working together to produce sound. It has input, input control, input-to-output translation, output and output control elements. It is reiterative. Its output is fed back into the system, continuously reinforming the input. **Figure 21** illustrates the reiterative design of this system.

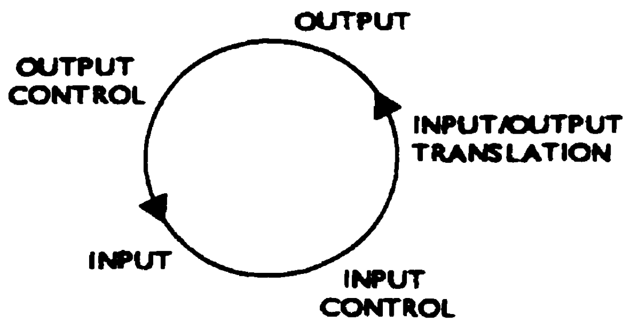


Figure 21.
Model of an upright bass system.

The musician provides the input in an upright bass system by causing its strings to vibrate. He or she most likely has a purpose in doing so: to practice or perform a piece of music, or to create a new one. The musician manipulates the instrument's strings with the fingers and/or a bow. The role of the instrument in the system is to translate these manipulations into sound. There are similarities and differences between the ways acoustic and electric upright basses perform this task. These are discussed below.

3.1.1: The Acoustic Upright Bass As A System

The musician is the operator of an acoustic upright bass system. He or she performs operations on the instrument resulting in the vibration of some of its components. These vibrations are the raw data that is **input** into the system.

The musician is trained to control the input of data in specific ways. These are **input control** techniques, otherwise known as playing. The instrument must allow the musician to play the instrument: to control its strings to produce all the frequencies required for the performance of a piece of music. The instrument must also allow the musician to input the data relatively easily, in the manner in which he or she is trained. For this reason, the shape and size of the components that musicians physically interact with vary little between instruments, acoustic or electric.

The **input-to-output translation** of data in the system begins when the vibrations of the strings are transmitted into the body of the instrument. The musician's manipulation of the strings causes them to vibrate at varying frequencies. The system requires that the instrument accurately transmit these vibrations into its body. The bridge is pressed into the belly of the hollow body by the tension on the strings. It vibrates in unison with the strings when they are vibrated. This vibration is transmitted throughout the hollow body by the soundpost and the bass bar, located inside the instrument. The hollow body amplifies the vibrations and transmits them into the surrounding air. The input is processed and **output as sound.**

Input directly affects output in the reiterative acoustic bass system. The output is fed back to the operator of the system, who adjusts the input accordingly to produce the desired result. **Output control** is provided when the musician hears the sound being produced and adjusts his or her playing. Output in an acoustic bass system is controlled largely through the player's modulation of the input (reiteration).

The input in an acoustic upright bass system is the frequencies of the vibrating strings. The input control in the system is provided by the musician: controlling the strings. The input is processed into output by the vibration-amplifying structure of the instrument's body, and the output appears as sound. The output is controlled when the musician hears the sound and adjusts the input accordingly.

3.1.2: The Electric Upright Bass As A System

Input and input control in an electric upright bass system are similar to input and input control in an acoustic upright bass system. The musician vibrates an instrument's strings (**input**) and controls the frequencies they produce (**input control**) by physically interacting with components of the instrument. On an electric instrument, this includes controlling the strings as on an acoustic instrument, but also setting the volume and tone input controls. These are usually located on the instrument.

The main difference between these two systems begins to appear in the **input-to-output translation.** This process takes place in an electric upright bass system when the strings' vibrations are transmitted to the instrument's pick-ups and are converted into an electrical signal. In an acoustic bass system, the strings' vibrations are transmitted to the instrument's hollow body. The electrical signal coming from the pick-ups may also be passed through electronic effects devices that further process, or translate, the signal on its way to be amplified. Some examples of these effects are reverberation, equalization, distortion, and pitch-to-MIDI conversion. These devices are located between the pick-ups and the amplifier. The signal carries on to the amplifier and is broadcast over a loudspeaker (**output**).

Output control in an electric bass system is basically the same as output control in an acoustic system. The musician still receives feedback from the system in the form of sound and adjusts his or her playing accordingly. The modulation of input still controls the output of sound but, in an electric upright bass system, the musician also controls the electronic effects devices in the system as well as the output settings on the amplifier.

The input in an electric upright bass system is the frequencies of the vibrating strings. The musician provides input control by controlling the strings, varying the frequencies as desired. Also, volume and tone input settings are controlled by the musician. Input is processed into output when the strings' vibrations are transmitted into the instrument's pick-ups, converted into an electrical signal and sent for amplification. Output appears at the amplifier as sound, which is controlled by the player through playing techniques and by adjusting the settings on the amplifier and the electronic devices the electrical signal is run through.

3.2: ACOUSTIC UPRIGHT BASS SYSTEM: Components & Functions

The acoustic upright bass is the logical starting point for the design of an electric upright bass. We have seen how an acoustic upright bass functions as a system. It will be of further help to know what the individual components of this system are: what they are called, how they are made, where they are located, and how they work.

The acoustic upright bass, also known as the double bass, is made from over 60 separate pieces. This section, rather than try to detail each piece, will identify and describe the main components of these instruments and their functions. The descriptions of these components are based on [8]Raymond Elgar's books: An Introduction to the Double

[8] Raymond Elgar, Introduction to the Double Bass, pp. 31-58.

Bass(1960), More About the Double Bass(1963), and Looking at the Double Bass(1967). Elgar, an English historian and musician, was the world's leading authority on the history and construction of the double bass. As these instruments are made by hand, they can vary somewhat in size. All measurements are approximate.

3.2.1: The Scroll and Neck

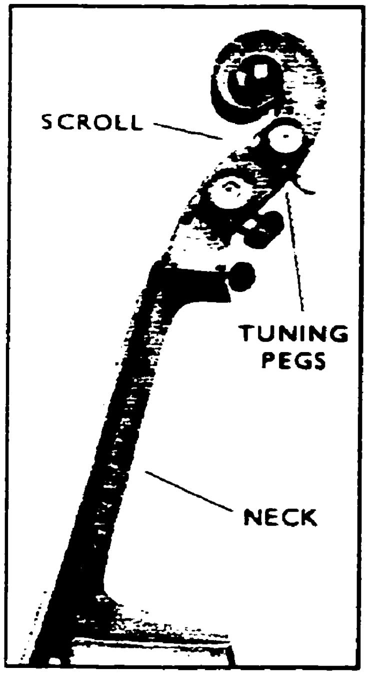


Figure 22.
Acoustic components
-scroll, neck, pegs.

The scroll and neck of an acoustic upright bass are carved as one piece from a solid block of wood, usually maple (Figure 22). The scroll is the elaborate structure at the end of the neck that holds the tuning pegs, which tighten the strings. The scroll is sometimes called the head, or the peg box. The strings enter the carved-out centre of the scroll and proceed upward to meet the shafts of the tuning pegs. Each side of the scroll is bored out to hold two tuning pegs. A five-stringed instrument will have an extra hole on one side to hold the required fifth tuning peg. The traditional, circular shape at the top of the scroll is a stylized snail shell.

The neck is the straight element that connects the scroll and the body of the instrument. The neck is flat on top and rounded behind to fit the shape of the hand. These rounded shapes vary. Common neck shapes include the soft V, the hard V, the U, and the asymmetrical. At the top of the neck, where it joins the scroll, the neck deepens. This feature is called the upper thumbstop, and is located on the back of the neck, beneath the nut. The neck (without the fingerboard) is 3.8 cms (1-1/2 inches) wide and 3.8 cms (1-1/2 inches) deep at the nut. The neck flares out into the lower thumbstop about 33 cms (13 inches) below the upper thumbstop. The depth of the neck just above the lower thumbstop is 4 cms (1-9/16 inches).

Elgar states that the standard neck length, from the nut to where the neck meets the body, is 42.3 cms (16-5/8 inches) but this measurement may vary. When the hand holding the neck meets the body, if the index finger is on the D note of the G string, the neck is a D neck. A neck this long provides 24 playable full tones, equal to two octaves of notes. If the index finger is on the E note of the G string, the neck is an E neck, which is a little longer.

3.2.2: The Tuning Pegs

The tuning pegs are located on the scroll. They are the devices that the strings are attached to for tightening. Tuning pegs used to be actual tapered, wooden pegs that were jammed into the holes in the scroll to provide friction to hold the strings taut. Smaller stringed instruments still use this technique. Modern tuning pegs are made of steel or brass and have offset gears that make it easier to tighten the thick, steel bass strings players use today. Strictly speaking, these mechanisms are called tuning machines, but either term is applied. The offset gears move the tuning peg handles back 90 degrees from their shafts, so they protrude backwards from the scroll, instead of out from either side, as in other instruments (eg: the violin). The shafts of the tuning pegs extend into the centre cavity of the scroll. Each shaft has a hole through it that the end of a string is pushed through. The handle is then turned and the string tightens, coiling around the shaft. The tuning pegs can be seen in **Figure 22**.

3.2.3: The Fingerboard

The fingerboard is attached to the flat top of the neck. It provides a surface for the musician's fingers to press the strings against. This action is called fingering. When fingering, the musician shortens and lengthens the vibrating length of the strings, changing their pitch. The top of the fingerboard is radiused to match the radius at the top of the bridge. The bridge is radiused to allow each string to be bowed separately. Acoustic upright bass fingerboards are traditionally smooth and fretless. Some have small inlaid buttons which function as visual guides, indicating the position on the fretboard where certain notes are found. The fingerboard can be seen in **Figure 23**.

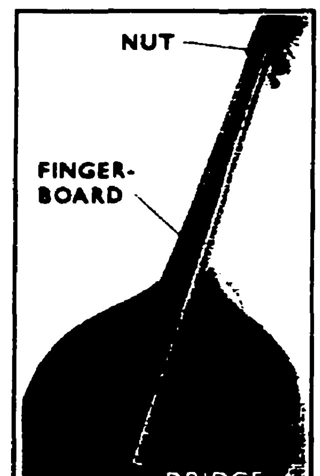


Figure 23.
Acoustic components -nut, fingerboard, bridge.

The fingerboard begins at the nut, near the top of the neck where the neck meets the scroll. It follows the neck down to where the neck is joined to the body of the instrument, and extends out past the bottom of the neck to an overall length of 83.8-86.4 cms (33-34 inches). The fingerboard widens and deepens as it moves down the neck. The fingerboard is 3.8 cms (1-1/2 inches) wide and 0.5 cms (3/16 inches) deep at the nut. It is 8.9 cms (3-1/2 inches) wide and 2 cms (3/4 inches) deep at the bottom. It is always made from hardwood, usually ebony, to prevent wear and tear from contact with the strings.

3.2.4: The Nut and Bridge

The nut and bridge form the two ends, or nodes, of the vibrating segments of the strings. The distance between the nut and bridge provides the free vibrating length of the strings, which determines the pitch they produce. The tightened strings are bent over the nut at one end and over the bridge at the other, leaving the string to vibrate freely in between. The shorter ends of the strings above the nut and below the bridge produce sounds when the strings are vibrated but these are faint and barely audible.

The nut is located at the top of the fingerboard where the neck meets the scroll. When musicians are adjusting the height of their instruments, they usually set the nut at the level of their ear. The nut is now made of ebony, or sometimes a synthetic material. The nut was traditionally made from ivory but this practice is no longer acceptable. There are small notches cut into the top of the nut where the strings are seated. These are normally spaced about 1 cm (3/8 inches) apart. The nut is radiused to match the radius at the top of the fingerboard. The nut holds the strings about 0.35 cms (1/8 inches) above the top of the fingerboard.

The bridge serves a number of purposes. It provides an end node for the vibrating strings. The radius at its top positions the strings in an arc so they can be accessed one at a time by the bow. It raises the strings high enough above the body of the instrument that the bow can stroke the outside strings without coming into contact with the sides of the body. It transfers the vibrations of the strings into the body of the instrument, which reverberates and amplifies the sound. The bridge can be seen in Figure 23.

Bridges are normally made out of maple. Their tops are notched to hold the strings in position when they are tightened down. The notches are spaced 2.8 cms (1-3/32 inches) apart. Bridges vary between 12.7-15.3 cms (5-6 inches) in overall width and 12.7-16.5 cms (5-6-1/2 inches) in overall height.

Bridges are stylized bridge-looking structures with two feet. They are normally not mechanically attached to the body. The feet are pressed into the belly plate of an instrument and held in place by the tightened strings. The bridge vibrates in unison with the strings and transfers these vibrations to the instrument. The soundpost and bass bar inside the hollow body are located beneath the feet of the bridge to transfer the vibrations throughout the whole structure.

The height of some bridges can be adjusted by threaded bolts in their feet or legs. This allows the strings to be raised or lowered above the fretboard. The closer the strings are to the fretboard, the easier it is to push them down when fingering. If the strings are too close to the fretboard, they will hit the fretboard and rattle when vibrating. Non-adjustable bridges are usually carved down to the point where the strings are as close to the top of the fingerboard as they can be without striking it when vibrating.

3.2.5: The Saddle and Tailpiece

The saddle and tailpiece can be seen in **Figure 24**. The tailpiece, traditionally made of ebony, is the fan-shaped device that holds the bottoms of the strings below the bridge. The strings run through holes in the tailpiece and are held in place by steel balls at the ends of the strings.

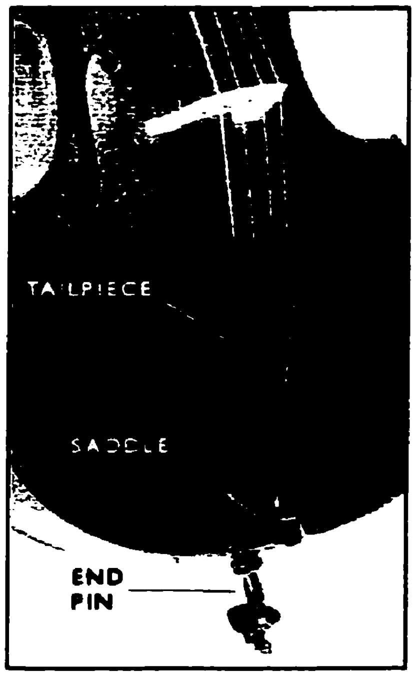


Figure 24.
Acoustic components -tailpiece, saddle, end pin.

A thin, steel cable coming off the bottom of the tailpiece is secured to the saddle. The saddle is the bottom nut, usually made of ebony, that secures the tailpiece to the instrument. It is fitted into a slot cut in the bottom edge of the top plate of the instrument.

3.2.6: The Strings and Bow

The strings pass through holes in the tailpiece, which is secured to the bottom of the instrument by the saddle. They pass up and bend over the bridge, where they are seated 2.8 cms (1-3/32 inches) apart. They continue up, running along just above the top of the fingerboard until they reach the nut and are seated again, 1 cm (3/8 inches) apart. The strings grow closer together as they extend up from the bridge to the nut. The strings bend over the nut and run up into the scroll cavity where they meet the shafts of the tuning pegs. Their ends pass through holes in the shafts, the tuning pegs are turned and the strings are tightened, coiling around the shafts.

Most bass strings used today are made of steel wire, tightly wrapped with thinner wire. These are known as steel-wound strings. Strings are also available in nylon, composite materials and even traditional animal gut. The different types of materials used to make strings have different acoustic characteristics. Steel strings are bright-sounding and resonant. Nylon and gut strings produce a duller, warmer sound. Strings are, on average, 168.3 cms (66-1/4 inches) long. Each string will have a ball, made of steel or some other material, at one end that will not pass through the holes in the tailpiece. Some strings are wrapped in black thread for a short distance above the end ball.

Strings are available in a variety of thicknesses. Strings of different thicknesses produce different sounds. Generally, the thicker a string, the deeper the sound it will produce. On a four-stringed upright bass, the low E string will be the thickest. The A string will be a little thinner. The D string will be thinner yet and the G string will be the thinnest. Strings are usually sold in sets of four or five, their relative thicknesses all proportionately and acoustically accurate. Common bass string thicknesses are 3 mms diameter for an E string, 2.25 mms diameter for an A string, 1.75 mms diameter for a D string and 1.25 mms diameter for a G string.

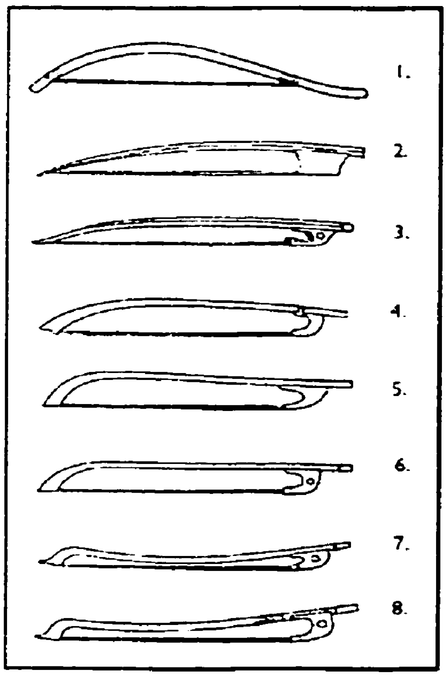


Figure 25.
Bass bows.

Bass bows have changed over the years. Figure 25 illustrates the different shapes and sizes of bass bows through the ages. Bow 1 was the earliest type of bass bow and resembled an archery bow. Bows 2 and 3 were early violone and bass bows. Bows 4 and 5 were developed by the famous contre-bassist, Domenico Dragonetti (1755-1846). The sticks on these curled up slightly towards the tip, making them deeper at the tip than at the handle, or frog. This design allowed the player to push the bow hair down onto the strings with more force. In a later design, Bow 6, the stick is made straight. Improvements in bass construction meant the bow did not have to be pushed down so hard on the strings. Modern bass bows, Bows 7 and 8, resemble violin, viola and cello bows.

Modern bass bows are made of wood, traditionally a pernambuco stick and an ebony handle. They are strung with hair from a horse's tail or mane. This is usually white or black. The stick keeps the hair under tension. When the hair is moved across a string, scales on the hair "bite" the surface of the string, causing it to vibrate. Rosins are applied to the hair to enhance this effect. Most modern bows vary in length from 66-68.5 cms (26-27 inches) but specialized bows can be longer. The average weight of a bass bow is 126 grams (4-1/2 ounces).

3.2.7: The Body

The body absorbs vibrations from the strings through the feet of the bridge. The front plate vibrates in unison with the strings and these vibrations are transmitted to the top and bottom of the body by the bass bar and to the back plate by the soundpost. Both plates vibrate, like membranes, vibrating the air inside the body, producing sound waves. The sound waves resonate (echo) inside the body and escape through the sound holes (**Figure 26**).

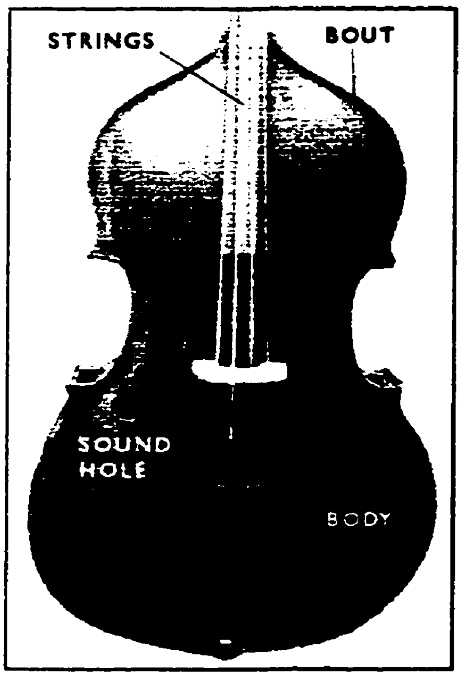


Figure 26.
Acoustic components
-strings, bout, body.

The front plate of the body (the belly) is made from pine or spruce, the back plate from maple. The wood must be very well-seasoned. This means that it has been air-dried in controlled storage for years. The wood is chosen to get the best possible figure from the grain. The front and back plates of the bass are made from solid pieces of wood when possible. These pieces of wood are quite large, measuring approximately 122 cms (48 inches) long by 71.2 cms (28 inches) wide, and top quality pieces can be expensive and hard to come by. For this reason the fronts and backs are sometimes made from narrower pieces of wood that are sawn in two and joined together so their grains form a sort of butterfly or inkspot pattern. This pattern is sometimes called the 'flame' of the finished surface. The front and back shapes are drawn onto the wood and cut out. The areas that will form the 'waist' of the body are cut away so that, when complete, the bow can play the outside strings without hitting the sides of the instrument. The 'f' or sound holes are marked out on the wood and cut out with a very sharp knife. The 'shoulders' of the bass are usually sloped, which facilitates playing in the higher positions. The shoulders are known as the upper bouts. The 'hips' are called the lower bouts.

The wood is planed down with gouges and other specialized hand tools. When done, the front plate should be approximately 9 mms thick in the middle bridge/soundpost area, thinning down to 7 mms for other parts of the middle and tapering down to 6-6.5 mms at the edges, or flanks. The flanks are planed down to give the front plate a gentle side-to-side arch. The overall rise of this arch is about 3.8 cms (1-1/2 inches). The back plate is almost always flat, like its ancestor, the viol, and is usually an even 5 mms (3/16 inches) thick. The sides, or ribs, are made from six strips of maple, 2.5 mms thick, heated and bent around a mould to form the outside contours of the side of the body. The overall depth of the sides varies from 17.8-25.5 cms (7-10 inches).

The bass bar is a piece of pine, 22-25 mms thick, that is cut to fit inside the body between the upper and lower edges. The grain of the wood should run straight throughout its length. It is fit at a slight angle, snugly contacting the inside surface of the front plate from top to bottom over its entire length. The bass bar must pass directly below the E (right) foot of the bridge. The bass bar is bent slightly when it is put into position, providing a little outward thrust under the bridge to resist the pressure from the strings. It is eventually glued onto the inside surface of the front plate.

The soundpost is a rod of straight grained pine, approximately 1.9 cms (3/4 inches) in diameter, cut to fit snugly between the insides of the front and back plates. This is called a pressure fit. The soundpost must be pressure fit just behind the G (left) foot of the bridge. The soundpost must not be glued or otherwise fixed into place. It is positioned so its end grain runs at right angles to the grain of the front plate.

There are often narrow wood inlays running around the outside edges of the front and back plates, usually two black strips separated by a white strip. These composite strips run in a smooth flowing line around the contours of the body and are known as 'purfling.' Purfling is meant to prevent the outside edges of the plates from cracking in case of an accident. It is cheaper and easier to repair purfling than to repair a crack in a plate. The body pieces have bracing added and are eventually assembled using clamps and animal hide glue. Hide glue is very strong and can be softened with water if the instrument has to be disassembled for repair.

3.2.8: The End Pin and Stand

End pins come in a variety of forms but the most common is a sliding steel rod with a small, solid rubber ball at one end. The rod is fit into a hole bored into the bottom rib brace of the body. The end pin is not adjustable itself but different lengths are available to raise or lower the overall height of the instrument. Bass players usually like to have the nut of the instrument at the level of their ear.

There is no particular design for a stand for an acoustic bass. A variety of musical instrument stands are commercially available. These are usually made from steel tubing and expand and collapse for easy transportation. Some musicians use a stand while playing, some rest the bass against their bodies. When not in use, the acoustic bass is often laid on the ground on its side, or propped up against a wall or chair.

3.3: ELECTRIC UPRIGHT BASS SYSTEM: Components & Functions

We understand that electric upright bass designs are primarily informed by the design of the acoustic upright bass. We have seen how acoustic and electric upright basses function as systems and what the requirements of these systems are. We have looked at the individual components of the acoustic upright bass system and the functions these components perform to make the system work. From this information, we can extrapolate the components and functions required in the design of an electric upright bass. This section will identify these components and their functions, and give examples of these, good and bad, taken from existing electric upright bass designs. This will provide a determination of what is necessary and desirable in the design of an electric upright bass.

Existing electric upright basses appear to be, for the most part, clever adaptations of electric bass guitar technology (pick-ups, controls, amps) to the acoustic upright's string length and playing techniques. The acoustic's long strings and the methods used to play them are required to produce the trademark upright bass sound. Electric bass guitar electronics and hardware have shown they can be successfully adapted to an upright bass system. The way in which these elements are combined varies from manufacturer to manufacturer and from design to design. Despite these variations, there are components and functions these designs reflect in common, based to one degree or another, on the acoustic upright bass.

3.3.1: The Head

The head of an acoustic upright bass is called the scroll. The head of an electric bass guitar is called the head. Most existing electric upright bass (EUB) designs have a structure that locates and holds the tuning machines at the top end of the strings and is called either the head or the scroll. These tend to resemble the scrolls on acoustic basses in how they position the tuning machines, but are simplied, lacking the ornate, carved character of an acoustic scroll. The Vektor EUB (**Figure 27**) is a good example of this.

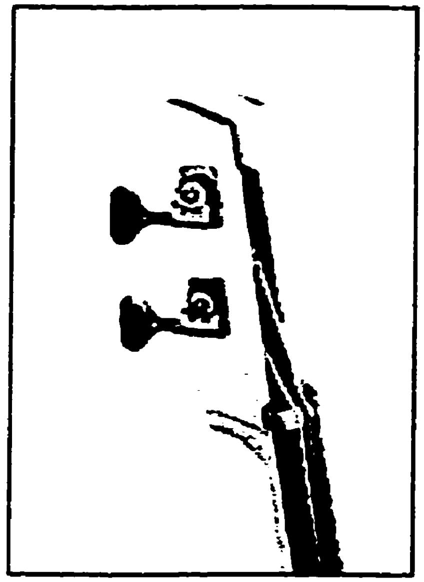


Figure 27.
Vektor EUB headstock

One design, along the lines of the Steinberger electric bass guitar, has opted to forego the head entirely and locates the tuning pegs at the bottom end of the strings.

Figure 28.
Kydd headless bass.

The Kydd bass (**Figure 28**) is a very short-scale instrument, designed for easy transportation, and the head has been removed to keep the instrument as small as possible.

Consider these two criteria: it is necessary to locate the tuning machines at one end of the strings or the other, and the player must be able to tune the instrument while playing. As the instrument is intended to be played in the vertical position, it is quicker and easier to reach the tuning machines at the tops of the strings to tune them while playing than it is to bend over and tune the strings from near the bottom of the instrument.

3.3.2: The Tuning Machines

An electric upright bass must provide accurate string tuning capabilities. The mechanisms that perform these functions on an EUB are called the tuning machines. EUBs are non-traditional instruments and tend to eschew traditional terms like tuning pegs and scroll. There is one machine required for each string on an instrument, as strings tend to stay in and go out of tune independently of each other.

Most existing EUBs have tuning machines with handles, like those on electric bass guitars. These handles either protrude out from the sides of the head like a bass guitar (**Figure 16**), or are angled back away from the head like an acoustic bass. The Vektor EUB (**Figure 27**) features rear-pointing tuning machines. The handles on EUB tuning machines must be large enough that the hand can grip and turn them easily, applying the considerable force necessary to tighten the thick, steel bass strings. The mechanisms must be strong enough to hold a tightened string in its tuned position, even when the string is tugged at fairly violently.

3.3.3: The Neck and Fingerboard

The size and shape of the neck and fingerboard on an electric upright bass are largely determined by the number of strings on the instrument, the length of the strings, and whether the instrument has a wide body or shoulders. A five-stringed instrument will necessarily have a wider neck and fingerboard than a four-stringed instrument. On a four-stringed instrument, the standard spacing between strings is 1 cm (3/8 inches) at the nut and 2.8 cms (1-3/32 inches) at the bridge. Most EUB manufacturers reduce this spacing a little at the nut, especially on their six-stringed instruments. This is done to prevent the neck from becoming too wide. The player must be able to hold the instrument with the fingering hand (the left hand for a right-handed player), with the thumb on the back of the neck and the fingers curling around to meet all the strings, easily and comfortably. It gets harder to reach the right-most E (or low C) string as the fingerboard gets wider. A standard 83.8 cms (33 inches) long, four-string acoustic bass fingerboard is 3.8 cms (1-1/2 inches) wide at the nut and 8.9 cms (3-1/2 inches) wide at the bottom. The NS Design five-stringed EUB fingerboard is a little wider, being 5 cms (2 inches) wide at the nut and 9.3 cms (3-11/16 inches) wide at the bottom.

EUB necks are similar in shape to acoustic upright bass necks and are usually as long or longer. An EUB neck must be at least as long as an acoustic neck to provide the same number of playable notes. A standard acoustic neck is 42.3 cms (16-5/8 inches) long. This length provides 24 playable tones, equal to two octaves of notes. To play higher up the neck (closer to the bridge) acoustic bass players must dramatically adjust their fingering technique. The fingering hand runs into the body of the instrument when it reaches the bottom of the neck on an acoustic upright bass. To continue playing higher up the scale, players must remove their thumb from behind the neck, pass their hand over the shoulder of the instrument to its front, and press down on the strings from above the fingerboard. This is called playing in the thumb position. Most EUBs have a reduced body shape and have no shoulders for the fingering hand to run into, eliminating the need for this tricky manoeuvre. As a result, EUB necks and fingerboards may be substantially longer than acoustic necks and fingerboards, extending the range of notes playable without having to move the fingering hand into the thumb position.

Some players, trained on the acoustic bass, are so accustomed to having to move to playing in the thumb position at a certain point up the neck, that when they switch to a shoulderless EUB and no longer have to, they get confused. To accommodate this, some EUB designs include a removable rod that attaches to the fingering hand side of the neck at the height of an acoustic bass shoulder. Players can rest the forearm of their fingering hand on this rod and play higher up the fingerboard in the thumb position, as they would on an acoustic bass.

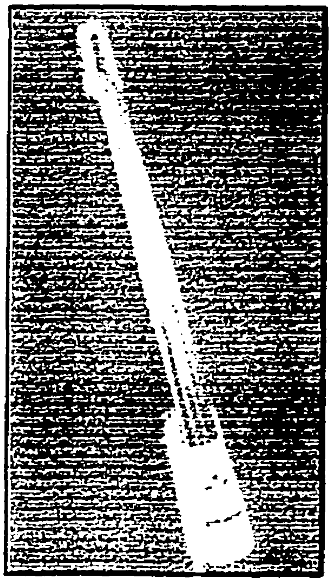


Figure 29.
NS Design EUB.

Besides being a little longer, or shorter in a few cases, and a little wider to accommodate a fifth or sixth string, most EUB necks and fingerboards are not dramatically different in size or shape from acoustic bass necks and fingerboards. There has been one innovation in this area worth mentioning, however. The back of the neck on the NS Design five-string EUB (**Figure 29**) is concave, rather than convex, providing a channel for the thumb of the player's fingering hand to slide up and down in. This feature, after a little getting used to, reportedly feels quite comfortable and natural.

Most EUB necks and fingerboards are made of maple and ebony respectively, though there is some degree of experimentation in this area. EUB fingerboards are always fretless. A fretted fingerboard produces a significantly different sound: incremental rather than smooth between notes.

3.3.4: The Nut and Bridge

Due to the importance of tradition in classical music, it is highly unlikely that an EUB would ever be accepted as a legitimate instrument in a classical music ensemble. Classical bass is usually played arco: with a bow. EUBs are much more likely to be used in playing jazz or popular music.

The bass in these musical forms is mainly played pizzicato: by plucking. One might think that this would eliminate the need to make EUBs playable with a bow. This, however, is not the case. Most EUB manufacturers seem intent on making their designs playable by both methods. It might be that they do not want to deviate too much from the experience of playing an acoustic upright. It might be that eliminating bow players would reduce their customer base too greatly, as EUBs can certainly be played with a bow to practice classical music, if not to perform it. To be playable with a bow, the nut and bridge, as well as the fingerboard, must be radiused so the bow can reach all the strings individually.

The neck of the acoustic bass is angled back from the body for two reasons. The angle puts the area where the strings are bowed high enough above the instrument that the bow can stroke the outside strings without hitting the instrument's body. The angle also brings the neck back towards the player, who stands behind the instrument, making it more comfortable to hold the neck and easier to see and finger the strings. The angle between neck and body on an acoustic bass is usually between 14 degrees and 16 degrees. This results in a bridge height of between 12.7 cms (5 inches) and 16.5 cms (6-1/2 inches).

Figure 30. Messenger EUB bridge.

The height of the bridge on an EUB depends on the angle that the neck and fingerboard meet the body. The strings run down, just above the fingerboard, and extend out over the body to the top of the bridge. The greater the angle between neck and body, the taller the bridge will be. Not all EUBS have an angled neck, but those that do have about the same angle between the neck and the body that an acoustic bass does. This angle, as mentioned above, is usually between 14 degrees and 16 degrees. EUBs with angled necks, therefore, usually employ acoustic bass-style bridges. **Figure 30** shows the bridge on the Messenger four-string electric upright bass, an EUB with an angled neck like an acoustic bass.

The NS Design five-string EUB (**Figure 29**) does not feature an angled neck. The whole instrument sits angled back on its stand. This design is

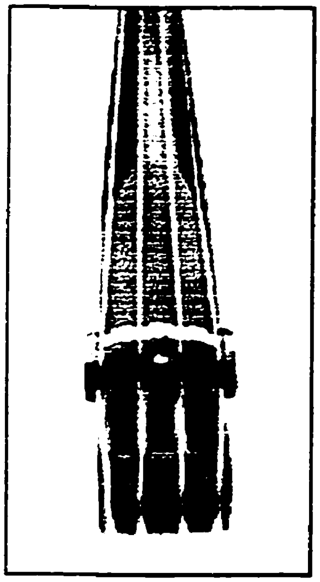


Figure 31.
Jensen EUB bridge.

still bowable because it has a radiused bridge and a narrow body that allows the bow to pass by. Having no angle between neck and body, this design does not require a tall bridge. The Jensen EUB also has no angle between its neck and body. The Jensen's bridge (**Figure 31**) is radiused to be bowable but, like the NS Design EUB, is shorter than an acoustic bridge.

The nut on most EUBs is like the nut on an acoustic bass. It is radiused to match the radius of the fingerboard and bridge, and it positions the strings vibrate without hitting the fingerboard yet close enough that they can be pressed down onto the fingerboard fairly easily. EUB nut and bridge construction and materials vary from the traditional to the experimental. Some EUB bridges have pick-ups built into them, located under the notches in the top of the bridge that seat the strings.

3.3.5: The Saddle and Tailpiece

Some EUBs have a hollow body similar to an acoustic bass. These more traditional designs are more likely to feature acoustic bass-style saddle and tailpiece mechanisms. The Conklin EUB (**Figure 32**) is a good example of this. Less traditional designs usually opt for something a little less elaborate, like combining the saddle and tailpiece into one simple component. Some try to be innovative. The Jensen EUB (**Figure 31**) features a unique saddle/tailpiece design, located at the back of the bottom of the instrument. Either way, an EUB must provide the means to secure the strings to the instrument at the opposite end of the instrument from the tuning machines.

Figure 32.
Conklin EUB.

3.3.6: The Strings and Bow

The strings used on electric upright basses are the same as the strings used on acoustic upright basses, except in two cases. Some EUBs feature relatively short string scales, being designed with portability in mind. Shorter instruments require shorter strings. Bass strings are commercially available in a variety of lengths, but if a custom string length is required for an instrument, those strings are usually available through the manufacturer of that instrument. An EUB with magnetic pick-ups must use steel strings as the strings must be able to conduct the electromagnetic field of flux coming from the pick-up's magnets. Any acoustic bass bow will work on an electric upright bass, although the bow hair and the rosin used should be able to "bite" the surface of the material that the strings are made from.

3.3.7: The Body

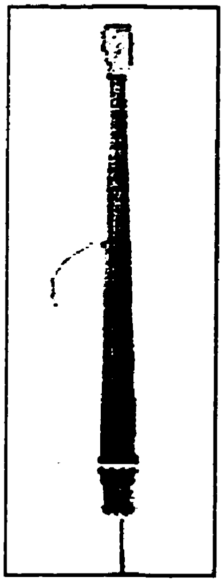


Figure 33.
Jensen EUB.

Some EUBs, like the Conklin (**Figure 32**), have a reduced hollow body. Others, like the NS Design (**Figure 29**) and the Jensen (**Figure 33**), have slender, solid wood bodies. Hollow body EUBs still need to be amplified. Their hollow bodies are intended to flavour the tone of the instrument, not amplify its sound. Electronic amplification does away with the need for the big acoustic sound chamber and it is here that we see the greatest degree of divergence in EUBs from traditional bass design.

There is an inherent problem in doing away with the acoustic bass hollow body. Musicians trained on the acoustic are accustomed to leaning the bout (shoulder) of the instrument against their bodies while they play it. The hollow body of the instrument provides a specific distance between the player and the neck of the instrument that players get used to.

On an EUB, the hollow body is gone or reduced, and the space between the player and instrument disappears. To address this, many EUBs provide an artificial bout that replaces the back shoulder of the acoustic instrument. EUB bouts vary in design but all serve the same purpose: to space and hold the instrument in front of the player at a distance about equal to the depth of an acoustic upright bass: 17.8-25.5 cms (7-10 inches). The bout on the Messenger EUB is seen in **Figure 34**. This bout mirrors the contours of an acoustic bass bout. Some EUBs are designed to be locked into a stand instead of being held while playing. These designs do not require a bout.

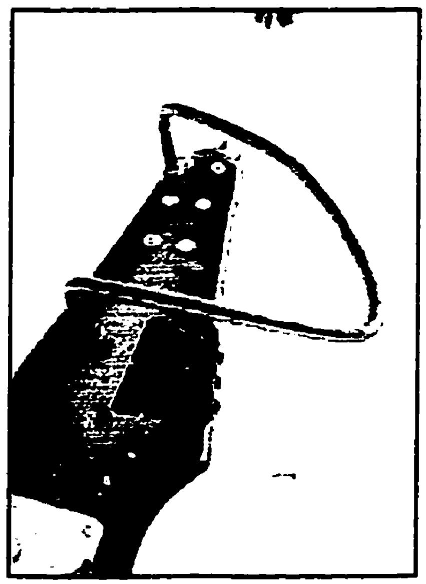


Figure 34.
Messenger EUB bout.

3.3.8: The Pick-Ups

The types of pick-ups used on electric upright basses vary considerably, depending on the sound that the manufacturer wants the instrument to produce. Contact pick-ups provide a warmer, more natural sound. These can be located on the surface of the instrument if it has a hollow body, under the feet of the bridge, under the strings at the top of the bridge, or on the strings between the bridge and the saddle. Magnetic pick-ups provide a sharper, "electric" sound. These have to be positioned close to the strings so that the strings are within the electromagnetic field of the magnets in the pick-up, which is not very far.

Contact and magnetic pick-ups each produce their own kind of sound. Some EUBs have one type of pick-up or the other. Some have both types and allow the player to choose the sound he or she wants by selecting one pick-up or the other by using a switch. Some EUBs also allow the player to blend the input from both pick-ups into a third, hybrid sound.

The pick-ups in an electric upright bass are what make it electric. The quality of the pick-ups in an instrument is extremely important as it greatly affects the sound the instrument produces. The sound of an instrument is ultimately what sets it apart from other similar instruments. Many manufacturers design and build their own pick-ups to suit the particular requirements of their instruments.

Whatever type of pick-ups are used in the end, the overall quality of an EUB's sound will only be as good as its pick-ups. It is important to note that if a piezoelectric contact pick-up is used it will require a pre-amp because of the very low voltage generated by the piezo crystal in the pick-up.

3.3.9: The Controls

The number and range of the controls on an EUB will depend on the number and type of effects, if any, there are in the EUB system between the pick-ups and the amplifier. Volume and bass/treble tone are basic controls and are considered standard on all electric stringed instruments. These are usually located in a place on the instrument that the player can easily access, especially while playing. These controls are usually potentiometers, or "pots". Potentiometers are small electronic devices with protruding shafts that can be turned up or down to increase or decrease elements of an instrument's electrical signal.

If an EUB has more than one pick-up, it will require a switch to select pick-ups individually or to select them all for a blended output. If an EUB is MIDI-equipped, it will require a separate MIDI on/off switch and MIDI volume and tone controls.

External effects devices in an EUB system almost always have their own sets of controls and are not controlled directly from the instrument. Changing the settings on these devices may require the player to re-set the volume and tone controls located on the instrument.

3.3.10: The Jacks and Wiring

Every EUB requires one output phono jack to connect it to an amplifier. Some instruments may have more than one jack if, for some reason, the output has to be sent to more than one location. Phono jacks are receptacles for phono plugs. Phono plugs are medium-duty, probe type, two-conductor, tip/ring electrical connections that are standard on all electric instruments.

Every pick-up on an EUB will have to be wired through the selector switch and the volume and tone controls to the output jack. If an EUB is MIDI-equipped, the instrument will require a separate MIDI electrical connection. These are usually amphenol-type plugs with multiple contacts as MIDI requires multiple conductor cables to handle the relatively large volume of information moving between the instrument and its microprocessor.

3.3.11: The End Pin and Stand

Like the acoustic upright bass, EUBs are meant to be played in the vertical position. They can either be balanced in this position by the musician while playing, or can be locked into position on a stand. If an EUB is designed to extend all the way to the ground, it should be equipped with an end pin to protect the bottom of the instrument and to provide some degree of height adjustment. Some instruments, like the NS Design EUB (**Figure 35**), end just below their bridges and are not designed to extend to the ground. These types of EUBs require a stand to lift them up to playing height. EUB stands tend to be the telescoping, chromed, tubular steel tripod

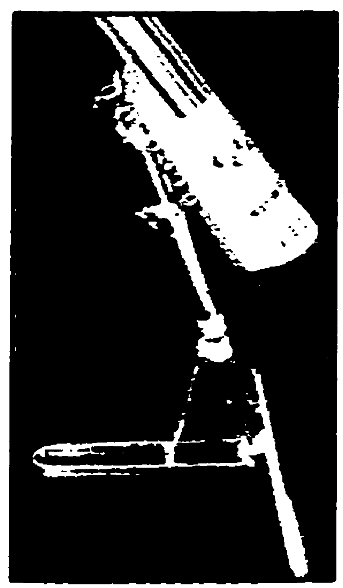


Figure 35.
NS Design EUB stand.

variety and, by and large, do not complement the aesthetics of their instruments very well.

3.4: SUMMARY

We can look at the upright bass as a system. This system has input, input control, input-to-output translation, output and output control elements. These elements are required in both an acoustic upright bass system and an electric upright bass system. An electric upright bass system includes its electronics: the pick-ups, cables, amplifier. Both systems necessarily include the musician.

The acoustic upright bass system is comprised of components that perform specific functions. These components work together to produce sound. Due to the traditional nature of classical musical instrument design, there is not a great deal of variation in the size, shape, materials or construction of these components or in the functions they perform within the system to make the system work.

Electric upright bass design is primarily influenced by the design of the acoustic upright bass. An EUB that deviates too far from the way an acoustic upright bass works, is played, or sounds, ceases to be an electric upright bass, and becomes another instrument altogether.

An electric upright bass system requires components similar to those in the acoustic upright bass system, although some of the functions the components perform in an electric upright bass system differ from the functions they perform in the acoustic system. Unconstrained by tradition and the need for a hollow body to amplify their sound, electric upright basses demonstrate a variety of sizes, shapes, materials and construction. EUBs are meant to be played in the same way as the acoustic upright bass and should accommodate both arco and pizzicato playing techniques.

4.0: PLAYER/INSTRUMENT INTERFACE

The acoustic upright bass is designed the way it is for specific reasons. Its long, thick strings are required to produce the trademark acoustic upright bass sound. The neck and fingerboard provide a place for the musician to hold the instrument and finger the strings. The headstock holds the tuning pegs. The pegs allow the musician to tighten the strings. The nut and bridge lift the strings high enough above the bass that they may be bowed without the bow or strings hitting the instrument. The bridge transfers the strings' vibrations into the instrument's body. The hollow body vibrates in unison with the strings and amplifies their sound. By providing these components and working as intended, the acoustic bass performs its task.

The player's task is to address this instrument physically and manipulate its strings in such a way that it produces the desired sounds. The way that the player addresses the instrument can be described as the player/instrument interface. Upright bass players use the term, bass method, to describe this interface.

Bass method is a long and well-established means of interfacing with an acoustic upright bass. This method has been developed and perfected by bass players over the last three centuries. Bass players are taught how to position themselves beside the instrument and how to hold it. They are taught the proper way to vibrate the instrument's strings and control their vibrating length. The method clearly indicates the exact positioning and action of their hands in this process. The first part of this section will describe the acoustic upright bass method.

Electric upright basses incorporate some acoustic upright elements in their designs rather faithfully, such as the overall string length, the radius of the strings and the shape of the neck. Other elements are not required. Electric amplification eliminates the need for the large, hollow body of the acoustic bass. Different instrument designs will necessarily have a different player/instrument interface. The second part of this section will discuss the differences between the electric upright bass/player interface and the acoustic method mentioned above.

4.1: ACOUSTIC UPRIGHT BASS METHOD

The following descriptions are based on information found in two of the most important books written on the subject of acoustic bass method.

These are [9]The Improvisor's Bass Method, by Chuck Sher, and [10]Ray Brown's Bass Method, by Ray Brown. Mr. Sher has been a professional bass player and music instructor in the San Francisco area since 1967. Mr. Brown is an award-winning bass player who has dominated the jazz bass field since 1953. He has played in Dizzy Gillespie's big band and in the Oscar Peterson trio.

The description of the bass method that follows is written for a right-handed player. Left-handed players need only to substitute right for left.

4.1.1: The Stance

The musician usually stands while playing the acoustic upright bass, although playing in the seated position is permitted. Sher writes, "The body of the player should be behind the bass enough that the player can bow the E string comfortably (**Figure 36**). The left armpit should not touch the body of the bass. The left elbow should be up and forward so the whole arm rotates as you play different strings."

Figure 36.
Acoustic bass method stance.

4.1.2: The Left Hand

"The left hand's basic posture is a relaxed kind of claw in which the fingers are spread apart from each other and arched so that the fleshy part of the fingertips press the strings down (**Figure 37**). This arch is much more pronounced on the acoustic bass than on the electric bass. On acoustic bass, this arch is the continuation of an unbroken arch of energy from the spine to the arm, to the palm (where a baseball glove kind of pocket is created), and finally to the fingers. In this way, the strength of all of these muscles contribute to holding the strings down. For beginning players it will take time for this claw to feel natural. As you practice, however, just periodically remind yourself to approximate this position of the hand.

[9] Charles Sher, The Improvisor's Bass Method, 1979, Chapter 1, pp. 1-5.
[10] Raymond Brown, Ray Brown's Bass Method, 1963.

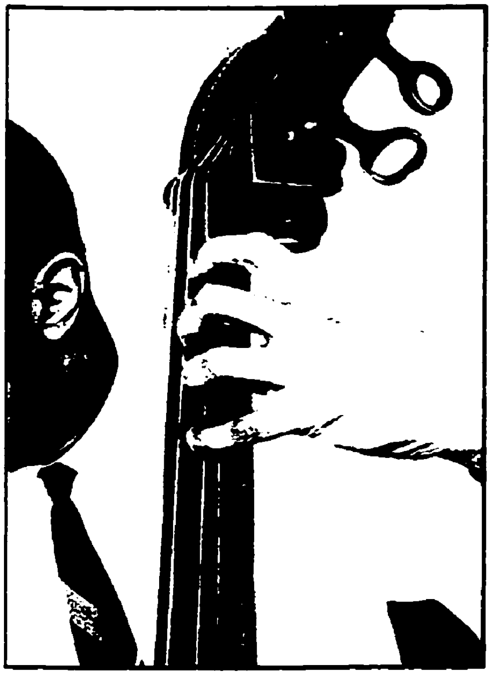


Figure 37.
Basic posture of the left hand.

Figure 38.
Acoustic bass thumb position.

On acoustic bass, the thumb joint should remain unbroken (**Figure 38**). Most electric players bend the thumb backwards. The thumb should be across from the second finger when playing acoustic bass, and across from the first finger when playing electric bass. This position should be maintained as the left hand glides from position to position.

On acoustic bass, after E or E flat is reached on the G string, the thumb starts to come around to the side of the neck as you go up the string (**Figure 39**). Finally, at approximately the 12th 'fret' up from the nut, the thumb comes on top of the fingerboard and its right side at the joint is used to hold the strings down, in addition to the 1st, 2nd, and 3rd fingers.

Figure 39.
Thumb comes to side of neck going up the string.

Figure 40.
The thumb position.

This is called the thumb position (Figure 40). Once in the thumb position, it is useful to extend it lower than the 12th fret, so that unnecessary shifts between the thumb position and the lower positions are avoided. The thumb position should be learned along with the lower positions. It is not any harder than the others (Figure 41).

Figure 41.
Playing in the thumb position.

In the lower positions, the fingers that are not in use should be kept relaxed and as close to the strings as possible. The pinky should remain above the string so that the fingers are perpendicular to the strings, not angled off. In general, try to eliminate all excess movement in the left hand. Its function is only to serve as a platform to support finger movements (Sher)."

4.1.3: The Right Hand

"The right hand in pizzicato playing on the acoustic bass can be used in one of two ways. The first way alternates the tip of the 1st and 3rd or the 1st and 2nd fingers. The hand is held perpendicular to the strings. The second way has the hand at a 45 degree angle to the strings and the side of the 1st and 2nd fingers are used (Figure 42). Electric bassists use the perpendicular approach or else use a pick. In any case the direction of force used is half towards you and half down into the fingerboard.

On acoustic bass, the thumb will rest on the side of the fingerboard, near the bottom (Figure 43). Electric basses often have thumb rests, or the E string is used for that purpose. Moving the thumb closer to the bridge gives you more power, while moving it further away gives you more speed

Figure 42.
Right hand pizzicato position.

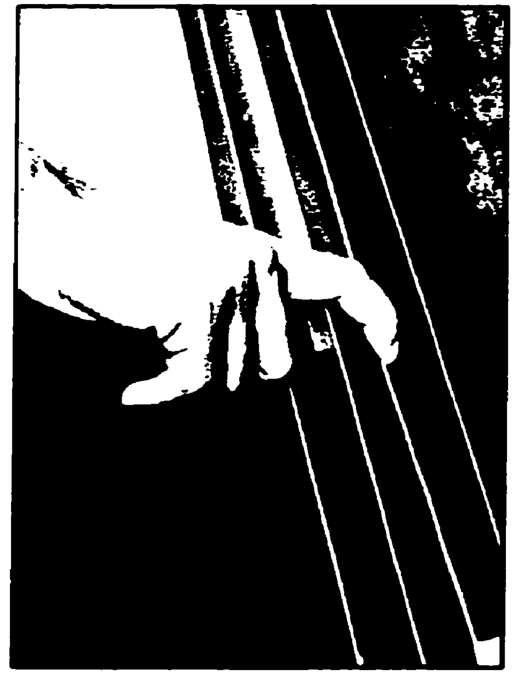


Figure 43.
Right hand pizzicato position.

and sensitivity. On electric bass, when plucking the strings with the thumb, it should be placed right at the bottom of the fingerboard. Try hitting a string both on the downstroke and the upstroke of the thumb, in addition to using the fingers to give you more rhythmic versatility.

On acoustic bass, when using the bow, make sure that it remains perpendicular to the strings at all times and that the right elbow does not bend very much, the right shoulder and wrist being the main sources of motion (Sher)."

4.2: ELECTRIC UPRIGHT BASS METHOD

4.2.1: The Stance

Electric upright basses may be played while standing up or while seated. Their reduced body sizes make them more conducive to playing in the seated position than acoustic basses. Many are equipped with adjustable stands that will hold the instrument in position in front of a seated player, or a bout could be used to hold the instrument at a comfortable distance from a seated player. A standing player will hold the neck of the instrument with the left hand, balancing it on its end pin. A bout may be used to hold the instrument at a comfortable distance away from the player. As with the acoustic bass, the player stands just far enough behind the instrument that he or she can bow the E string comfortably.

4.2.2: The Hands

The strings, their radius, the fingerboards and necks of most electric upright basses are modelled fairly closely on the acoustic model. Some necks are longer and EUBs with five or six strings will have somewhat wider fingerboards. The strings may be shorter on some EUBs but they will still be about the same thickness as the strings on an acoustic. As such, the positioning of the hands varies little between EUBs and acoustic basses, with one notable exception. Playing an EUB with a narrow body eliminates the need to take the left hand over the top of the instrument into the thumb position. The player can play higher up the neck of the instrument without having to change the left hand position. Players who want to use the thumb position anyway can add a support to the left side of the neck of an EUB to imitate the shoulder of an acoustic bass. Some manufacturers provide this option. Plucking and bowing the strings with the right hand is done the same as on an acoustic bass.

4.2.3: Operating the Controls

The operation of the controls on an EUB (volume, treble/bass, etc.) is usually done the same way it is on an electric bass guitar. Dials or 'knobs' attached to potentiometers are turned forward or back, increasing or decreasing elements of the electrical signal. Their ease of use depends on where they are located on the instrument. The player must be able to operate the controls while playing the instrument's strings, so the best location for the controls is near one of the hand positions. Controls positioned near the left hand on the neck would interfere with the up-and-down motion of the left hand. The right hand position is at the bottom of the fingerboard, near the top of the body of the instrument. This is the most sensible location for the controls. The right hand can quickly access the knobs while the left hand sustains a note on the strings.

4.3: SUMMARY

The player and the instrument physically come together to produce music. This can be called the player/instrument interface. The term acoustic bass players use for this is <u>bass method</u>. Bass method has been developed and perfected by acoustic bass players over the centuries. It tells the bass player how and where to stand in relation to the instrument, how and where to position the hands, and the different hand positions required to play certain notes.

Players generally use the established bass method to play the electric upright bass as well. Despite some variations, the strings, necks and fingerboards on electric upright basses are similar to those on acoustic basses. The absence of the large, hollow body might confuse some acoustic players but bouts and false shoulders can be added to EUBs to approximate the acoustic playing experience. EUBs can also be held in place on stands in whatever position is comfortable for the player. Their reduced body sizes make electric upright basses more conducive to being played in the seated position.

Unlike the acoustic bass player, the electric upright bass player has electronics to control. The player must be able to quickly access these controls, usually knobs, and adjust them while playing. The best location for the controls is on the instrument, near the player's plucking/bowing hand (the right hand for right-handed players).

5.0: EXISTING ELECTRIC UPRIGHT BASSES

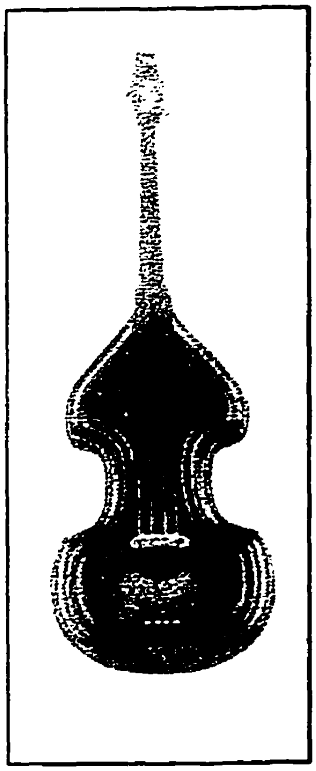
The following pages offer a compendium of all existing electric upright basses in production and commercially available at the time of the publication of this document. Photos and brief descriptions of these instruments are provided. These have been obtained from EUB manufacturers internet sites and from product reviews in bass publications. They are intended to give the reader a clearer understanding of what existing electric upright basses look like, how they are made, and how they vary from one to the next.

It is estimated that for every electric upright bass in production there are three in development. EUBs have been growing in popularity, especially in the last few years, and many instrument makers are scrambling to get an EUB of their own into production. Companies that already have an EUB in production often make ongoing improvements to their instrument and new products or new 'editions' of products are frequently released. As such, the following compendium should not be viewed as a comprehensive survey of all existing electric upright basses, but rather as an indicative sample of available instruments.

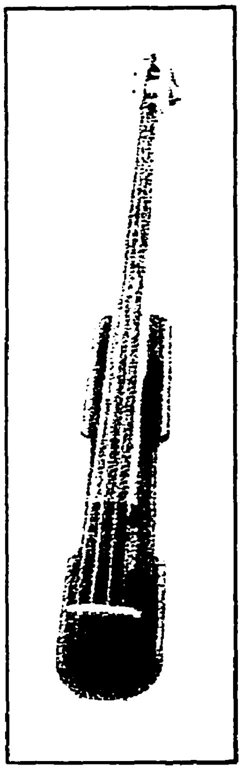
Some of the descriptions that follow contain subjective opinions regarding an instrument's pizzicato and arco tones. These are the opinions of [11]Bob McCaskey, an acoustic bass player and music instructor in the New York/Philadelphia area for the last thirty years. Mr. McCaskey reviewed sixteen electric upright bass designs in the December 1996 edition of Bass Player magazine.

Some of the images provided have been obtained from internet sites and can only be reproduced here at 72 dots-per-inch of resolution. Details in these images may be hard to make out. Anyone wishing a clearer look at any of these instruments can consult the list of manufacturers provided in the appendix of this document. It contains all the electric upright bass URLs used in this section.

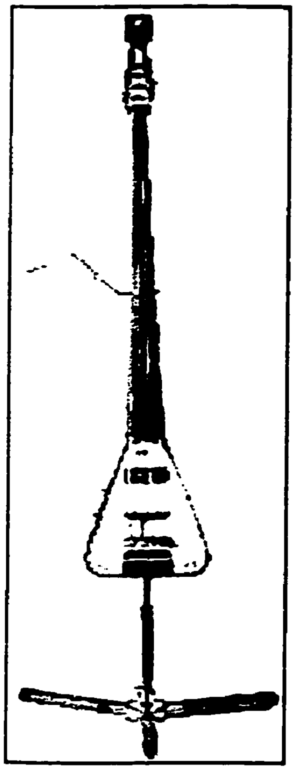
[11] Robert McCaskey, Mission Impossible, Bass Player, Dec.'96, pp.57-63.



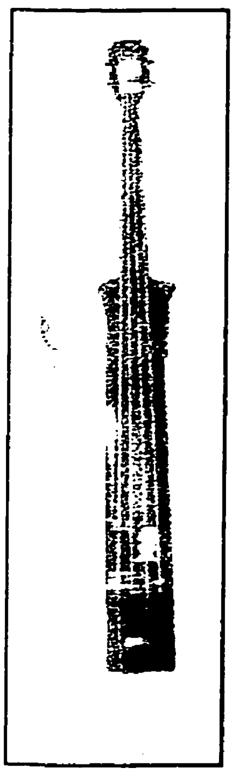
Baby Bass (Ampeg)
- -Four-string
  - -104.2cms/41"string scale length
- -Hollow body
  - -fiberglass over a urethane-coated aluminum frame
- -Maple neck
  - -laminated
  - -adjustable angle
- -Macassar ebony fingerboard
- -Rock maple bridge
- -Pick-Ups
  - -magnetic diaphragm pick-up under bridge
  - -piezos (2) in wings of bridge
- -Controls
  - -master volume
  - -active blending circuit between pick-ups
- -Overall length: 152.8cms/60"
- -Overall weight: 9.16k/20 lbs
- -String spacing
  - -nut: 0.9cms/3/8"
  - -bridge: 2.5cms/1"
- -End pin



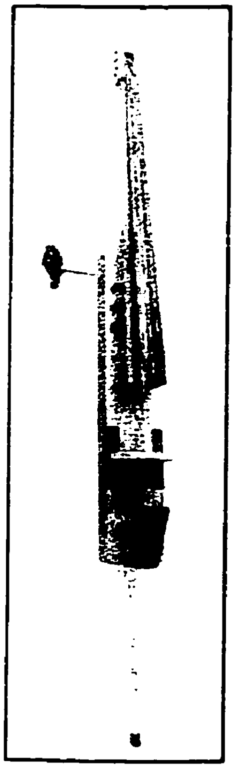
Bug Bass (Ampeg)
- -Four-string
- -Solid wood body (alder)
- -Maple neck
- -Pauferro fingerboard
- -Pick-Ups
  - -Clevinger bridge pick-ups
- -Overall weight: 5.5k/12 lbs
- -End pin (not shown)



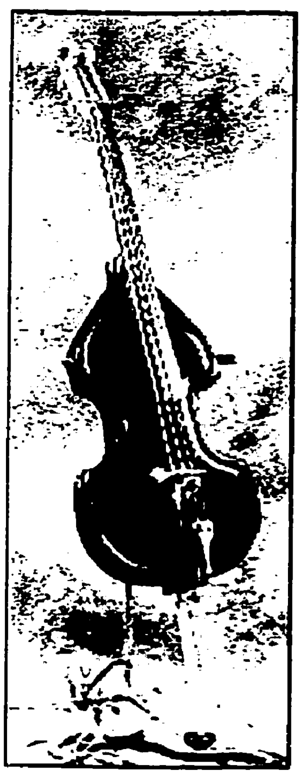
Triumph Electric Upright Bass (Warwick)
-Four and five-string
-3/4 string scale length
-Solid wood body (maple)
    -flamed maple
    -arched Bavarian spruce top
-Maple neck
-Rosewood fingerboard
-Scrolled headstock
-Pick-Ups
    -MEC quad magnetic pick-up/pre-amp system
-Bout
-Tripod stand



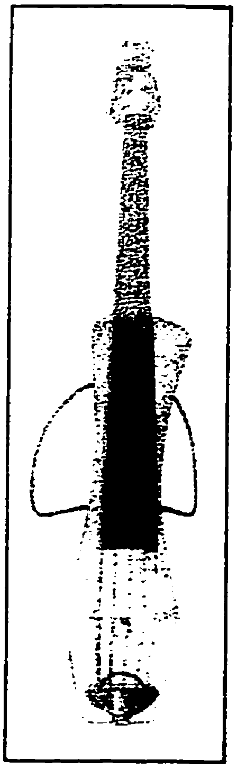
T-4 Electric Upright Bass (BSX)
-Four-string
-3/4 string scale length
-Solid wood body (poplar)
-Maple neck
    -removable
    -5 minute breakdown
-Ebony fingerboard
-Good in pizzicato mode
-Less impressive arco tone
-Bout
-End pin



SUB-1 (Carruthers)
-Four-string
-Solid wood body (alder)
-Maple neck
    -removable
        -loosen the strings
        -turn one screw
-Striped ebony fingerboard
-Bout
-End pin
-Rugged flightcase

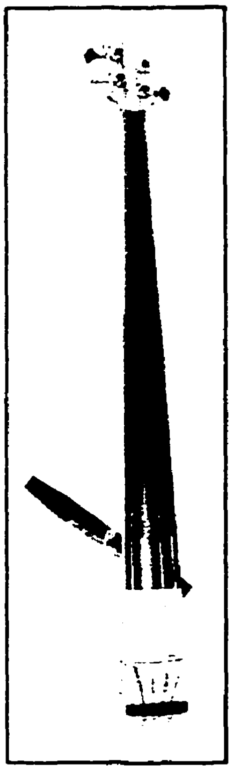


Composite Series EUB (Ray Ramirez)
-Four, five and six-string
    -106.7cms/42" string scale length
-Body
    -fiberglass composite shell
    -internal foam construction
-Maple neck
    -purpleheart centrepiece
    -removable
    -adjustable
-Ebony fingerboard
-Pick-Ups
    -custom diaphragm magnetic pick-ups
    -piezos available
-Controls
    -passive volume
    -passive treble
-Stand
-End pin

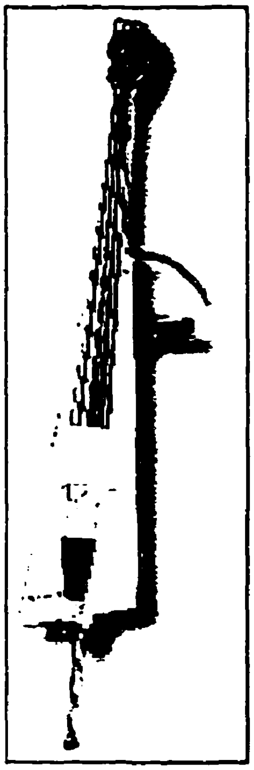


Clevinger Opus (Clevinger)
-Five-string
  -105.5cms/41-1/2" string scale length
-Solid wood body (poplar)
-Maple neck
  -D neck
-Long, ebony fingerboard
  -3 octaves
-Pick-Ups
  -Clevinger ABST bridge pick-ups
  -RMC saddle sensors
-Controls
  -volume and treble/bass tone
  -blending and EQ
  -located on back of instrument
-Overall weight: 7.8k/17lbs
-Bouts (2)
-End pin (not shown)
-Excellent in pizz mode
-Less impressive arco tone

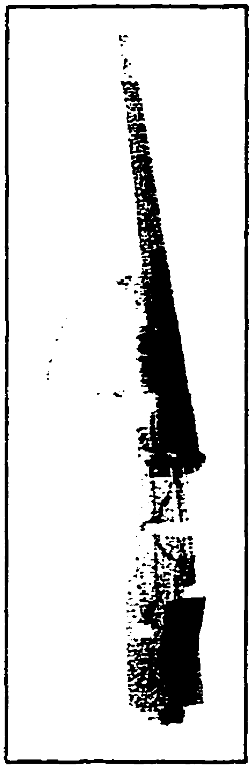
Impression Contrabass (Linc Luthier)
-Four-string
  -106.7cms/42" string scale
-Semi-hollow wood body
-Sound hole
  -runs the length of the body
  -parallel to the neck
-Pick-Ups
  -four piezos
  -bridge-mounted
-End pin
  -adjustable



Fichter Electric Upright (Fichter Basses)
-Four and five-string
    -104.2cms/41" string scale length
-Solid wood body and neck
    -maple and pearwood
    -D neck
-Ebony fingerboard
-Adjustable bridge
-Pick-Ups
    -Highlander integrated coaxial transducer
    -mounted in the bridge
    -pre-amp
-Controls
    -none
-Excellent in pizz mode
-Less impressive arco tone
-Overall weight: 5.9k/13 lbs
    -smallest, lightest EUB
-Bout
-Stand mounted

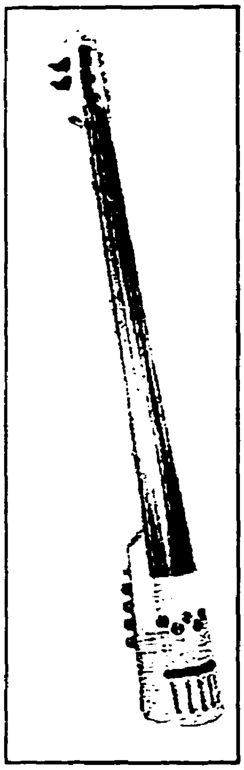


Electro-Dynamic Double Bass (Fabrice Gougi)
-Four-string
-3/4 string scale length
-Solid wood body
-Removable neck
-Pick-Ups
    -Schertler electrodynamic transducers
    -mounted in the bridge
-Bout
-End pin



Vertical Bass (Merchant)
-Four-string
-3/4 string scale length
    -string and neck length built to customer's specifications
-Solid wood body
    -hollow sound chamber under bridge
    -cherry veneer finish
-Ebony fingerboard
-Pick-Ups
    -Underwood bridge pick-ups
    -Bartolini magnetic pick-ups
-Controls
    -blending circuit between pick-ups
-Good in pizz mode
-Reasonable arco tone
-Bout (wood)
-End pin
    -inverted T-shape prevents turning

Classico Electric Upright Bass (Alembic)
-Four and five-string
-3/4 string scale length
-Semi-hollow body
    -mahogany
-Maple neck
    -laminated (3 piece)
-Rosewood fingerboard
-Pick-Ups
    -magnetic pick-ups concealed in maple/rosewood pick-up bridge below end of fingerboard
-Controls
    -master volume and treble/bass tone
    -four trim pots located on underside of pick-up bridge set the volume for each string
-Overall weight: 11k/24 lbs
-Stand
-End pin



NS-CR Electric Upright Bass (NS Design)
-Four, five and six-string
- -106.7cms/42" string scale length

-Solid wood body
- -rock maple laminated with graphite fibre

-Maple neck
- -curves inward at the back

-Macassar ebony fingerboard
-Pick-Ups
- -directional piezo bridge pick-up system
- -EMG magnetic pick-ups

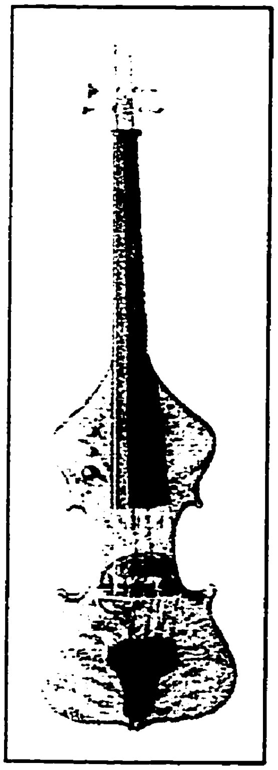
-Controls
- -master volume and treble/bass tone
- -switch between arco/pizz mode in bridge pick-ups
- -active blending circuit between pick-ups
- -active EQ

-Excellent in pizz mode
-Excellent in arco mode
-Overall length: 132cms/52"
-Overall weight: 4.8k/10-1/2 lbs (8k/17-1/2 lbs with stand)
-Stand

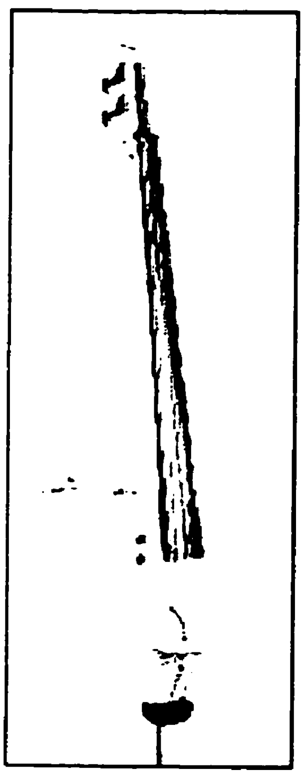
Hand-Carved Electric Upright Bass ("A" Basses)
-Four-string
-Optional string scale length
-Solid wood body (mahogany)
-Maple neck
-Ebony fingerboard
-Maple bridge
- -height adjustable

-Options (built to customer's specifications)
- -body shape
- -fingerboard radius
- -back of neck profile
- -scroll shape
- -scale length

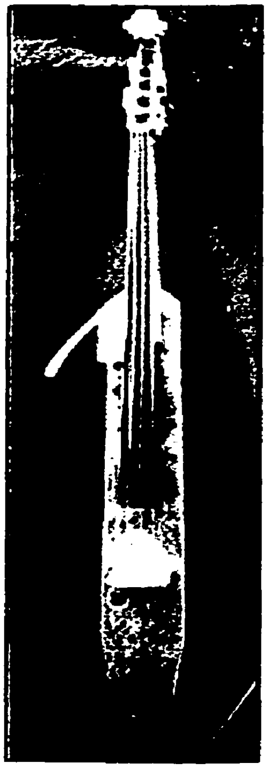
-End pin



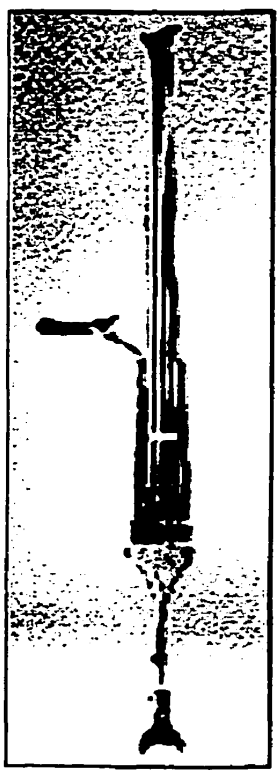
Mobile Electric Upright (MEU) (Conklin)
-Four-string
-3/4 string scale length
-Hollow wood body
    -swamp ash
    -cherry veneer top
-Maple neck
-Ebony fingerboard
-Pick-Ups
    -Shadow piezo bridge pick-ups
    -Seymour Duncan magnetic pick-ups
-Controls
    -master volume
    -treble/bass tone
    -active blending between pick-ups
-Very good in pizz mode
-Reasonable arco tone
-Straps onto the shoulder
    -for vertical play without
    a stand or end pin



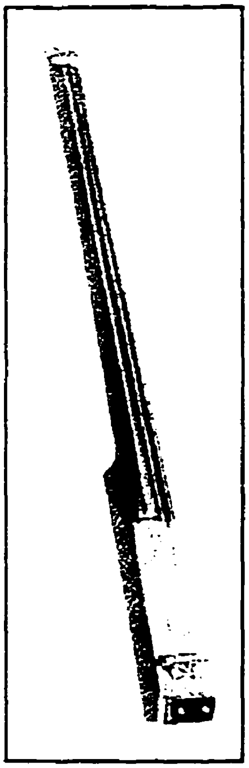
Vektor Electric Upright Bass (Vektor Germany)
-Four, five and six-string
    -99cms/39" string scale length
-Solid wood body (maple)
    -three piece laminated
-Maple neck
    -optional thumb stop at D position
-Ebony fingerboard
-Pick-Ups
    -Wilson piezo system
    -FWF contact pick-up located on bridge wing
-Controls
    -master volume
    -active blending circuit between pick-ups
-Good in pizz mode
-Less impressive arco tone
-Bout
-End pin
-Stand optional



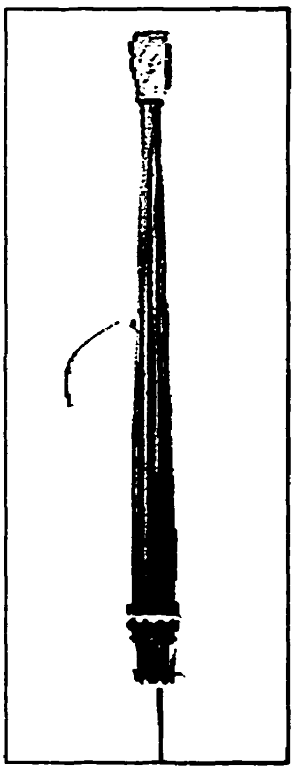
<u>Classic Model Electric Upright Bass</u> (Hembrook)
-Four and five-string
-3/4-size string scale length available: 105.5cms/41-1/2"
-full-size string scale length available: 111.8cms/44"
-Semi-hollow body
    -hollow sound chamber under bridge
    -mahogany
    -Texas mesquite veneer top
-Maple neck
    -D neck
-Ebony fingerboard
-Maple bridge
    -height adjustable
-Pick-Ups
    -one contact pick-up in bridge
    -two contact pick-ups in sound chamber
-Controls
    -master volume
    -active blending between pick-ups
-End pin



<u>KP Series Electric Upright Bass</u> (Moses)
-Four, five and six string
3/4 string scale length: 104.2-106.7cms/41-42"
-Solid graphite body
    -graphite/epoxy with diamondwood detailing
-Graphite neck
    -Moses American Ebony Graphite
-Graphite fingerboard
-Graphite/diamondwood bridge
-Pick-Ups
    -Moses Advanced Air Coupled Sensor system
    -contact and magnetic pick-ups available
-Controls
    -master volume
    -treble/bass tone
-Overall height: 129.5cms/51" without end pin
-Overall weight: 5.9k/13 lbs (4-string)
    7.7k/17 lbs (6-string)
-Bout
-End pin
-Stand optional

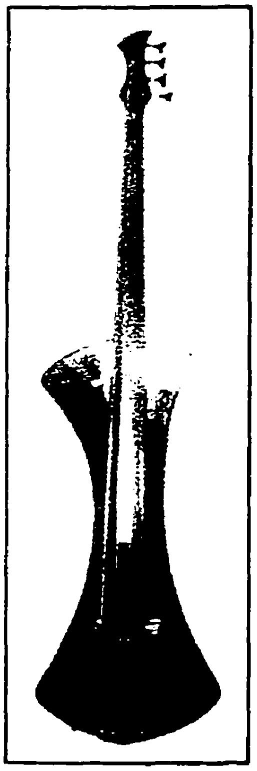


Carry-On Bass (Kydd)
-Four-string
-short-scale EUB
    -76.2cms/30" string scale length
-Solid wood body (maple)
-Maple neck
-Granadillo fingerboard
-Tuning machines at bottom of instrument
-Pick-Ups
    -Fishman Transducer (contact) pick-ups
Overall length: 90.1cms/35-1/2"
Overall weight: 2.7k/6 lbs
-Stand
    -telescoping tripod (camera type)

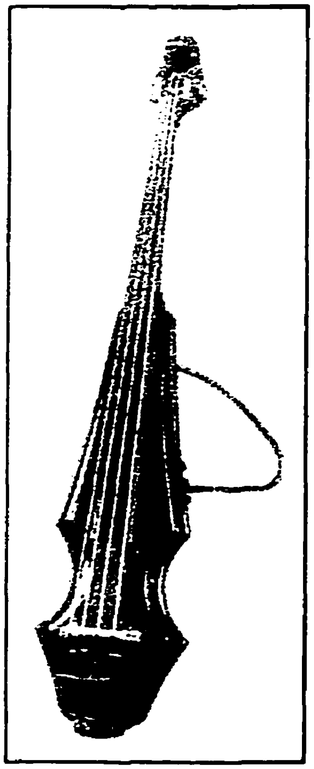


Jensen Upright Bass (Jensen)
-Four and five-string
-3/4 string scale length
-Solid wood body (maple)
    -exotic hardwoods optional
-Maple neck
    -thumb stop optional
-Ebony fingerboard
-Pick-Ups
    -Jensen Series 700/Series 2000 polyphonic pick-ups
-Controls
    -master volume
    -treble/bass tone
    -active electronics
-Bout
-Leg stabilizer
-End pin

Marinac Bass (Marinac)
Four-string
-3/4 string scale length
-Solid wood body (maple)
  -hollow sound chamber under bridge
-Maple neck
  -removable
    -loosen strings
    -remove four bolts
-Ebony fingerboard
-Pick-Ups
  -Fishman contact pick-up standard
  -optional electronics available
-End pin



Zeta Uprite (Zeta)
-Four-string
  -adjustable string scale length
  -105.5-110.5cms/41.5-43.5"
-Solid wood body
-Three-piece neck
  -maple/purpleheart/maple
-Ebony fingerboard
-Adjustable bridge
-Pick-Ups
  -patented Zeta bridge pick-up system
  -8 bridge piezos (2 per string)
-Controls
  -master volume
  -treble/bass tone
  -switch between arco and pizz mode
-Overall height: 146.4cms/58"
-Overall weight: 6.8k/15 lbs
-End pin
-Swivel stand available



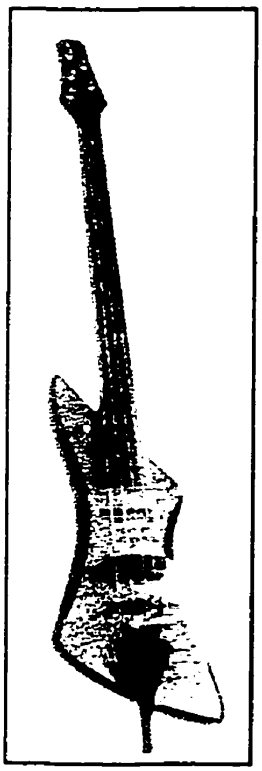
Messenger Electric Upright Bass (Knutson Luthiery)

- Four-string
  - two string scale lengths available
  - 103cms/40-1/2"
  - 105.5cms/41-1/2"
- Solid wood body
  - poplar/spruce
  - sunburst finish
- Maple neck
- Ebony fingerboard
- Height adjustable bridge (maple)
- Pick-Ups
  - Barbera Multi-Transducer bridge pick-up system
  - 2 EMG pre-amps
- Controls
  - master volume and treble/bass tone
  - active blending circuit between pick-ups
- Superior sound in pizz mode
- Less impressive arco tone
- Detachable bout
- End pin
- Swivel stand available

Vector Deluxe Custom Upright (Vector Canada)

- Four and five-string
  - 106.7cms/42" string scale length
- Solid wood body
  - select curly maple over mahogany
- Maple neck
  - E neck
- Ebony fingerboard
- Height adjustable bridge
- Pick-Ups
  - Barbera Multi-Transducer bridge pick-up system
  - Fishman Acoustic Bass pre-amp
  - Biesele DP magnetic pick-up system available
- Controls
  - master volume and treble/bass tone
- Good pizz tone
- Reasonable arco tone
- Overall height: 145.9cms/57-1/2"
- Overall weight: 4.5k/10 lbs
- Tripod stand
- End pin optional

<u>Orca Bass</u> (Starfish Stringed Instruments)
-Four and five-string
-Custom-built to order
-Optional string scale length
-Carved wood body (maple)
-Maple neck
-Ebony fingerboard
-Pick-Ups
    -custom-designed piezo system
    -high impedance, high output
-End pin



<u>EUB-35</u> (Fleishman)
-Four, five and six-string
    -88.9cms/35" string scale length
-Solid wood body (mahogany)
    -Japanese blistered ash top
    -hollow sound chamber under bridge
-Maple neck
    -flatter near the nut than on an acoustic bass
-Ebony fingerboard
-Pick-Ups
    -RMC bridge pick-up system
    -Bartolini magnetic pick-ups
-Controls
    -volume
    -treble/bass tone
-Superior pizz tone
-Reasonable arco tone
    -bowing area reduced by placement of magnetic pick-up
-End pin

PART 2: DESIGN

6.0: DESIGN OF AN ELECTRIC UPRIGHTBASS

6.1: OBJECTIVES

This Master's Degree Project (MDP) is intended to demonstrate proficiency in industrial design. Industrial design is the design of products that may be mass-produced or batch-produced by mechanical/industrial means. The topic of this project is the design of an electric upright bass (EUB) that may be mass-produced or batch-produced. The following sections will describe the process of designing this instrument and will provide the details of the final proposed design.

The topic chosen for this project offers an opportunity to address the various aspects of industrial design. These are: materials and manufacturing technologies, marketing, aesthetics, sustainability and human factors. This project will undertake the design of an electric upright bass with these aspects in mind. It should be pointed out that while human factors considerations are taken into account, human factors and ergonomics are not a major focus of this project.

Good industrial design is the design of products that are at once economically viable, environmentally sustainable, and sensitive to the needs of the user. This project will strive to meet these objectives.

6.2: DESIGN BRIEF

6.2.1: Criteria

An electric upright bass should demonstrate certain advantages over the acoustic double bass. Its reduced bulk should make it easier to transport. Its electronics should provide the user with access to all the creative possibilities that modern music technology has to offer (volume/tone control, MIDI control, sound effects, etc).

This project aims to arrive at the design of an EUB that offers ease of use, portability and a full range of bass electronics and controls. It should have a market niche, be easily manufacturable and environmentally sustainable. It should provide a rich, clear, deep sound that can take the stringed bass role in a musical performance. It should offer an interface that is recognizable to the trained upright bass player and easily learnable by the budding musician. It should be easy to balance in the playing position and comfortable to play. It should be easy to operate the controls and tune the strings during performance. It should also be visually appealing.

6.2.2: Methodology

This project began in 1996 as an industrial design studio project in the Faculty of Environmental Design at the University of Calgary, under the supervision of Prof. Denis Gadbois and Dr. Stuart Walker. The results of that work will serve as the starting point for this project.

The design process will begin with a thorough definition of the task. This is the **problem definition**. The problem will be defined in the areas of marketing, form, human factors, manufacturing and sustainability. It will begin with a description of the target user.

The **problem solution** will begin with a wider, intensive literature search conducted on electric upright basses and related topics in all available publications and periodicals and on the internet. Precedents will be examined and expert users will be consulted. Ongoing sketching and sketch-modelling will develop and refine the form and operation of the instrument. A working rig will be built to test materials, electronics and functional considerations. These activities will result in a final proposed design. The final proposed design of the instrument and its components will be described in detail and illustrated in a set of general assembly drawings. The GA drawings will serve as a blueprint for the fabrication of the **prototype**. The prototype may be used to evaluate the quality of sound the instrument produces and its playability.

6.2.3: Deliverables

The project will produce a document containing the relevant background information on the topic, a definition of the problem and a detailed description of the problem solution. The final design will be illustrated in a set of general assembly drawings and in the prototype. The design will be presented to the public and to the MDP committee in September 1999.

6.3: PROBLEM DEFINITION

6.3.1: The Target User

The target user is a musician or an aspiring musician. He or she may be a professional musician or an amateur. He or she is a trained upright bass player, a self-taught upright bass player, or someone in the process of learning the bass. The target user is an upright bass player whose repertoire is probably not restricted to classical music alone. The user may have an acoustic bass already but would like an electric as well for its portability, the different sounds it can produce, or its additional strings.

6.3.2: Marketing

It is wise to consider whether there is a demand for a product before undertaking a long and possibly expensive design project. No precise data on the size of the EUB market is currently available but the growing number of manufacturers seems to indicate that there is a market for the instrument. There are currently about 30 different EUBs commercially available in North America. They are advertised extensively in bass, bass guitar and guitar periodicals and on the internet. EUBs are turning up more often in live performances and on recordings. Is there room in the market for another electric upright bass? The answer is probably yes, but only if the design is unique, offers improvements or has features that other instruments do not.

It would be helpful to describe typical elements of EUB design in order to identify the main areas where these improvements can be made and alternatives offered. Most existing EUBs are made out of wood. Some have fibreglass bodies and one is made entirely of graphite fibre. Most use a piezo pick-up system and some have magnetic pick-ups as well. Four and five-string models are most common. Some six string models are available. Most EUBs have a radiused bridge and fingerboard and can be played with a bow. They have reduced body shapes and require a long end pin or a stand to get their strings and fingerboard up to playing height. On some designs, the neck detaches from the body to improve portability.

We can now identify areas of EUB design where improvements or alternatives may be offered. These are: the materials, the combination of pick-ups, the number of strings, bowability, the body shape, the end pin and/or stand and the detachable neck. If a design is unique or offers improvements in these areas it is reasonable to assume it could be competitive in the EUB market.

6.3.3: Form and Aesthetics

Electric upright basses use electronics to amplify the sounds they produce. This eliminates the need for the large, hollow, wooden body of the acoustic upright bass. The removal or reduction of the hollow body raises some important issues.

Most upright bass players have learned to play on the acoustic double bass. The strings and fingerboard on a double bass are attached to the top of the hollow body and are located well above the ground. When played standing up, the top of the fingerboard is at the height of the player's ear hole. Without the hollow body, there is some distance to make up between the bottom of the strings and the ground. Most existing EUBs address this by using a long end pin or a collapsible, tubular steel stand. An instrument can spin on a long end pin, making it awkward to hold and balance while playing. A stand limits mobility. Neither option is very visually appealing.

The upper shoulders of an acoustic double bass are called its bouts. When playing an acoustic, players usually rest one of the bouts against their chest. This helps to balance the instrument and puts the player in the proper bass-playing stance. Without a large, hollow body, an EUB has no bouts. Something else is required to space the instrument the proper distance from the musician's body. Some EUBs provide an adjustable arm at the relative position of an acoustic double bass bout.

Trained upright bass players would expect an upright bass to have a radiused bridge and fingerboard. These features make the instrument playable with a bow. They would expect the neck and fingerboard to be about the standard size and shape of an acoustic bass neck and fingerboard, and to provide at least as many octaves and playable notes. An upright bass could be designed with a flat fingerboard like an electric bass guitar, but it would not be playable with a bow, and it would offer a very different playing experience. Most players would not consider it a legitimate upright bass.

The design should locate the tuning machines at or near the top of the instrument so it can be tuned quickly and easily during performance. Nothing should protrude or hang from the bass that could be bumped or kicked while playing.

There is a slight angle between the neck and the body of an acoustic double bass. This angle serves two purposes. It elevates the strings above the body so the bow does not strike the sides of the instrument when playing arco, and it brings the neck and fingerboard back to a position that allows the player to hold the neck comfortably and see the top of the fingerboard when playing. For the latter reason, EUBs with bodies tend to retain the neck/body angle. Some EUBs have little or no body and the angle issue is irrelevant.

The overall height of the instrument will be determined in part by the length of the string scale. The string scale is the distance between the nut and the bridge, and is also called the free string length. A longer string scale produces a deeper sound. The string scale on a full-size upright bass is 112 cms (44 inches). The string scale on a three-quarter-size upright bass is 103-108 cms (41-42 1/2 inches). Most EUBs are three-quarter-size. Some full-size models are available.

The aesthetics of existing EUBs, as seen in Section 5 of this document, vary greatly. Some are highly stylized while others are odd-looking. Some are nicely designed from the top to just below the strings, and then introduce an inconsistent-looking end pin or stand to raise the instrument up. Some have an acoustic double bass look. Others appear to be little more than strings stretched over boards.

The aesthetics of a well-designed EUB should refer to the rich history and tradition of musical instrument design and acknowledge the serious intellectual and emotional aspects of music. A bland design may fit in well with some jug band but will look out of place in an ensemble of well-designed and beautifully-crafted instruments. Most importantly, an EUB should look like what it is: an upright bass with electronics rather than a hollow body.

6.3.4: Human Factors

It should be stated that a detailed, in-depth human factors/ergonomics analysis of the problem is beyond the scope of this project. Information processing, anthropometry, work and safety issues will be considered.

Most of the **information processing** involved in playing the upright bass occurs in plucking, bowing and fingering the strings. These activities occur on the neck, fingerboard and strings of the instrument. The size, shape and relative position of the neck, fingerboard and string spacing have been solidly established over the centuries. Modifications to these elements would not be well received by trained bass players.

Some basses have small buttons inlaid at certain places along the fingerboard. These visual references show the player where to finger the strings to produce certain notes. Some players like these indicators while others see them as a sign of poor training or inadequate practice: like training wheels on a bicycle.

Anthropometry is human measurement. We can use it to determine the average height, arm length and hand size of upright bass players but this does us little good. The main elements of the bass that the player interfaces with are the neck, fingerboard and strings. The size, shape and relative position of these elements are based mainly on the requirements of the instrument and have been well-established for a long time. The strings must have room to vibrate freely, without hitting each other or the fingerboard. The player must have a large enough hand to hold the neck and finger the strings comfortably, or must be willing to work a little harder to compensate for smaller hands.

The height of the instrument should be adjustable up and down for players of different stature. Most bass players like to have the nut of the instrument at the level of their ear hole. Shorter players sometimes stand on risers to get up to the playing position on an acoustic double bass. This should not be necessary with an EUB.

Most of the **work** involved in playing the upright bass occurs, again, in plucking, bowing and fingering the strings. Most players have their instrument, acoustic or electric, "set up" to suit their particular playing style. This means to finely adjust the distance of the strings above the fingerboard to reduce the amount of work required to play them. The exact nature of the "set up" depends on the musician's individual playing style, hand size and physical strength. Sometimes the radius of the bridge is shaved down on one side or the other to lower the strings closer to the fingerboard.

Other work activities include tuning the strings, operating the controls and assembling and disassembling the instrument, if it comes apart. Tuning the strings requires considerable effort as bass strings are usually made of steel and are fairly thick. Tuning machine handles should be wide enough that the hand can grip them between the thumb and the forefinger and turn them easily. Operation of the controls (switches, knobs, dials) often takes place while playing and they should be located where they can be accessed quickly and comfortably. The bass, if it comes apart, should assemble and disassemble quickly and easily. If mechanical fasteners are required, there should be as few as possible.

The player should be able to balance the instrument while playing but not have to support its weight, as this can cause tendonitis. A locking stand would meet this need, but a stand can hinder a player's mobility. If a bass uses an end pin, it should be designed to prevent it from spinning while being played.

The EUB should be designed with **safety** in mind. There should be no sharp corners or edges that might injure the user when playing or transporting the instrument. It should not be heavy or awkward to balance and hold while playing. If the instrument comes apart, it should do so without pinching the hands or fingers of the user. The wiring must be insulated and all electrical connections should be grounded to prevent electric shock. Cables used to connect the instrument to an amplifier should not be run near the player's feet.

6.3.5: Manufacturing

This instrument is intended to be batch-produced or mass-produced. It must be designed to be made quickly and economically. This will require the application of industrial technologies. The components of the instrument should be manufactured separately and then assembled into the final product. The number of components required should be kept to the minimum.

Plastic parts should be made by plastic injection-molding. Metal parts should be made by pressure die-casting (zinc/aluminum), thixel-molding (magnesium) or computer-numeric-controlled (CNC) milling (steel/brass). Wood components should be made by CNC milling or woodworking techniques. All parts should be anodized, powder-coated, painted or stained according to the aesthetic requirements of the design. The components should be assembled and the wiring done by hand.

The electronic components can be outsourced or designed and built in-house. The design and construction of the electronic components is beyond the scope of this project. These parts, as well as the strings, will be outsourced.

6.3.6: Sustainability

Sustainability is a term used to describe sustainable human development. Sustainable product design is an important aspect of sustainability. The impact that the manufacturing of the design has on the natural and built environments must be minimized. This is true if the design is to be batch-produced, and even more true if it is to be mass-produced.

The environmental impact of manufacturing the design can be minimized in a number of key areas. The type and amount of materials that go into the fabrication of the design should be thoroughly considered. The amount of energy required to produce the design should be considered, as should the amount of waste material generated by the manufacturing process. The instrument should be designed to have a long and trouble-free product life cycle. The planned obsolescence of the design's parts or components, or of the product itself, is unethical and will not be considered. It should be stated that a thorough, in-depth life cycle assessment (LCA) of the design is beyond the scope of this project.

6.4: PROBLEM SOLUTION

6.4.1: The Original Project

This project got its start in an industrial design studio course in 1996. Students were allowed to design a product of their own choice as long as they demonstrated due attention to the various aspects of industrial design mentioned above. Electric upright bass design precedents were researched, a design was proposed, put through a number of iterations and finally, defined and described in general assembly drawings (**Figure 44**) and an appearance model (**Figure 45**).

The design had four strings, magnetic pick-ups and an end pin. It did not come apart. Its fingerboard and bridge were gently radiused but

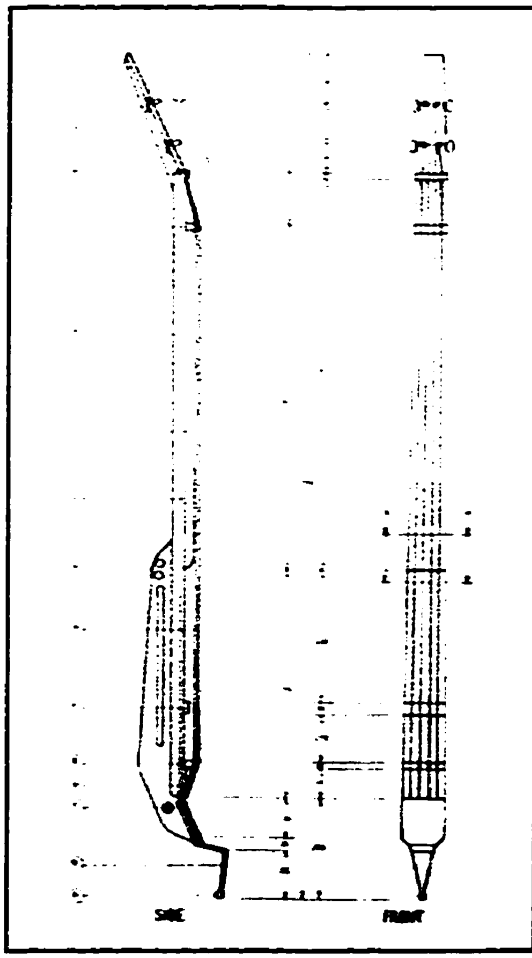


Figure 44.
Original project.
-general assembly drawing.

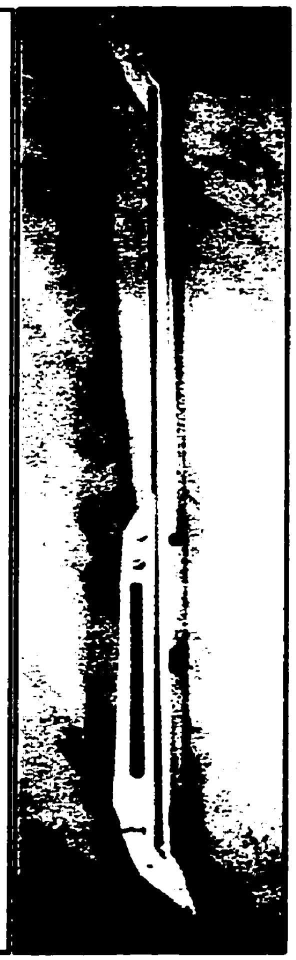


Figure 45.
Original project.
-appearance model.

the instrument was not playable with a bow. It was three-quarter-size and straight, with no neck/body angle. It was designed to be made from a pressure die-cast aluminum chassis with wood components attached behind to complete the shape of the neck and a hardwood fingerboard attached in front. The spine protruding perpendicularly from the back, lower part of the chassis provided rigidity and located the controls and phono jack.

In the end, the original project was fairly well-received. No further work was done on the design until late in 1997, when this MDP began.

6.4.2: Literature Search

The literature search reveals that very little has been written on the electric upright bass, perhaps because it is a relatively new arrival on the musical instrument scene. Some books on acoustic double bass history and construction are available as are some on the double bass-playing method. General information on bass and guitar electronics is available but a lot of specific information is proprietary and unavailable from the manufacturers. Some articles on electric upright basses are available in periodicals and on the internet. Bob McCaskey's December 1996 review of 16 different EUBs in Bass Player magazine is particularly informative. Martin Clevinger includes a history of the EUB on his website, and Mikael Jansen is a self-styled electric upright bass historian, based in Sweden.

Most of the information on electric upright basses is to be found on the internet, on the various manufacturers websites. The quantity and quality of information on these websites varies considerably, but looking at them helps one form a clear overview of current EUB design. Images and general information on existing EUBs are presented in Section 5 of this document.

6.4.3: Expert Users

Expert users were consulted early in the project for their ideas about EUB design. These included Mr. John Hyde; Calgary's pre-eminent upright bass player, Mr. Chipp Robb; a member of a popular local band and a dedicated EUB player, and Mr. Scott Peterson; a talented, young double bass student in the Music Department at the University of Calgary.

Mr. Hyde provided access to his 300-year old acoustic double bass and his Carruthers SUB-1* electric upright. He suggested that a thumb slot on the side of the fingerboard near the bottom would be a nice feature and expressed some dissatisfaction with the adjustable bout provided on his EUB. Mr. Robb provided access to his Messenger EUB* and had some insight into the types of strings available, the size and shape of EUB necks and fingerboards and the number of playable notes they might provide. (*The Carruthers and the Messenger were the only EUBs available for hands-on inspection over the course of this project. Both are included in Section 5 of this document). Mr. Peterson provided access to his 150-year old acoustic double bass and provided information about double bass "set-ups" (shaved bridges, scooped fingerboards). All three said they would prefer a five-string EUB over a four-string model, that the fifth string should be a low B rather than a high C, and that an EUB should be playable with a bow.

6.4.4: Idea Generation

Comparing the design from the original project against the design of existing EUBs helps identify some problem areas. The original design should have had a properly radiused fingerboard and bridge to make the instrument playable with a bow (arco) as well as by plucking (pizzicato). The neck should have been angled back from the body to provide the standard interface between the player and the instrument. A piezo pick-up system should have been added to the design, along with the magnetic pick-ups, to provide a more natural double bass sound.

A reconsideration of other elements of the original design confirms their appropriateness. A metal or plastic internal chassis is still a good idea. These components are readily manufacturable and will provide the instrument with both a rigid infrastructure and enough mass to resonate. Rigidity is required to resist the tensioning of the strings. Resonance is needed for the instrument to produce a warm, rich sound. If the chassis and connection are made in two sections, of a durable material, the instrument can be assembled and disassembled regularly without causing undue wear. This will improve its portability. It will be easier for the user to transport the instrument between home, rehearsal and performance venues.

Sketch models comparing the form and shape of a single chassis and a chassis with two sections that connect in the middle (**Figures 46 & 47**) confirm the two-part, connectable chassis solution is feasible.

Figure 46. Sketch model. 1-piece chassis.

Figure 47. Sketch model. 2-piece chassis.

The place where the neck meets the body is the logical site for the connection. The neck/body angle can be established at this position. The assembly/disassembly task should be designed to be as easy as possible.

The headstock and lower chassis stand out on these sketch models as components demanding special aesthetic refinement. These areas are front-facing and are not covered or obscured by other parts. A reference to traditional instruments in these components would be appropriate and would lend a sense of classic elegance to the design. At the same time, the amount of material needed to make these parts should be limited to reduce the weight and size of the instrument.

The spine that runs along the backs of the chassis sections makes them very rigid, even on the sketch models, and it should remain a part of the design. When an instrument's strings are tightened, they want to bend the instrument, like an archery bow. Rigidity is necessary to resist this tensioning. Also, strings are normally tuned one at a time. When a string on one side is tightened it wants to torque the instrument to that side. If it does, the string will be in tune but the instrument will be slightly bent. When the string on the other side is tightened it pulls the instrument back toward that side, straightening the instrument but putting the first string out of tune. The spine and the connection should be designed to resist bending under side tension.

Four, five and six string models should be considered. Four strings are conventional and do not offer anything new. A fifth string extends the range of notes available to the player by twenty-five per cent. A sixth string extends the range by fifty per cent but begins to introduce some problems. A neck and fingerboard wide enough to accommodate six strings would be considerably harder to play on.

6.4.5: Idea Refinement

Some fundamental decisions need to be made in order to proceed. Work done up to this point pushes the design in some very clear directions. A two-part detachable chassis made of an appropriate material will provide a rigid infrastructure for the design. Each chassis section should have a spine running perpendicularly along its back for added rigidity. The two sections should connect where the neck meets the body. The neck/body angle can be established at this connection. The connection must be made of durable material and should resist the forward and side tensioning of the strings. The lower chassis will raise the neck, fingerboard and strings up to the playing position. A short end pin will reduce the size of the lower chassis, in turn lowering the amount of material needed to make it, and therefore its overall weight.

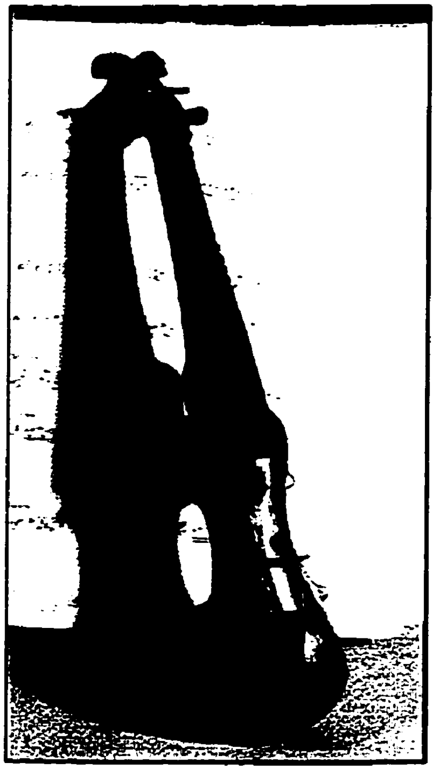


Figure 48.
Pochette.

The headstock and lower chassis need to be aesthetically refined, with a reference to traditional instrument design. Earlier research uncovered an old, interesting-looking instrument called a "pochette" (**Figure 48**). It was a small, pocket-sized violin, designed for easy portability. Its reduced body shape and traditional appearance make it an appropriate design precedent and it can be used to inform the design of the headstock and lower chassis of the EUB.

The instrument should have five strings to extend the range of playable notes. The string scale should be full-size to set the design apart from most other EUBs. The bridge and fingerboard need to be properly radiused to be playable with a bow. The neck should be about the same size and shape of an acoustic neck to preserve the well-established player/instrument interface. The tuning machines should be located at the top of the instrument, in the headstock, for easy access while playing. Additional components can be manufactured separately and attached to the chassis to complete the instrument. The design should include both piezo and magnetic pick-up systems wired to controls that are located for quick and easy access.

With these fundamental decisions in place, refinement of the overall design and its components can begin. It is logical to start by identifying areas that are established and cannot be changed, and to design out from these into areas that can.

It has been established that most players like to position the upright bass so the nut, or top of the fingerboard, is at the level of their ear. The anthropometric stature, or height, of most players is between the tenth and ninetieth percentile of these measurements. As such, the end pin should be adjustable to position the nut between 147 cms (58 inches) and 167.6 cms (66-1/2 inches) above the ground.

Because of the full-size string scale, the bridge of the instrument will be located at a 12 degree angle (neck/body angle) 112 cms (44 inches) below the nut. The piezo unit must be attached to the bridge to pick up the vibration of the strings. The bridge should be made out of maple, for its acoustic properties, and should sit solidly on the front of the body (the lower chassis). The saddle must be firmly attached to the body below the bridge to secure the ball-ends of the strings. The tuning machines should be located on both sides of the headstock to distribute the tension of the strings evenly.

An aluminum test rig built for this project (**Figure 49**) confirms that material as a suitable choice for the chassis. It is very rigid, reasonably lightweight and recyclable. A thermoplastic chassis was briefly explored and appeared promising, but proved to be beyond the budget for this project. Magnetic pick-ups were used on the test rig and they worked perfectly well. The test rig was also used to determine the electrical wiring requirements of the design and to test different brands of tuning machines.

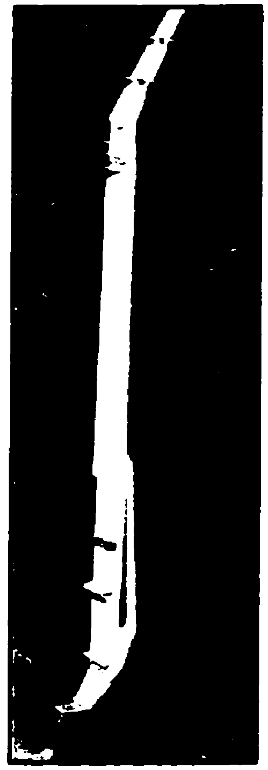


Figure 49.
Aluminum test rig.

7.0: PROPOSED DESIGN

This section contains the final proposed design of the electric upright bass. The individual components of the instrument are described as to their dimensions, their form, and the materials they are to be made from. A general assembly drawing of the complete instrument and photographs of the individual components accompany these descriptions. General assembly drawings of the components are included in the appendix of this document.

7.1: GENERAL ASSEMBLY DRAWING (Complete Instrument)

A general assembly drawing of the proposed design (**Figure 50**) is included on the following page. The list below corresponds to the letters indicating the various components on the drawing.

COMPONENT		MATERIAL	NOTES
A.	Headstock	aluminum	
B.	Tuning machines	aluminum (handles)/steel (gears)	outsourced
C.	String lock	aluminum (anodized)	
D.	Nut	hardwood (maple)	
E.	Fingerboard	graphite fibre	
F.	Upper chassis	aluminum	
G.	Thumb-boards	hardwood (maple)	
H.	Neck	wood/aluminum/graphite fibre	
I.	Connection	aluminum	
J.	Lower chassis	aluminum	
K.	Controls	aluminum (knobs)/wiring/circuitry	outsourced
L.	Magnetic pick-up	magnets/wiring/circuitry	outsourced
M.	Adjustable bridge	maple (bridge)/aluminum (adjusters)	
N.	Back-boards	hardwood (maple)	
O.	Saddle	aluminum (anodized)	
P.	Phono jack	wiring/circuitry	outsourced
Q.	Short end pin socket	aluminum	
R.	Long end pin	steel	
S.	Ball	rubber	
T.	Overall Height	2.03 m/80 inches	

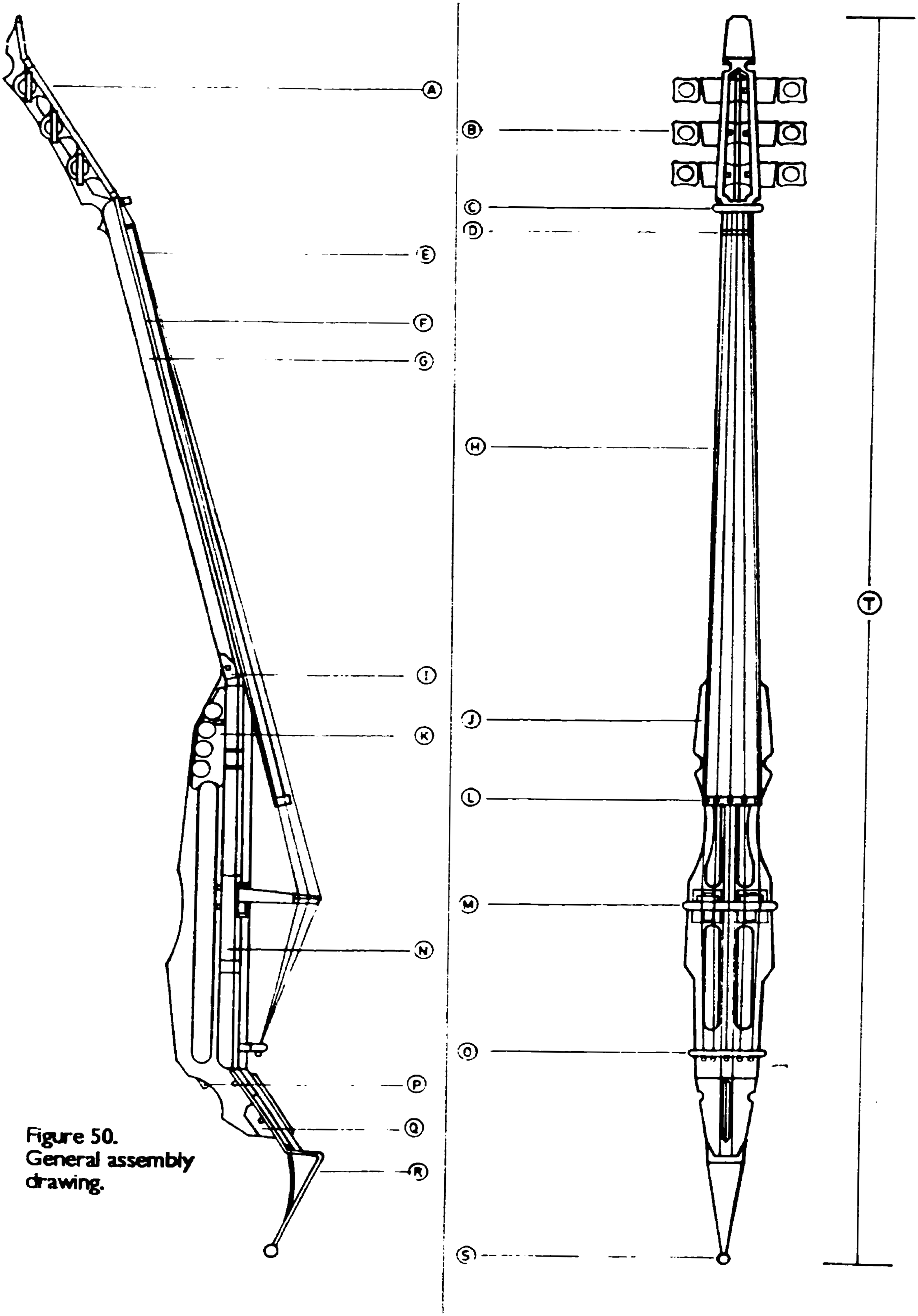


Figure 50.
General assembly drawing.

7.2: UPPER CHASSIS

The upper chassis is a single component, comprised of the headstock, neck and upper half of the connection. It is made from die-cast aluminum or injection-molded thermoplastic (ABS). It is finished in either a tint (plastic) or is anodized, powder-coated or painted (aluminum).

Dimensions (Upper chassis)

Overall length	114.5 cms	45 inches	
Width at top	7.0 cms	2-3/4 inches	(headstock)
Width at bottom	7.7 cms	3 inches	(connection)
Depth at top	7.0 cms	2-3/4 inches	(headstock)
Depth at bottom	4.0 cms	1-1/2 inches	(connection)
Thickness (front)	0.9 cms	3/8 inches	(varies in headstock)
Thickness (spine)	1.2 cms	1/2 inches	(varies in headstock)

7.2.1: Headstock

The headstock (**Figure 51**) is the structure located at the top of the instrument that holds the tuning machines. It is angled back 15 degrees from the neck to brace against the forward pull of the tightened strings. It is approximately the same size as an acoustic double bass headstock and has a similar composition, although the carved, curving shapes of the acoustic are replaced by simple geometric forms (planes, straight lines, circles).

Figure 51. Headstock.

Three tuning machine locators are positioned on each side of the headstock. This arrangement provides visual symmetry and evenly distributes the tension of the strings. Only five tuning machines are required, so one locator will hold a "sleeper" or false tuner, again, for visual symmetry. The locators are drilled out to fit anodized aluminum bushings that in turn hold the tuning machines. The tuning machine shafts must be aligned straight through, like banjo tuners. Most tuning machines are offset 90 degrees between the exterior shaft (the handle end) and the interior shaft that holds the end of the string. The straight shaft allows the tuning machine handles to protrude straight out from the sides of the headstock, rather than angle to the back as on conventional designs. This exposes the handles, which adds an interesting visual element to the headstock, and makes them easier to grab and turn.

Dimensions (Headstock)

Overall length	36.5 cms	14-3/8 inches
Width at top	3.6 cms	1-7/16 inches
Width at bottom	7.0 cms	2-3/4 inches
Depth at top	4.5 cms	1-3/4 inches
Depth at bottom	7.0 cms	2-3/4 inches
Locator length	4.8 cms	1-7/8 inches
Locator diameter	3.8 cms	1-1/2 inches

7.2.2: Neck

The neck (**Figure 52**) of the upper chassis is the long, narrow element between the headstock and the upper part of the connection. The fingerboard will be attached to its flat, front surface and the thumb boards will fill in the two gaps behind, on either side of the spine, to complete the rounded shape of a standard upright bass neck. The neck gets wider as it approaches the bottom, where the upper half of the connection is located. This mirrors the shape of the fingerboard and the string -spacing. It also gets slightly deeper, mirroring the shape of a standard upright bass neck and providing added material and strength at the connection. The spine of the neck provides rigidity. The spine flares out near the top of the neck, beneath the nut. This feature is called the thumb-stop.

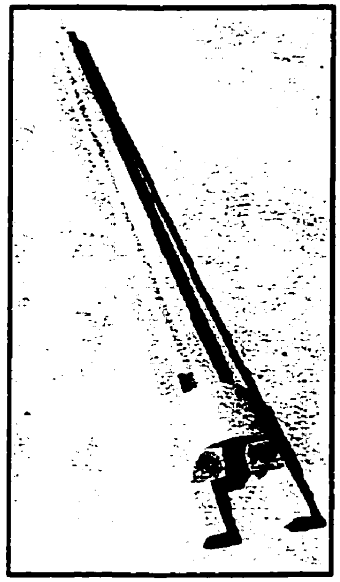


Figure 52. Neck.

Dimensions (Neck)

Overall length	71.5 cms	27-3/4 inches
Width at top	4.2 cms	1-11/16 inches
Width at bottom	7.7 cms	3 inches
Depth at top	3.5 cms	1-3/8 inches
Depth at bottom	4.0 cms	1-1/2 inches
Thickness (front)	0.9 cms	3/8 inches
Thickness (spine)	1.2 cms	1/2 inches

7.3: FINGERBOARD

The fingerboard (**Figure 53**) is the long, narrow component attached to the flat, front surface of the neck of the upper chassis. It should be made of graphite fibre over a lightweight core material. It is radiused to match the radius of the nut and bridge. It gets wider as it approaches the bridge, mirroring the string-spacing. It also gets slightly deeper, providing more material and strength at its bottom, where it leaves the support of the neck and overhangs the lower chassis. It is fretless but may have flush-mounted inserts along its length to indicate note positions. A slight scoop (4-5 mms) should be sanded into the upper two-thirds of the fingerboard to reduce string rattle.

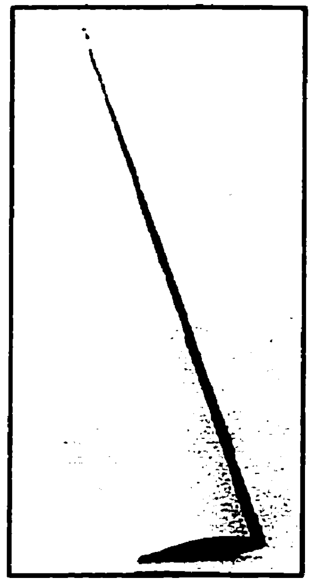


Figure 53. Fingerboard.

Dimensions (Fingerboard)

Overall length	91.5 cms	36 inches
Width at top	4.5 cms	1-3/4 inches
Width at bottom	8.5 cms	3-1/4 inches
Depth at top	1.0 cms	3/8 inches
Depth at bottom	2.5 cms	1 inches
Radius at top	6.1 cms	2-3/8 inches
Radius at bottom	7.7 cms	3 inches

7.4: THUMB-BOARDS

The thumb-boards (**Figure 54**) are the two wood components that fit in behind on either side of the T-shaped upper chassis. They are gently rounded over, completing the U-shape of a standard upright bass neck. They should be made of a sustainably-managed hardwood, like maple. They can be stained or painted any colour to suit the aesthetic requirements of each instrument. The thumb-boards get slightly wider and deeper as they approach the bottom of the upper chassis.

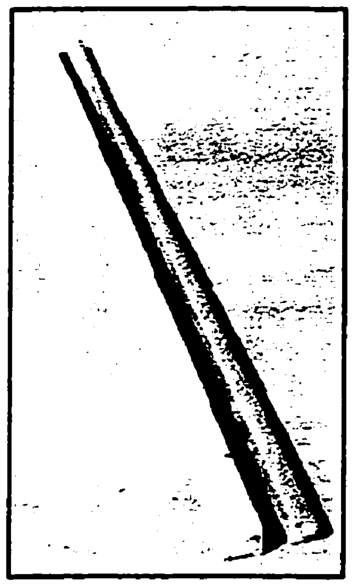


Figure 54. Thumb-boards.

Dimensions (Thumb-boards)

Overall length	67.7 cms	26-5/8 inches
Width at top	1.3 cms	9/16 inches
Width at bottom	2.5 cms	1 inches
Depth at top	2.2 cms	7/8 inches
Depth at bottom	2.5 cms	1 inches

7.5: CONNECTION

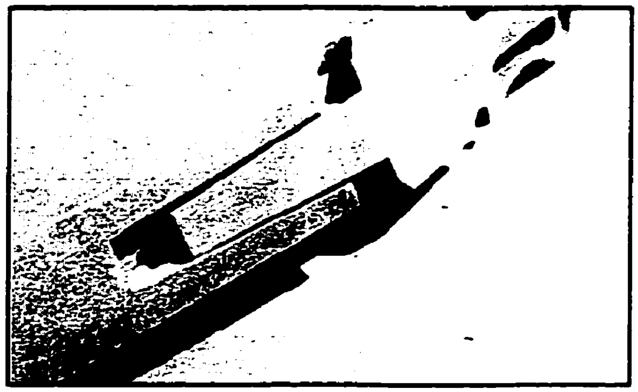


Figure 55a. Connection.

The upper part of the connection (**Figures 55a & 55b**) is located at the bottom of the upper chassis. The lower part of the connection is located at the top of the lower chassis. Both parts of the connection are built right into the chassis sections and are made of the same material. The connection is designed so the two halves fit together snugly, attaching and detaching smoothly and evenly. They are secured in place by two hex-head bolts screwed in from the back. The triangular-shaped tab at the top of the lower chassis is easily guided into the corresponding notch in the bottom of the upper chassis. This feature also helps the instrument resist bending under the side-tensioning that occurs when an outside string is tightened. Grooves on the sides of the tab help the instrument resist bending forward under the tensioning that occurs when all the strings are tightened. The rounded-over, bevelled joint at the back of the connection assures that the upper and lower chassis are aligned the same way each time they are assembled.

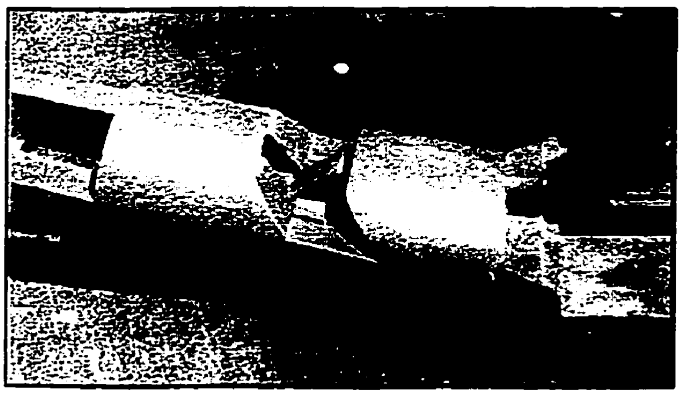


Figure 55b. Connection.

Dimensions (Connection)

Length		
-tab (front)	15 cms	6 inches
-bevelled joint (rear)	11 cms	4-1/4 inches
Width of tab		
-at top	2.5 cms	1 inches
-at bottom	4.3 cms	1-11/16 inches
Thickness of tab	0.9 cms	3/8 inches
Overall width	7.7 cms	3 inches
Overall depth	3.6 cms	1-3/8 inches

7.6: LOWER CHASSIS

The lower chassis (**Figure 56**) is a single component made from die-cast aluminum or injection-molded thermoplastic (ABS). It raises the neck, fingerboard and strings up to the playing height. It houses the controls and the phono jack connection. The saddle, which holds the bottom ends of the strings, is bolted onto the lower chassis below the bridge. The bridge stands out at a right angle from its centre area. Four bolts are threaded through the lower chassis from the back, beneath the feet of the bridge. These are used to adjust the height of the bridge. An adjustable (up/down) end pin is attached at the bottom from behind.

Figure 56. Lower chassis.

A slotted spine runs along the back of the lower chassis. The spine adds rigidity and provides a low centre of gravity, giving the instrument a nice sense of balance. The slot reduces weight and provides a place to connect the instrument to a stand. There are two "nests" located at the top of the spine, one on either side. These are buuilt right into the instrument. One of these holds the control knobs. The other holds the potentiometers the knobs are connected to. These are interchangeable to accommodate both left and right-handed players.

The phono jack connection is built right into the lower chassis. It is located near the bottom to keep the cable on the ground and out of the way. The phono jack can be on either side of the instrument. On a right-handed model, it should be on the left side. On a left-handed model, it should be on the right side. This will keep the cable away from the player's feet and reduce the danger of tripping over it or accidentally pulling it out.

The form of the lower chassis resembles the reduced, hollow body of the pochette, although the curving lines are again replaced by simple geometric forms (planes, straight lines, circles). There are six slots in the front surface of the lower chassis: two above the bridge, two below the bridge and two on the end piece. These can be seen as an abstract representation of the f-holes on an acoustic instrument and they lend a nice visual element to the design. They also reduce the weight of the instrument. The slots reduce the amount of material above and below the bridge. This should allow the instrument to resonate more freely in this area, something like a tuning fork.

Dimensions (Lower chassis)

Overall length	95.0 cms	37 inches
Minimum width	7.7 cms	3 inches
Maximum width	12.4 cms	4-3/4 inches
Minimum depth	8.5 cms	3-1/4 inches
Maximum depth	12.5 cms	4-7/8 inches
Thickness		
-front face	1.5 cms	5/8 inches
-spine	1.5 cms	5/8 inches
Slots (face)		
-length	17.2 cms	6-3/4 inches
-width	2.5 cms	1 inches
Slot (spine)		
-length	44.0 cms	17-3/8 inches
-width	2.5 cms	1 inches

7.7: BACK-BOARDS

The back-boards (**Figure 57**) fit in behind the lower chassis, on either side of the spine. They are shaped to follow the outline of the lower chassis and have corresponding slots cut into them. They are made of a sustainably-managed hardwood, like maple. They provide rigidity and give the lower chassis some added visual weight. Channels are cut into their undersides for the electrical wiring to run through. Compartments are cut into them to house the battery for the pre-amp and the circuit board for the piezo pick-up system. The compartments have removable covers.

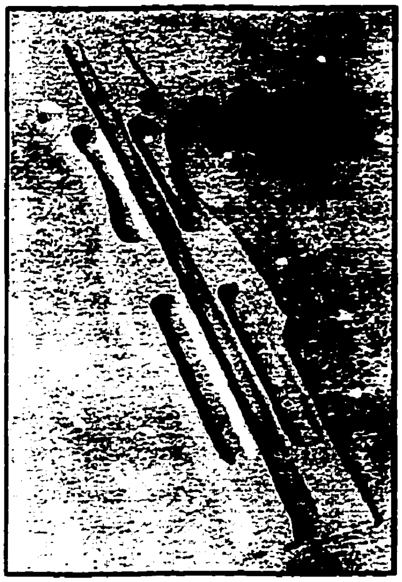


Figure 57. Back-boards.

Dimensions (Back-boards)

Overall length	63.5 cms	25 inches
Maximum width	12.4 cms	4-3/4 inches
Minimum width	8.5 cms	3-1/4 inches
Depth	2.0 cms	3/4 inches

7.8: BRIDGE

The bridge (**Figure 58**) is the bottom node of the string scale. It lifts the strings above the instrument and spaces them the appropriate distance apart. This design resembles an acoustic double bass bridge but it is simplified and less ornate. It must be made from hard-grain maple as this wood has excellent acoustic properties and is hard enough to withstand the downward pressure of the strings. The feet of the bridge are notched to hold two anodized aluminum blocks. The blocks are drilled out in two places underneath to accept the bolts threaded through from the back of the lower chassis. As the bolts are turned, they lift the blocks up or down, raising or lowering the height of the bridge, and consequently, the strings. The bridge can slide forward or back over the blocks, lengthening or shortening the string scale. The two blocks can be adjusted independently of each other to accommodate a variety of "set-ups." The bridge is notched in five places along its top radius to seat the strings. The piezo element is clipped onto the bridge to pick up its vibrations.

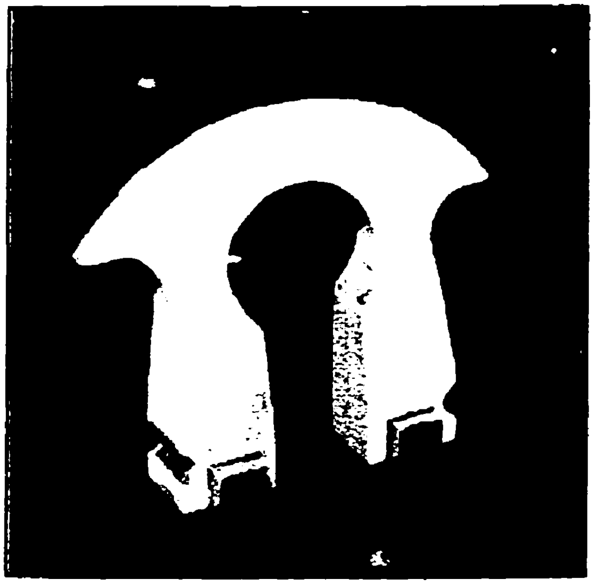


Figure 58.
Bridge.

<u>Dimensions (Bridge)</u>

Height	12.5 cms	4-7/8 inches
Width		
-at top	13.7 cms	5-3/8 inches
-at bottom	9.6 cms	3-3/4 inches
Depth		
-at top	0.6 cms	1/4 inches
-at bottom	2.5 cms	1 inches
Radius	7.7 cms	3 inches

7.9: NUT

The nut is the upper node of the string scale and is located at the top of the neck and fingerboard. It is made from a hardwood, like ebony or maple, to prevent string rattle. The nut is radiused along the top to match the radius of the strings and fingerboard. It is notched in five places to seat the strings. It spaces the strings the appropriate distance apart and holds them just above the fingerboard. It is bolted onto the neck from below.

Dimensions (Nut)

Height	1.5 cms	5/8 inches
Width	4.5 cms	1-3/4 inches
Depth	1.3 cms	1/2 inches
Radius	6.1 cms	2-3/8 inches

7.10: SADDLE

The saddle (**Figure 59**) secures the bottom ends of the strings to the body of the instrument. It is made from anodized aluminum and is drilled through at both ends to take the bolts that fasten it to the lower chassis. It has five countersunk holes drilled through its face for the strings to pass through. The strings have steel balls at their bottom ends that will not pass through these holes. The countersinking prevents any sharp edges from nicking or damaging the strings. The saddle has the same shape as the upper section of the bridge. This repetition of shapes, presented one immediately above the other, lends the design a sense of visual harmony.

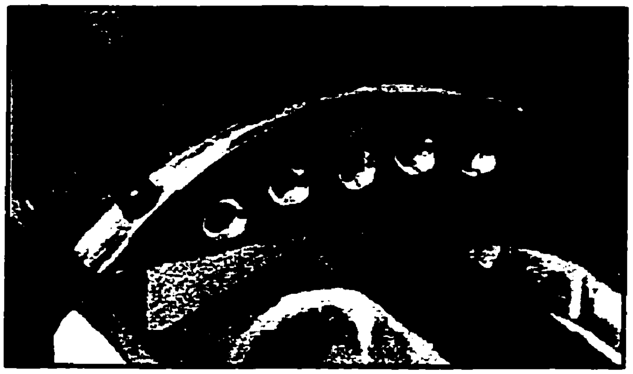


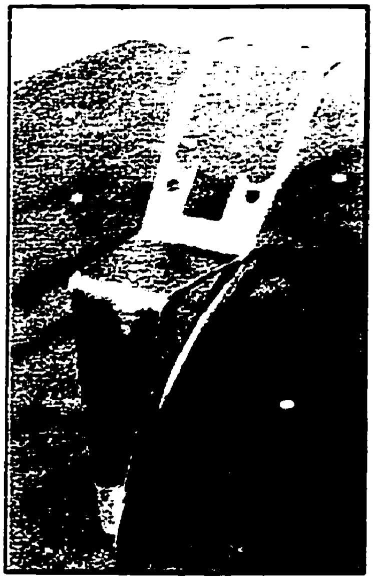
Figure 59. Saddle.

Dimensions (Saddle)

Height	2.5 cms	1 inches
Width	11.0 cms	4-3/8 inches
Depth	1.1 cms	7/16 inches
Radius	7.7 cms	3 inches

7.11: END PIN

The end pin (**Figure 60**) is a narrow, triangle-shaped piece of 12 guage steel. It is attached to the bottom of the lower chassis. A notch allows the end pin to straddle the spine and sit flush against the back of the chassis in this location. Bolts on either side of this notch fasten the end pin securely to the instrument. The bolts pass through slots, rather than holes, cut in the steel. The slots allow the end pin to be adjusted longer or shorter, setting the instrument at different playing heights for players of different stature.



The end pin bends forward, just below the bottom of the lower chassis. It extends out front of the instrument a short distance, then bends again toward the ground where it ends in a sharp point. The point should be covered with a small, hard, rubber ball to prevent damage to floors. Two curved steel rods are welded in place behind the end pin to reduce the spring in the bends. The end pin positions the weight of the instrument to the rear, making it want to fall back gently towards the player. This, in conjunction with the deep spine on the lower chassis, gives the bass an exceptional sense of balance, making it easy to hold and control while playing.

Figure 60.
End pin.

Dimensions (End pin)

Height	30.5 cms	12 inches
Width (max.)	8.5 cms	3-1/4 inches
Depth	0.3 cms	1/8 inches
Adjustable range	10.0 cms	4 inches

7.12: SHORT END PIN

A second, short end pin fits into a hole drilled into the bottom of the spine on the lower chassis. It is a short steel rod with a rubber ball on one end. The regular end pin can be removed and the short end pin attached to reduce the playing height a further 15 cms (6 inches). This gives the EUB an overall adjustable playing height range of 25.4 cms (10 inches).

7.13: CONTROLS (Knobs)

The volume and tone of the instrument are controlled by anodized aluminum knobs that are turned clockwise, to increase, and counterclockwise, to decrease. There are four of them (one volume and one tone control for each pick-up). They are located in the "nest" provided at the top of the spine on the lower chassis to provide the player with quick and easy access. They will be on the right side of a right-handed model and on the left side of a left-handed model. The knobs are round and are knurled to provide the fingers with some grip. The knobs protrude slightly above the "nest" so they can be turned by the ball of the thumb alone. They should turn effortlessly. A three-position switch is located near the knobs to select or blend the pick-ups being used.

Dimensions (Knobs)

Diameter	3.0 cms	1-3/16 inches
Depth	1.2 cms	1/2 inches

7.14: TUNER HANDLES

The tuner handles are gripped and turned by the player to tighten the strings. The handles used here will replace the small, plastic handles that come with the outsourced tuning machines. They are to be made from anodized aluminum. There are six of them although only five are required. The sixth is included to provide visual symmetry. They extend a short distance straight out from the sides of the headstock. They are broad and roughly square. Their fronts and backs are slightly scooped to fit the curved shape of a thumb/forefinger grip. The handles are larger than those on other stringed instruments because the strings are thicker and require more effort to tighten. A large hole in the centre of the handles reduces their weight. The handles have shafts that are drilled out to fit over the tuning machine shafts. A set screw is threaded through the side of each handle shaft to secure it to the tuning machine shaft.

Dimensions (Tuner handles)

Length	4.0 cms	1-9/16 inches
Width	3.8 cms	1-1/2 inches
Depth	1.6 cms	5/8 inches
Shaft		
-diameter	1.1 cms	7/16 inches
-length	1.2 cms	1/2 inches

7.15: BOUT

The bout (**Figure 61**) has a short, curved bracket at one end that bolts onto the back, upper half of the connection. The other end has a larger, curved piece, covered with padding, that rests against the player's hip. The bout is for players accustomed to playing an acoustic upright.

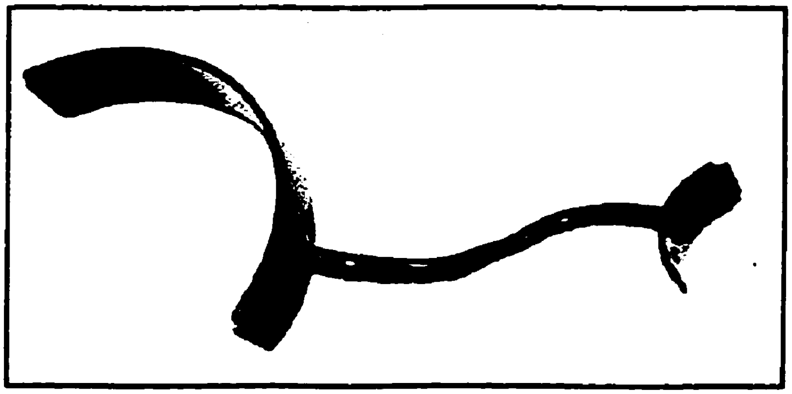


Figure 60L
Bout.

It replaces the shoulder of the acoustic hollow body, positioning the instrument the proper distance from the player, supporting its weight and providing added balance. A steel rod connects the two curved ends. It can be bent into the exact position the player finds most comfortable. The bout should be offered as an option with the instrument. It is not required if the instrument is held in position by a locking stand.

Dimensions (Bout)

Small bracket (14 gauge steel)		
Width	7.0 cms	2-3/4 inches
Height	3.5 cms	1-3/8 inches
Hip rest		
Width	25.4 cms	10 inches
Height	4.5 cms	1-3/4 inches
Bent rod		
Diameter	1.0 cms	3/8 inches
Distance from hip rest to instrument		
	15.5 cms	6-1/2 inches

7.16: STAND

The stand is not a component of this project. Some thought has been put into the basic design of one, but the time and resources needed to develop it further are unavailable. The basic concept of the stand is as follows: Two air or oil-filled cylinder pistons would be secured vertically to a weighted, steel base. A short roller would turn horizontally on an axle between the tops of the pistons. The roller mechanism could be raised or lowered manually and locked into place at any desired height. The roller would fit through the long slot in the spine of the lower chassis. The bass could be moved forward and backward over the roller along the length of the slot and locked into place in any desired position. This would make the instrument adjustable to any angle between the standing and the seated playing positions.

7.17: PICK-UPS

The pick-ups are to be outsourced. Research indicates that the best piezo pick-up systems are manufactured by Barcus-Berry, Fishman and Underwood. Five-string magnetic pick-up systems are available from NS Design, Seymour-Duncan and Pierre Josephs.

7.18: TUNING MACHINES

The tuning machines are to be outsourced. They must be the straight-through design, not the offset 90 degree design. Grover and Schaller are two of the top tuning machine manufacturers.

7.19: STRINGS

The strings are to be outsourced. They must be full-length and they must be made of steel to work with the magnetic pick-up system. They can be either low E, A, D, G, C or low B, E, A, D, G, according to the player's preference. Thomastik and Spirocore are two of the top string manufacturers. Top quality bass strings can cost hundreds of dollars.

8.0: PROTOTYPE

Building the prototype was deemed necessary to evaluate the single most important aspect of the design: the quality of sound the instrument produces. The prototype can also be used to test different strings and pick-ups. Defects in the design can be identified and remedied. The player/instrument interface can be evaluated and fine-tuned.

The background research and the design process culminated in a set of basic working drawings that were used to guide the construction of the prototype. Minor improvements in the design were made as the construction progressed. These are noted in the following sections.

Building the prototype added considerable time, expense and difficulty to this project. It took eight months longer than building a simple, appearance model. It cost about thirty-five hundred dollars, outsourced items included. A general accounting of the materials and items purchased for the project is included in the appendix of this document.

The sections below describe, in order, the steps taken through the prototyping process. The lost-wax casting method was used to reproduce the chassis components in aluminum, rather than pressure die-casting, because of the high costs involved.

8.1: A BRIEF OVERVIEW OF THE PROCESS

The design calls for the chassis parts to be made of thermoplastic or aluminum. The thermoplastic approach seemed promising but was prohibitively expensive. The aluminum approach could be done using the University of Calgary's facilities.

The chassis parts first had to be made out of wood. The wood parts were then used to construct rubber moulds. Casting wax was melted, poured into the hollow rubber moulds and allowed to harden. The wax parts were pulled from the moulds and sprued (sprues are wax vents that allow the metal to flow in and air to flow out of all areas of the piece being cast).

The sprued waxes were repeatedly dipped and coated in ceramic materials until a thick ceramic shell was built up around the wax shapes. The wax was melted out of the ceramic shell moulds, leaving them hollow. The hollow moulds were heated in a kiln to fire the ceramic material, making it able to withstand extremely high temperatures. Recycled aluminum was melted and poured into the moulds. After cooling, the ceramic shell was broken off the aluminum parts. The sprues were cut off and the parts were cleaned up and painted.

The design calls for a graphite fingerboard. The fingerboard on the prototype is fibreglass, pulled from a rubber mould. This method allowed a number of colour and finishing tests to be conducted and was more affordable.

The design calls for the smaller, metal components to be milled out of aluminum and anodized. On the prototype, these parts were made out of brass because of the relatively high cost of anodizing. The wood components were made and finished, the outsourced items purchased, and all the parts assembled to complete the prototype.

8.2: STEPS IN THE PROCESS

8.2.1: MDF Components

First, all the major components of the design had to be made out of MDF (**Figure 61**). MDF (medium density fibreboard) is affordable and easy to shape. This was done to verify that all the parts would eventually fit together as required, and to provide the shapes to pour the rubber mould-making compound over. Considerable effort went into refining the design of the connection during this stage of the process (**Figure 62**). The lower chassis was built as a single unit. The upper chassis was built in two pieces (headstock and neck) because as a whole it was too long to fit in the kiln at the university's foundry.

Figure 61.
MDF components.

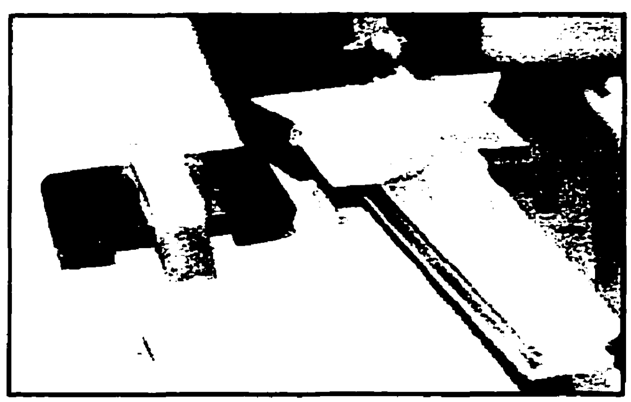


Figure 62.
Refining the connection.

Once they were built, the MDF parts were painted, varnished, waxed and polished. This was done to provide a glassy surface to pour the rubber up against and to make it easier to separate the pieces from the rubber after it had cured.

8.2.2: Rubber Moulds

Forms were constructed around the MDF components to pour the rubber compound into (**Figure 63**). The rubber is a liquid, two-part, room-temperature-vulcanizing (RTV) compound, designed specifically for mould-making. Great pains were taken in building the forms to reduce the amount of rubber required as it is very expensive ($25 per pound). In the end, 50 pounds of rubber compound were needed. Multiple-part, rubber moulds were made of the lower chassis and the neck and headstock of the upper chassis.

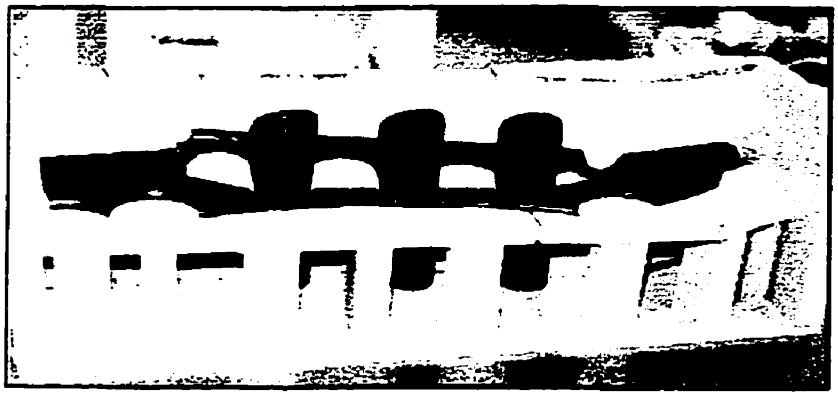


Figure 63.
Constructing forms to make rubber moulds.

The moulds were made of multiple parts so they could be taken apart and the MDF or wax parts inside removed. Each part of each mould had to have its own form built. The rubber had to be weighed and mixed and placed in a vacuum to remove air bubbles. Once this was done, the rubber was poured slowly into the form (**Figure 64**) and left for 24 hours to cure. This was a very painstaking and time-consuming step in the prototyping process.

On completion, the moulds were opened up, the MDF parts were removed and the moulds re-assembled so melted wax could be poured into them.

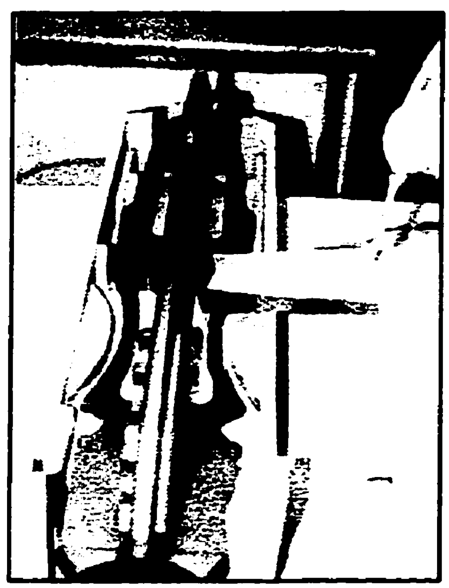


Figure 64.
Pouring the rubber compound.

8.2.3: Fingerboard

The fingerboard was a tricky item to produce. A different radius was required at each end and the bottom had to be flat to sit against the neck of the instrument. A large MDF column was built and turned on a CNC metal lathe to produce a cone shape of the required length with the appropriate radius at either end (**Figure 65**). A slice was cut off the side of the MDF cone at the required depth. The edges of the slice were bevelled and it was painted and polished. A form was built around it and a rubber mould was poured and allowed to cure.

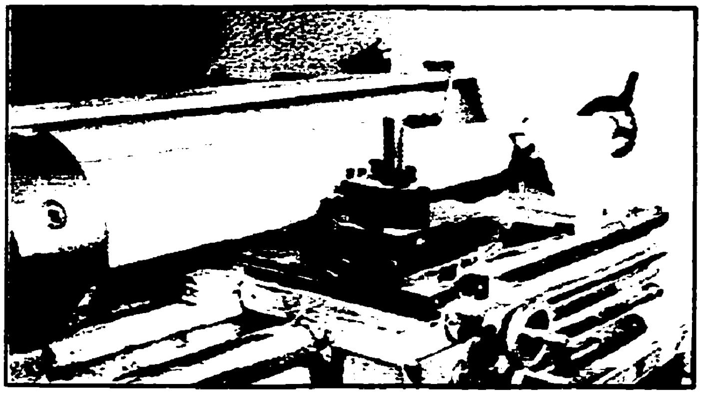


Figure 65.
Lathing the fingerboard.

Fibreglass mat and resin were mixed and poured into the rubber mould and allowed to cure. A number of fingerboards were made in this way to test different combinations of pigments and finishes (**Figure 66**).

Figure 66.
Fingerboard experiments.

The fibreglass fingerboards are lightweight and durable, though less so than graphite would be. They are smooth and shiny when they come out of the rubber mould. The sheen can be removed, if desired, by sanding with emery cloth or wet-and-dry sandpaper. They can be produced in almost any colour or combination of colours and are relatively inexpensive to make. The fiberglass fingerboard was used on the prototype to reduce expenses and it is not intended to replace the graphite fingerboard called for by the design.

8.2.4: Pouring Waxes

A problem arose when wax was melted and poured into the rubber moulds of the chassis parts. As the wax cooled and hardened, it also shrank a little, pulling away in places from the inside of the moulds. Three different kinds of wax were tried to see which would shrink the least. These were paraffin wax, micro-crystalline casting wax (yellow) and micro-crystalline modelling wax (brown). The yellow casting wax seemed to shrink the least but shrinkage remained a problem. In the end, melted wax was painted onto the insides of the moulds and built up layer upon layer until only a small, hollow core remained. Melted wax was poured in to fill this up.

A number of components were pulled from the moulds in both yellow and brown wax (Figure 67). The best two of each part were set aside and the others were melted down. The decision was made at this time to carry two complete chassis through the casting process in case something went wrong. This later proved to be a wise decision.

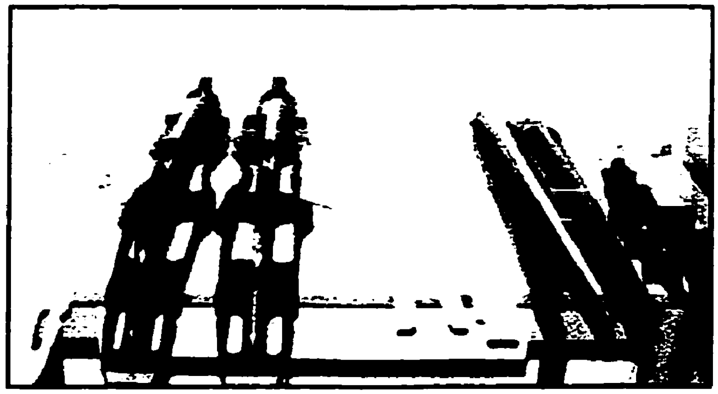


Figure 67.
Wax components pulled from moulds.

<u>8.2.5: Spruing Waxes</u>

Wax sprues needed to be added to the components. Sprues are wax rods of varying thicknesses that are melted (wax-welded) onto the main wax pieces at places where the flow of molten metal in and the flow of hot air out might cause a problem during casting (eg: an air pocket). The sprues melt out with the rest of the wax when the ceramic mould is heated, leaving hollow tubes, or vents, in the mould for the metal and air to run through. They will fill with metal during casting and are cut off when the piece has cooled and hardened. The sprues can be seen on the waxes in **Figure 68**.

Figure 68.
Sprued waxes.

Wax pouring cups were attached to the main pieces at this time as well. The pouring cups can be seen at the top of the waxes in Figure 68. The ceramic shell material forms around these cups. When they are melted out, they leave cup-shaped depressions that the molten metal is poured into during casting. Small wax buttons were also melted onto the surface of the main pieces at this time. These are added so that when the metal cools and begins to shrink, it will draw material from these buttons rather than pull away from the insides of the mould. The pouring cups and buttons fill up with metal during casting and are cut off later.

8.2.6: Ceramic Shell

Ceramic shell is a precision metal-casting method developed by Rolls-Royce to cast engine parts. It is a two-part system consisting of a liquid colloidal, or slurry, and fine silica flour and sand. The wax parts to be cast are dipped in the liquid and then coated while wet with very fine silica flour. Once the wax surface is completely covered with ceramic material, the silica flour is replaced by fine silica sand. On the last few coats, coarse silica sand is applied. The shells need to be built up to a thickness of about 1.2 cms (1/2 inch). This requires 12-15 coats. The pieces must be allowed to air-dry for about 8 hours between each coat. **Figure 69** and **Figure 70** below show the wax chassis parts drying after the first coat of ceramic material was applied and after the fifteenth and final coat.

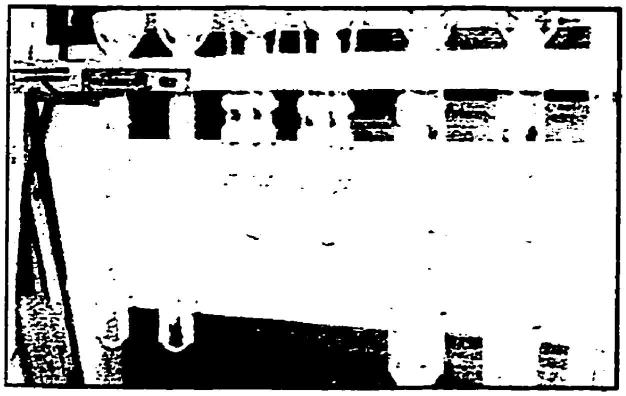
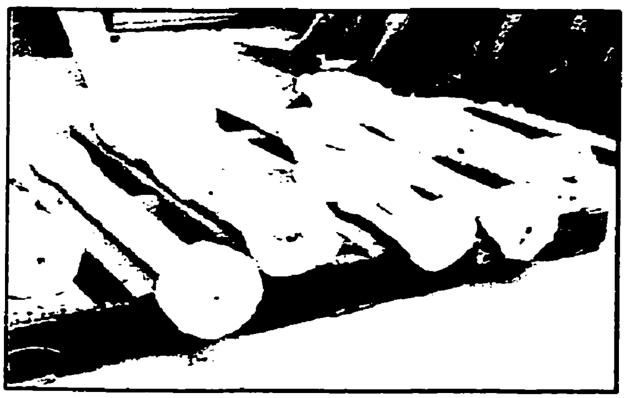


Figure 69.
After 1st coat of ceramic shell.

Figure 70.
After 15th coat of ceramic shell.



Steel hooks were embedded in the wax pouring cups so the pieces could be hung up to dry. When the ceramic shells were finished, the hooks were cut off. At this point, the pieces were ready for the wax burn-out (**Figure 71**).

Figure 71.
Ceramic shells ready for wax burn-out.

8.2.7: Wax Burn-out

The wax had to be melted out of the ceramic shells. Every trace of wax needs to be removed or it will burn when the molten metal is introduced into the moulds, creating hot gases and smoke that can ruin the casting. The wax-filled moulds were placed in a small, insulated burn-out kiln that was heated internally by a propane burner. The temperature inside the kiln was driven up as high as possible as quickly as possible. This is done so the wax starts to melt before it can expand and crack the moulds. This is called "flashing" the moulds (**Figure 72**).

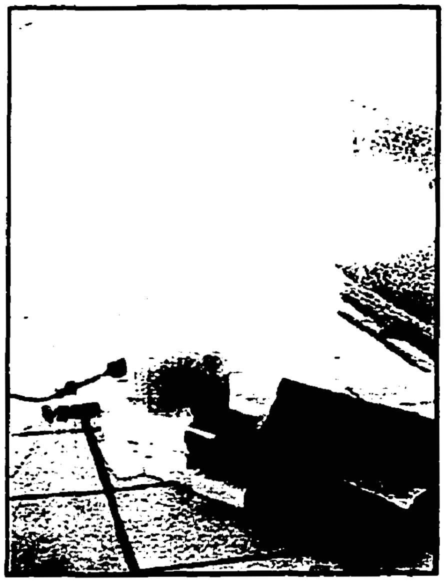


Figure 72.
Flashing the wax from the moulds.

Most of the wax ran out of the bottom of the burn-out kiln and was collected and saved for re-use. Some of the wax caught fire and burned, generating a lot of smoke. This usually happens during this step.

Figure 73.
Ceramic shells with wax melted out.

Once the wax was removed (**Figure 73**), the moulds were ready for firing. They were placed in a large kiln and the temperature was gradually brought up to 1400 degrees Fahrenheit. This changes the molecular structure of the ceramic material, making it able to withstand very high temperatures without cracking or breaking apart.

8.2.8: Casting the Aluminum

Clean, recycled aluminum is available from most scrap dealers for about $1.50 per pound. 120 pounds of aluminum flat stock end-cuts and pieces were purchased to melt down and pour into the ceramic moulds. The aluminum pieces were placed in a carbon/graphite crucible, which was then placed in a well-insulated blast furnace (**Figure 74**). The furnace was lit and the metal heated to just above its melting point (1400 degrees Fahrenheit).

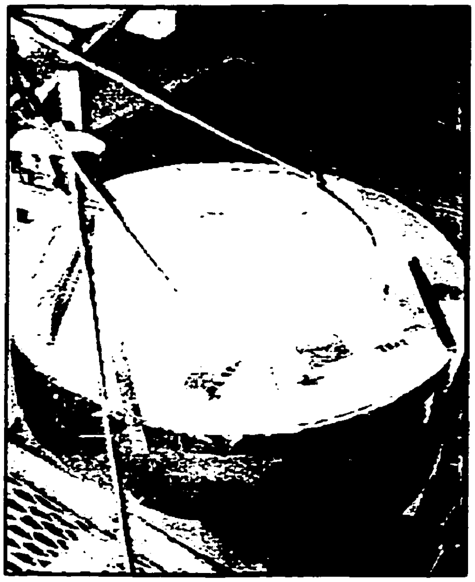


Figure 74.
Blast furnace melting aluminum.

Aluminum usually takes about 45 minutes to melt. Temperature readings are taken regularly with a pyrometer, a high-temperature thermometer, inserted into the crucible through an opening in the top of the furnace. When the metal had melted, the hot ceramic shells were taken out of the kiln and buried, pouring cup up, in a sand pit. Hot moulds reduce the thermal shock that occurs when the molten metal is poured in. The sand reinforces the walls of the moulds and provides thermal insulation, slowing the cooling process.

Wearing protective clothing and using special foundry tools, the crucible was lifted out of the furnace and the aluminum was poured into the moulds (Figure 75). Two crucibles of aluminum were needed to cast all six moulds. At one point, a heavy sludge was seen pouring out of the crucible, mixed in with the aluminum. It was later discovered that an ingot of magnesium had mistakenly been added to the crucible and had partially contaminated the batch. In the end, only one mould was lost: one of the lower chassis pieces. The remaining moulds were fine and enough parts were cast to make one complete upper and lower chassis. The earlier decision to make two moulds of each required piece proved to be a good one.

Figure 75.
Casting the aluminum.

8.2.9: Cleaning Up the Parts

The castings were allowed to harden and cool overnight. They were then taken out of the sand pit and the ceramic shell was chipped off with a hammer and chisel (Figure 76). Little bits of ceramic shell that remained were sand-blasted off.

Figure 76.
Chipping off the ceramic shell.

The pouring cups, sprues and buttons all had to be cut off of the parts. This job was done using special aluminum cutting wheels on angle grinders and pneumatic die grinders (Figure 77). Flat files and sanding blocks completed the work. Some of the larger surfaces were lightly milled to make them perfectly flat.

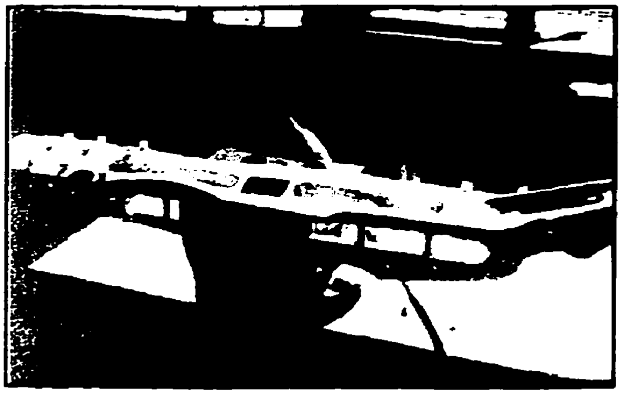


Figure 77.
Cutting the sprues off the lower chassis.

There were a few small areas of porosity on the surface of the metal. This is normal with large, lost-wax cast pieces like these. Porosity is caused by small pockets of gas that get trapped inside the moulds. These were filled in with body filler and sanded smooth. Once the pieces were completely cleaned up (Figure 78), the headstock was welded onto the neck and the two chassis parts were painted with metal primer.

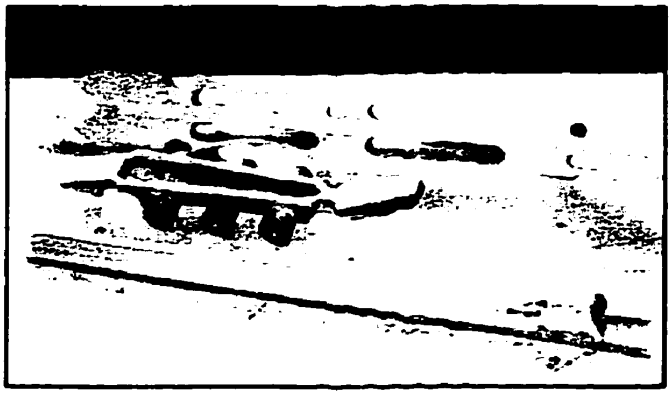


Figure 78.
Cleaned up aluminum parts.

8.2.10: Building and Fitting the Components

With the chassis and fingerboard in place, attention turned to building and fitting the other components of the instrument. These included the bridge, nut and saddle, the bushings to hold the tuning machines, the tuning machine handles, the control knobs, the end pins, the thumb-boards and back-boards and finally, the bout. The holes in the lower chassis for the bridge-adjusting bolts were drilled and tapped. All the components were positioned on the instrument to make sure they fit correctly (**Figure 79**).

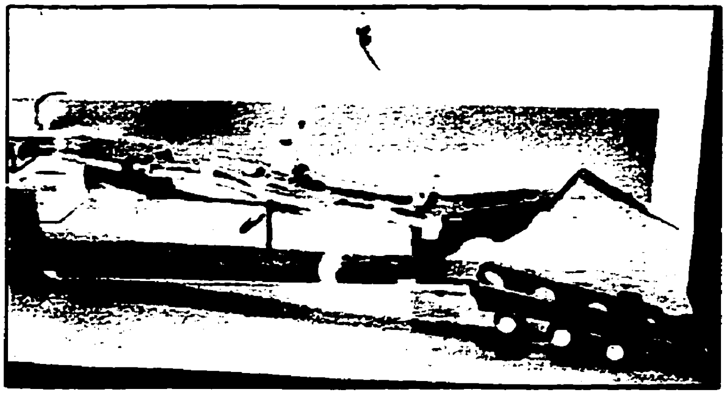


Figure 79.
Fitting the components onto the instrument.

8.2.11: Finishing the Components

The wood components were given a mahogany stain. The upper and lower chassis were painted with a dark red metallic automobile paint. The brass components were wet-sanded and polished. A red and black fibreglass fingerboard was formed in the fingerboard mould, sanded and polished.

The budget for the prototype only allowed for the purchase of one pick-up. A Barcus-Berry bridge-mounted piezo unit with a pre-amp was chosen. An appearance model of the magnetic pick-up was built and attached to the bottom of the fingerboard. With only one pick-up and time running out on the project, it was decided to not wire up the controls. The bass can be adequately demonstrated with just the piezo system in place. The bridge-mounted unit plugs into a small jack on the front of the lower chassis. This jack is wired to the phono jack at the bottom so the instrument can be plugged into an amplifier the way it is designed to.

The finished components were assembled and the strings and pick-up added. At this stage, all that remained was the "set up." The nut and bridge still had to be finely adjusted to position the strings close enough to the fingerboard to be easily playable but not so close that the vibrating strings would hit it. This is called 'string rattle.'

8.2.12: The Finished Prototype

The finished prototype (**Figures 80-83**) is solidly built and nicely finished in warm colours. It stands 2.03 meters (80") tall. It balances easily on either of its end pins. The bout, shaped as it is now, lets the instrument rest lightly against the hip of a right-handed player, approximately 185 cms (6'1") tall. It turns the bass slightly in towards the player, making it easier to see the strings and fingerboard. It has a full 112 cm (44") string scale that can be adjusted in length over 1.8 cms (3/4"). The height of the bridge can also be adjusted over 1.8 cms (3/4"). The instrument can be played with a bow.

The long end pin on the prototype does not adjust but it can be replaced by the short end pin, lowering the overall height of the instrument by up to 15.2 cms (6"). It disassembles easily by detaching the saddle and removing the two bolts at the connection. This only takes a minute or two to do. The gears in the banjo tuners are strong enough to tighten the strings into tune, but are not strong enough to hold them there. The string lock mechanism keeps the strings tight.

The knobs and switch are not wired up but the instrument can still be demonstrated. The volume and tone of the piezo pick-up can be controlled at the pre-amp. The pick-up is plugged into a mini-jack located near the bridge that is wired to the main phono jack at the bottom of the instrument. The phono jack can be connected to an amplifier by a cable.

The prototype weighs 12.5 kilograms (27.5 lbs), which is a little on the heavy side. If the brass parts were all anodized aluminum, as the design calls for, the bass would weigh 2 kilograms (4.4 lbs) less. If the chassis components were 6.3 mms (1/4") thinner all over, as the design calls for, the bass would weigh a further 2.3 kilograms (5 lbs) less, for a final weight of approximately 8.2 kilograms (18.1 lbs). This is very acceptable for an instrument this size.

Figure 80 shows the finished prototype disassembled. Figures 81-83 show it assembled and ready to play.

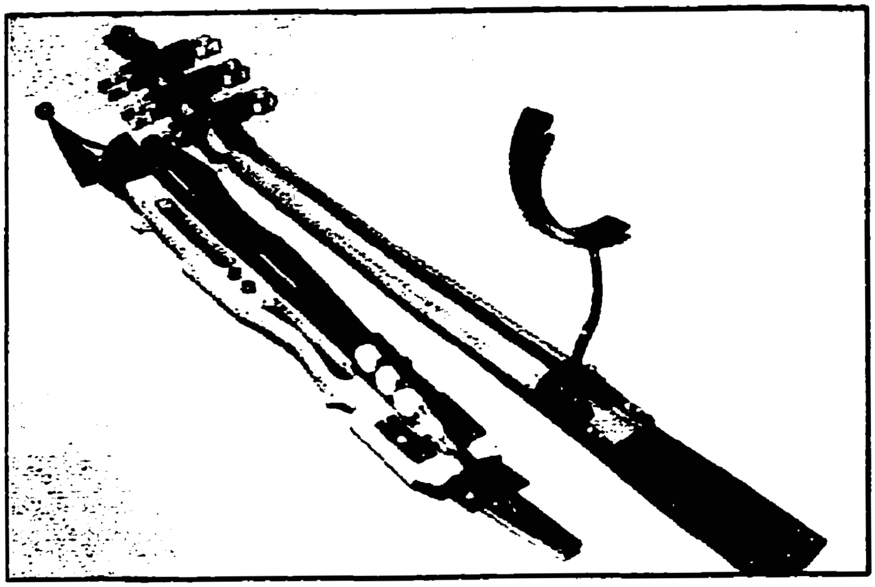


Figure 80.
Finished prototype.
-disassembled

Figure 81.
Finished prototype.

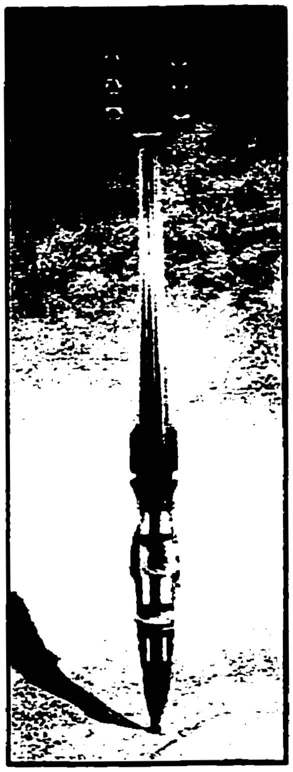


Figure 82.
Front view.

Figure 83.
With bout attached.

9.0: CONCLUSIONS

The primary objectives of this project were simple and straightforward: to design an electric upright bass and build a working prototype. The proposed design combines elements of traditional stringed instruments and modern electronic music capabilities. It illustrates the application of industrial design processes and activities to the design and manufacturing of a stringed musical instrument. The prototype confirms a number of important design decisions, raises questions about others, and provides a platform for further development.

The design was informed, in part, by a thorough consideration of traditional stringed instruments and existing EUB design precedents. It is designed to meet the needs of the musician and to be sustainably manufacturable. It demonstrates certain advantages over its acoustic counterpart. It is easily transportable, less prone to damage, and readily connectable to most electronic musical devices.

9.1: EVALUATING THE DESIGN

9.1.1: Materials and Technologies

The combination of cast aluminum, hardwood and polymer components has been a success. The instrument is very rigid, does not go out of tune and resonates beautifully.

-the **cast aluminum chassis components** are very rugged and resistant to damage. They are unaffected by changes in temperature and humidity.

-the **wood components** that house the wiring and some of the electronics are durable and lightweight. They also acknowledge the legacy of craftsmanship and use of natural materials that go into acoustic stringed instrument design.

-the **polymer fingerboard** is highly durable and resistant to wear from contact with the strings. It can be produced in a wide variety of colours and patterns.

-the finished prototype can play host to a wide array of **music electronics**. Combinations of different magnetic and transducer (piezo) pick-up systems can be fitted to it and experimented with to see what kinds of tones they produce. Different brands of strings can be tried out. A MIDI kit can be installed. An onboard EQ (equalization) module can be added to the design.

<u>9.1.2: Manufacturing and Sustainability</u>
This design, were it to be manufactured, would most likely see limited-run production of a few hundred instruments. Apart from the cost of the outsourced items (pick-ups, strings) and the tool-steel dies, it would be relatively affordable to produce. The required materials are abundant and readily available. The parts are easily assembled into the final product.

-the **polymer fingerboard** promotes sustainable development by eliminating the need to use **exotic hardwood**.

-all **the components** are readily and affordably manufacturable. They are designed to last a very long time, but can easily be repaired or replaced if damaged.

-the **metal components can all be recycled** if the instrument is ever damaged beyond repair.

-the chassis components can be made from **recycled aluminum.**

-the instrument can be **produced in one location**, eliminating transportation and inventory problems.

<u>9.1.3: Human Factors</u>
The bass is designed to be easy and comfortable to hold, balance and play. The controls are conveniently located, logically arranged and easy to operate.

-the instrument's low centre-of-gravity allows it to be **balanced with only a light touch**. When used with its optional bout and/or stand, it eliminates the risk of tendonitis.

-the instrument **provides a time-tested interface**, familiar to the trained bass player and easily learnable by the novice.

-the **overall height of the bass is adjustable** over 25 cms (10") to accommodate players of varying stature.

-it is **very safe to transport and play** and poses no health risk to the user.

-the bout holds the bass the **optimal distance** away and turns the strings and fingerboard slightly in toward the player, making it easier to see them.

9.1.4: Form and Aesthetics

There is a simple elegance to the overall appearance of the bass that reflects the beauty and long history of stringed instrument design. At the same time, it is sleek and modern looking.

-**custom finishes** can give the bass a variety of different overall looks: from refined and classical to flashy and aggressive.

-the **neck/body angle** makes it comfortable to hold the neck of the instrument and easy to see the strings and fingerboard.

-the lower chassis **spine adds an interesting visual element** to the design. It also provides extra rigidity and gives the bass a low centre-of-gravity and a nice sense of balance.

-the **design of the headstock** allows the bass to have either five or six strings. It resembles an acoustic bass headstock but is less frilly and ornate.

-the **slots in the lower chassis** reduce the amount of material in the bridge area, allowing it to vibrate more freely. They also reduce the weight and provide an interesting visual element.

9.2: RECOMMENDATIONS FOR FURTHER DEVELOPMENT

No suggestion has been made, nor should it be, that this design is either perfect or finished. There are some features that can be improved and others that need to be explored further.

-**different brands of magnetic and transducer pick-ups**, alone and in combination, should be tested on the instrument to determine which produce the best or most desirable tones.

-**different brands and types of strings** should be tested. The feasibility of a six-string model should be investigated.

-the **size and shape of the tuning machine handles** can be experimented with. The banjo tuning machines used on the prototype should be replaced by tuners with larger gears that can hold the tightened strings in tune.

-an **adjustable stand** needs to be designed. It should adjust to make the bass playable in both the standing and sitting positions and should be able to be locked in place. It must complement the aesthetics of the instrument and should break or fold down to be easily transportable.

-the bolts used in the connection and the saddle should eventually be replaced by **locking mechanisms**, eliminating the need for Allen wrenches.

-a **compatible MIDI kit** should be outsourced and installed to explore the possibilities and identify the limitations of MIDI in the design. The incorporation of other electronics, such as EQ, should be investigated as well.

-the **bridge-mounted piezo unit** should eventually be built right into the bridge, resolving the somewhat "tacked-on" appearance it has now. There are bridges available with the piezo elements built right into them (see Appendix E). These are expensive ($500US) but they could be outsourced and added to the purchase price of the instrument.

9.3: SUMMARY

Musicians are creative people. They seek and find inspiration in new developments and the creative possibilities they offer. Electric upright basses present musicians with an interesting and rewarding alternative to the electric bass guitar and the acoustic double bass.

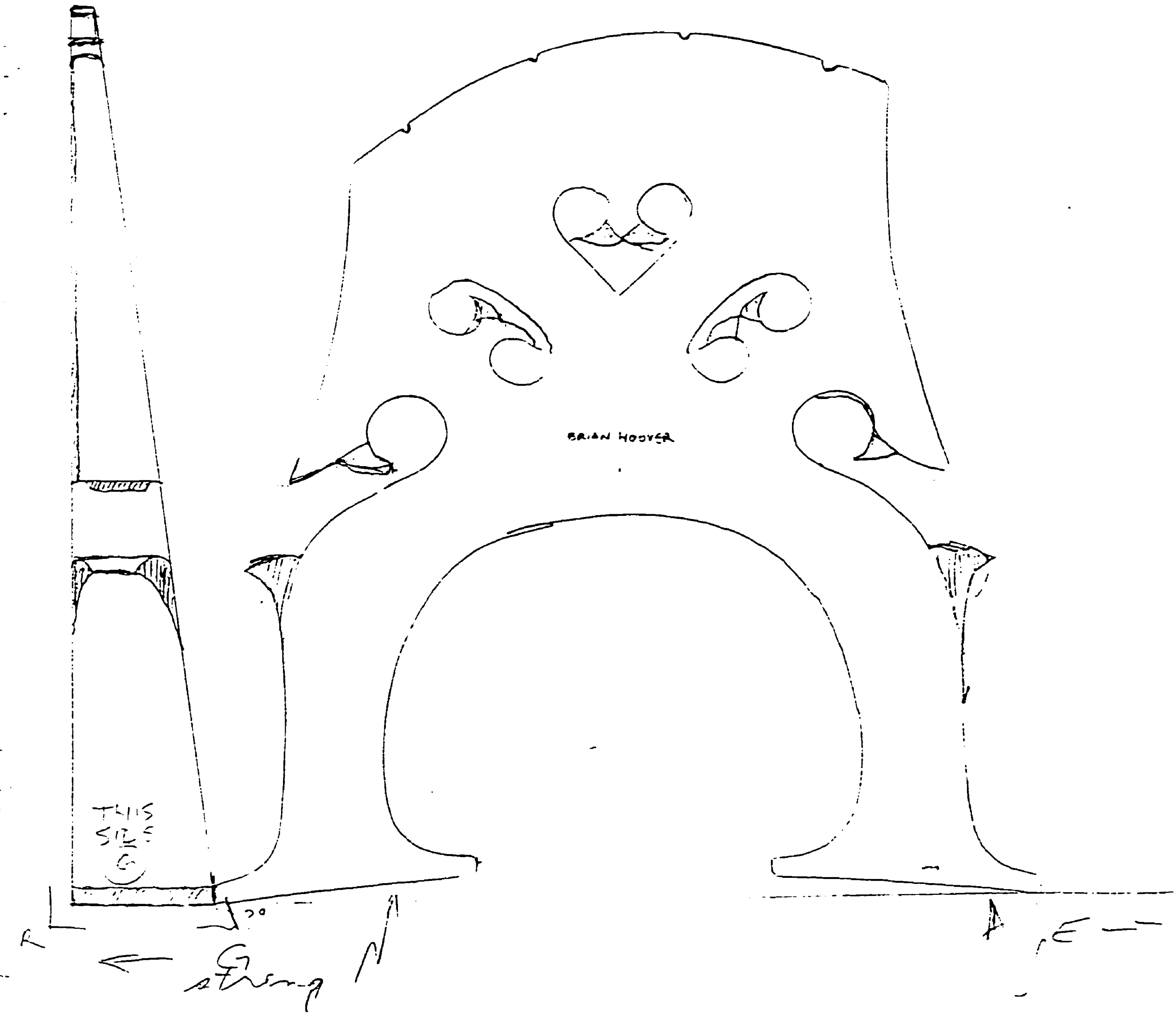
The fretless fingerboards and longer string scales on EUBs produce sounds that an electric bass guitar cannot. As well, they can be played with a bow. They also offer a different playing experience that re-connects the bass guitarist with the long tradition of bass playing.

EUBs are more adaptable to modern music technology than acoustic double basses could ever be. They are also far less delicate, more affordable, and easier to transport, service and maintain.

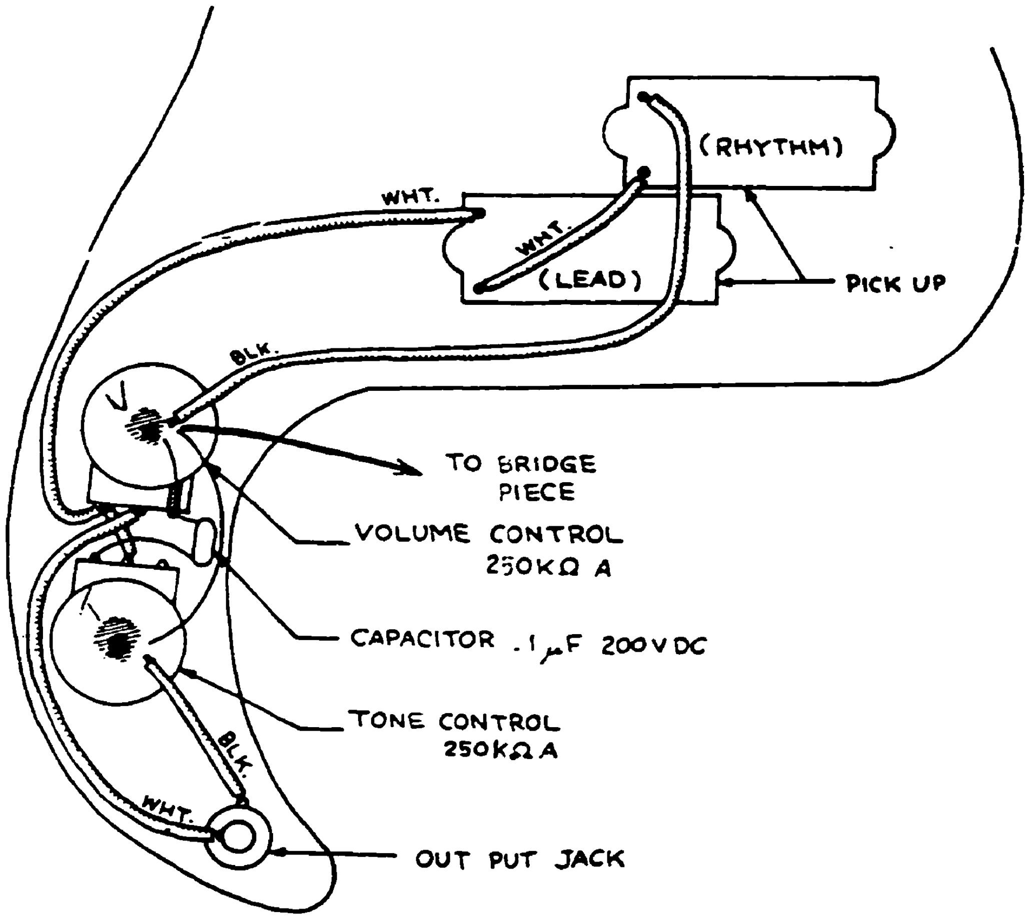
The music industry is always on the lookout for fresh ideas that can take it in exciting new directions. It is hoped that the design put forward here is in keeping with this kind of progressive thinking.

APPENDIX

APPENDIX A
Acoustic Double Bass Bridge
Tracing
Scale: 1:1



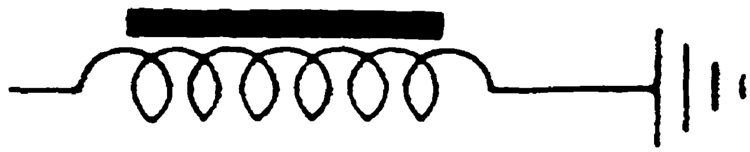
APPENDIX B
Volume and Tone Controls
Wiring Schematic



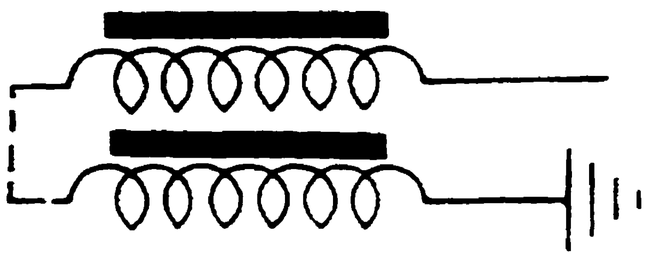
APPENDIX C
EUB Manufacturer URLs

http://www.telusplanet.net/public/pasc123/PE-HomePage.html
http://www.cyancorp.com/dingwall/
http://www.mosesgraphite.com/
http://www.abasses.com/
http://www.alembic.com/
http://www.ampeg.com/
http://members.aol.com/bridgeinst/home.html
http://www.spidermedia.com/bruguitars.html
http://www.gwi.net/~bdancer/EUB.html
http://www.batnet.com/jazmin/clevbass/
http://www.conklinguitars.com/
http://www.gelbass.com/
http://www.henge.com/~guitars/welcome.html
http://www.1212.com/gougi.html
http://www.hembrook.com/
http://www.halcyon.com/jensmus/
http://www.sas.upenn.edu/~nkaminsk/
http://members.aol.com/lincinc/lincluthier.html
http://www.sonic.net/~mssngr/
http://www.mosesgraphite.com/
http://lincoln.midcoast.com/~nsdesign/
http://home.coqui.net/rramirez/
http://www.kmh-online.com/gawron/
http://www.personal.u-net.com/~starfish/
http://www.income.it/allba/travel.htm
http://www.warwickbass.com/
http://www.zetamusic.com/

APPENDIX D
Pick-up Schematics



Schematic Diagram of a Single Coil Pick-Up



Schematic Diagram of a Humbucking Pick-Up

BARBERA MULTI TRANSDUCER BRIDGE FOR UPRIGHT BASS

"This unit is the best transducer on the market."

"...reproduces both pizz and arco playing in a simply amazing fashion..."

BARBERA CUSTOM BRIDGE-REPLACEMENT SYSTEM ($500)

Installation of this pickup is really special. You send an exact tracing of your bridge to Rich Barbera (in my case, only the top half of my adjustable bridge was necessary), and in a week or so he sends you a high-quality maple replacement bridge with eight piezo transducers hidden inside. The only signs of the pickup are a thin wire coming from the bottom of the bridge and a small graft along the top. The unit installs in minutes—but don't drop your soundpost!

Barbera included a demo tape with his unit, and while I was installing the bridge on my bass I played the tape on a high-end audio system. The demo, which consisted of pieces performed by Rufus Reid and Anthony Falanga, had the Barbera unit on the left channel and a studio mike on the right—and it knocked me over. I was very impressed with the bass reproduction, and I wanted to know more about the basses on the tape. Well, when I disconnected the tape deck and inserted the jack for the Barbera system, the great sound I had just heard was now coming from my bass! **This unit is the best transducer on the market. It reproduces both pizz and arco playing in a simply amazing fashion, with startling volume available and great sonic reproduction in all playing modes. It needs no improvement.** But don't take my word for it—call Rich and get the demo tape for yourself.

MY CHOICES

Which units get the job done best? As always, you must consider your instrument and your performance needs. **My favorite bass, the German flatback, will never part with the Barbera transducer; it's by far the best for volume, balance, and true acoustic-bass sound enhancement.** For the Juzek, I'll go with the Schertler electrostatic system—but this was a close call, with the Wilson coming in just behind. The Kay, used strictly for combat-zone rock gigs, will be outfitted with the combination of a Pierre Josephs String Charger and an Underwood. A Fishman Pocket Blender will become part of my gig bag's inventory, for use with all of my basses.

Once I had completed my test, I realized that a full-range amplifier is now an additional requirement for my gigs. A simple 1x15 combo just can't reproduce the harmonics, color, and voicing now available from my acoustic uprights. And so, perhaps, another quest has begun . . .

BARBERA TRANSDUCER SYSTEMS
21 Louis Street
Staten Island, NY 10304
(718)816-3025

Similar multi transducer bridges for violin, viola and cello are also available.

BARBERA
MULTI TRANSDUCER BRIDGE
FOR UPRIGHT BASS

The Barbera Bass Bridge is an integrated. multi transducer bridge/pickup system featuring two transducer elements per string.

MULTI DIMENSIONAL SOUND REPRODUCTION

The Barbera bridge is responsive to the vertical and horizontal vibrations of each string independently. in addition to the overall lateral twisting and flexing action of the bridge.

- Vertical sensitivity to each string provides clarity. balance and sustain for pizzicato.
- Horizontal sensitivity to each string provides for precise articulation of attack for pizzicato and a rich. natural arco sound which is dynamically in balance with the pizzicato.
- Overall lateral bridge motion sensitivity provides full tonal interaction with the instrument top.

These combined sensitivities produce a multi dimensional reproduction of the instrument's sound with full. clear fundamental and overtone response at flat EQ settings.

ALL MAPLE ELECTRO-ACOUSTICS

The bridges eight sensing elements are set in miniature vibrationaly responsive maple structures. These mini electro-acoustic structures are precision crafted within a maple graft set into the bridge. below the strings. The all maple construction of the system is tonaily compatible with the bridge and does not impede the acoustic function of the instrument.

Some additional features include:

- Stable and consistent tonal accuracy
- Warm and open quality of sound
- Even response across the strings
- Passive operation (no batteries or additional external circuitry)
- High gain output
- High resistance to feedback
- No fingerboard noise or distant. ringy edge to the sound
- Clean uncluttered appearance on the instrument

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Barbera Transducer Systems
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Barbera Multi Transducer Bridges are custom made to match individual instrument set-ups. Procedural options for submitting a set up to be duplicated are:

A) **Direct Tracing-** Remove bridge from the instrument and lay it flat on a piece of paper. With a sharp pencil make a tracing of the bridge.

B) **Tracing without removing bridge** Scissor cuts in a piece of paper corresponding to the string positions allows for the paper to be positioned on the bridge for tracing. (See enclosed instruction sheet)

C) **Submit a new fitted bridge** Pre fit a new bridge with your local luthier, and send the bridge for Multi Transducer graft installation. The new bridge should be completely set up ie; arc string spacing, adjusters, etc. The bridge should be left at full blank thickness though. **Final thinning will be done after installation of the Multi Transducer Graft.**

D) **Installation into the original bridge** If the original bridge is a minimum of 1/4 inch(.250) thick along the crown, it **may** be possible to install the graft into it. Determination of feasibility can only be made by direct evaluation of the bridge here at the shop.

FURTHER TO OPTION A) To indicate the angle that the adjuster holes were drilled;

-Cut two pieces of paper to apx. 4" X 6"

-Roll up a piece tightly into a thin tube (as if you were rolling a cigarette) you now have a stiff tube apx. 4" long.

-Insert the tube into an adjuster hole in the leg of the bridge. adjusting the diameter of the tube by unraveling and tearing off excess material as needed.

-Apply a piece of tape to the tube seam to keep it from unraveling The tube should fit snuggly in the adjuster hole

-Repeat process for other leg.

-With the tubes extending from the adjuster holes alighn the bridge back on your original tracing and trace the tubes as they extend out of the bridge legs.

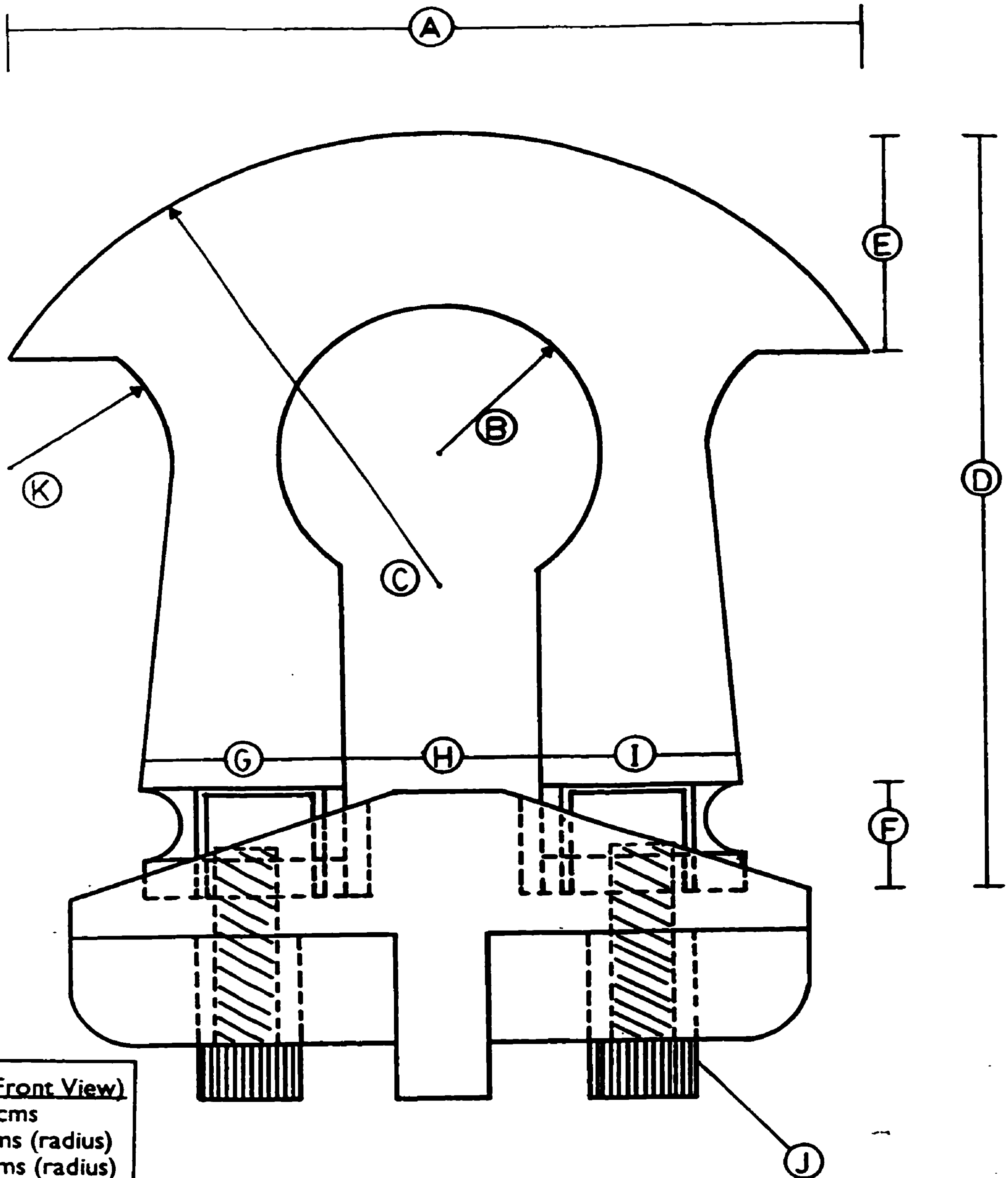
Be sure and indicate if you have metal or wood adjusters, and if they screw up into the legs or down into the feet of the bridge.

Send one of the tubes in with your tracing

APPENDIX F

Dimensioned Drawings

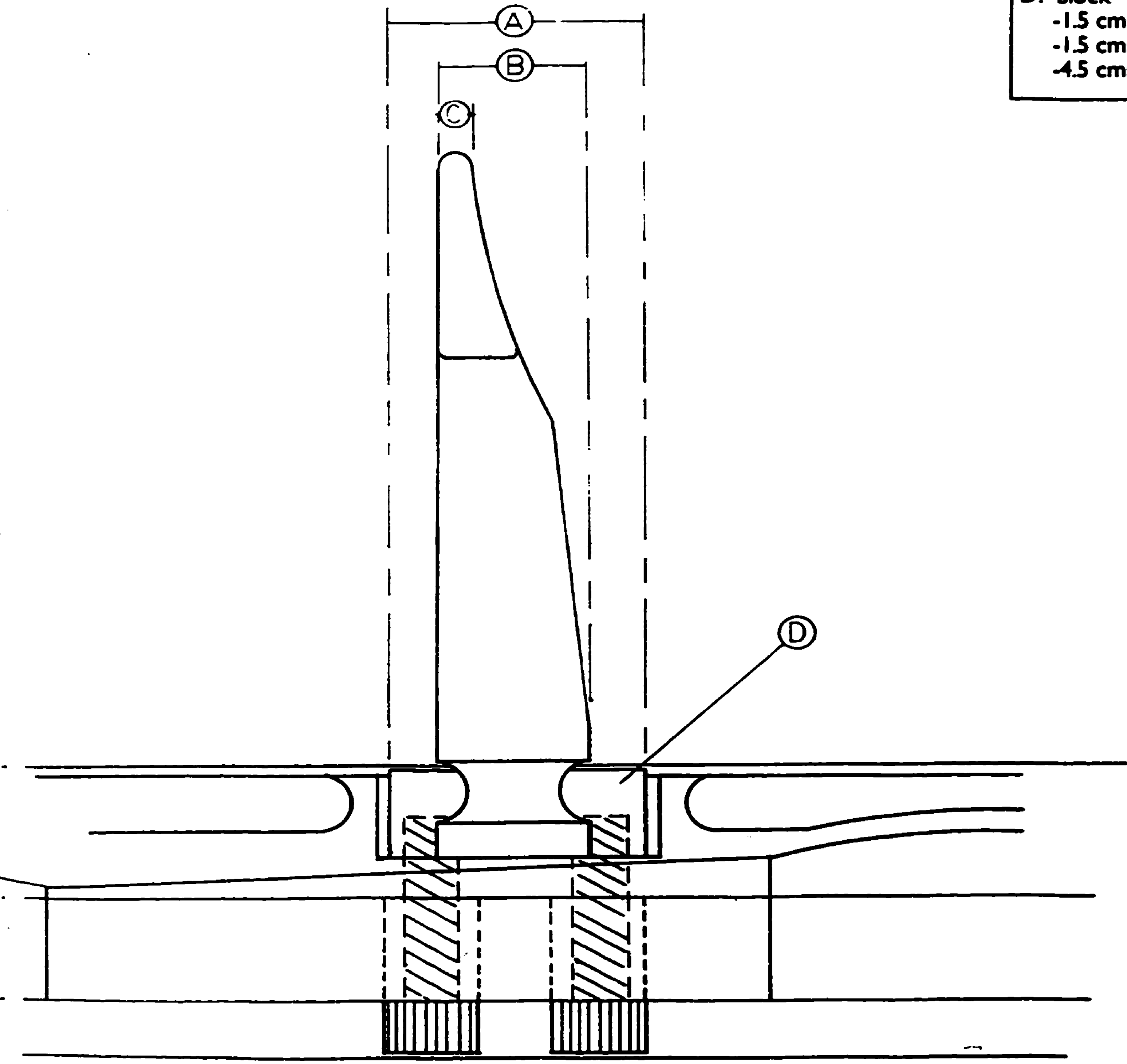
- -bridge
- -connection
- -lower chassis
- -headstock
- -bottom/end pins
- -overall



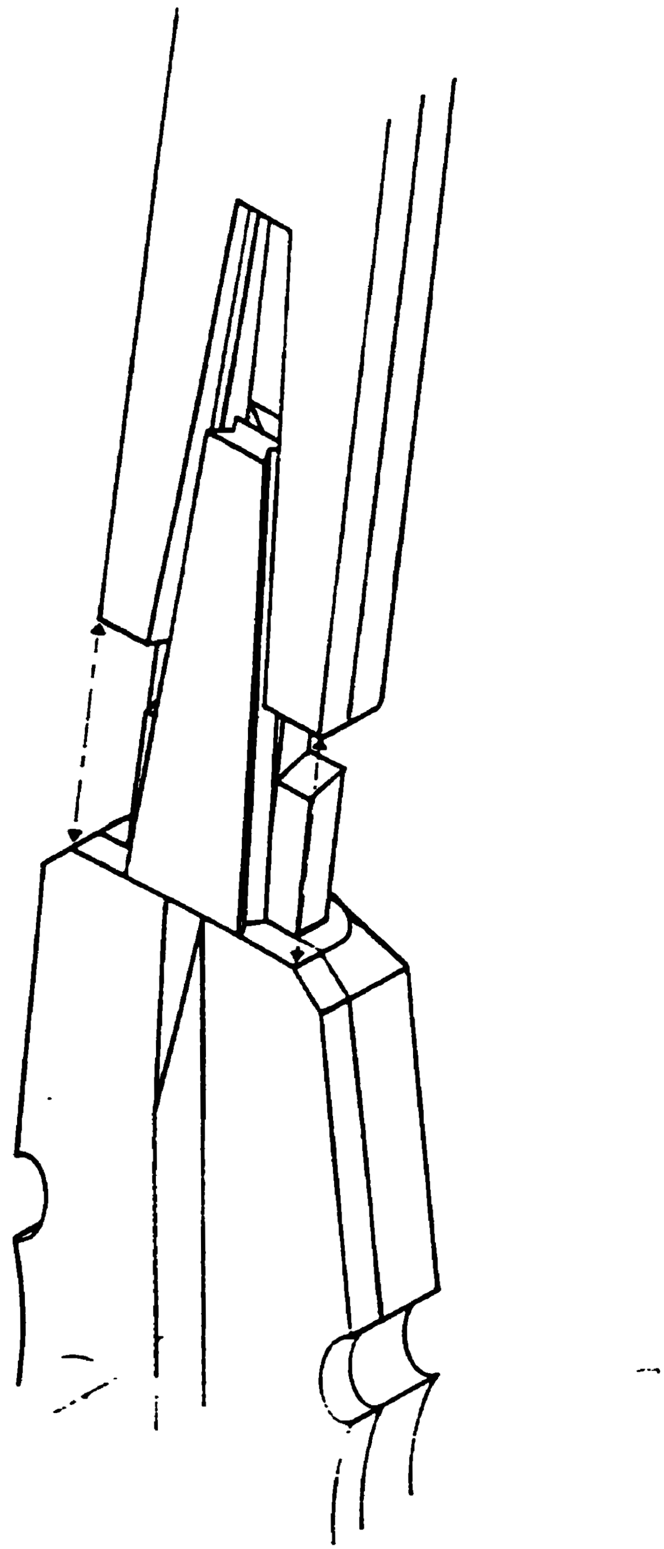
Bridge (Front View)
A. 13.5 cms
B. 2.5 cms (radius)
C. 8.0 cms (radius)
D. 12.5 cms
E. 4.0 cms
F. 2.3 cms
G. 3.0 cms
H. 3.0 cms
I. 3.0 cms
J. Bolts
-1.0 cms dia.
-3.5 cms long
K. 2.5 cms (radius)

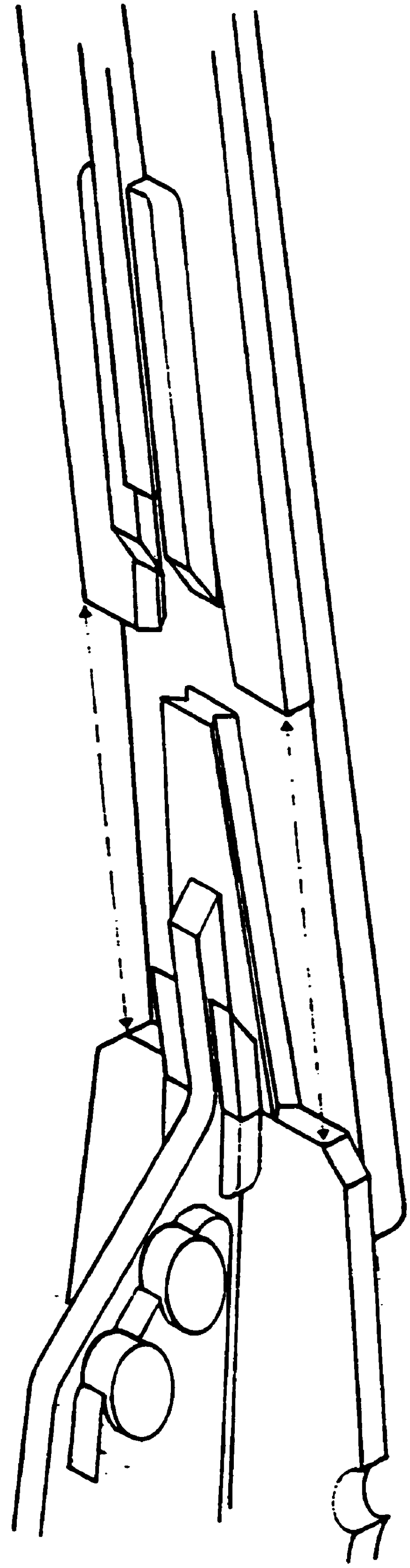
Bridge (Side View)

A. 4.5 cms
B. 2.5 cms
C. 0.5 cms
D. block
  -1.5 cms wide
  -1.5 cms high
  -4.5 cms long



Connection
-isometric projection
-front view
-fingerboard not shown

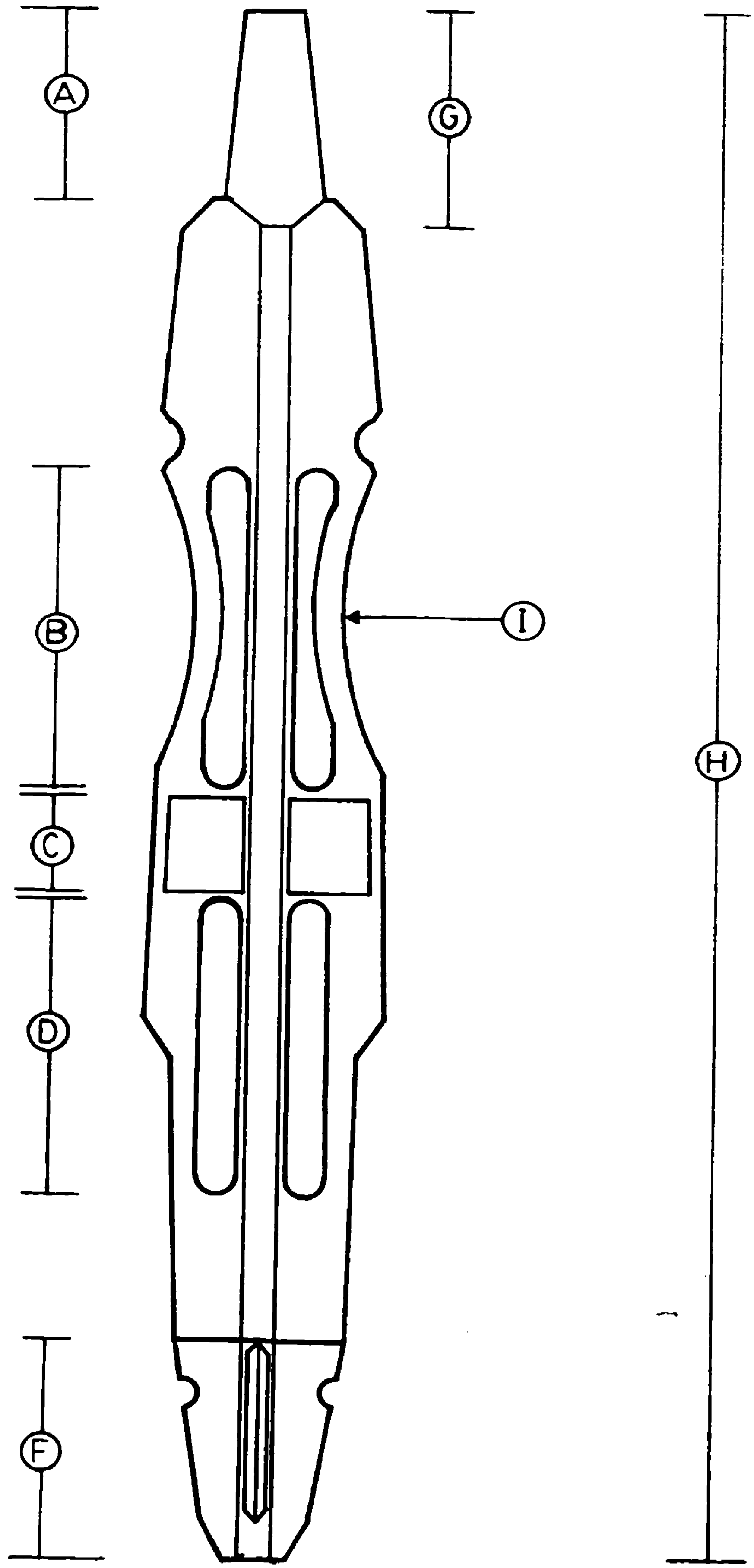




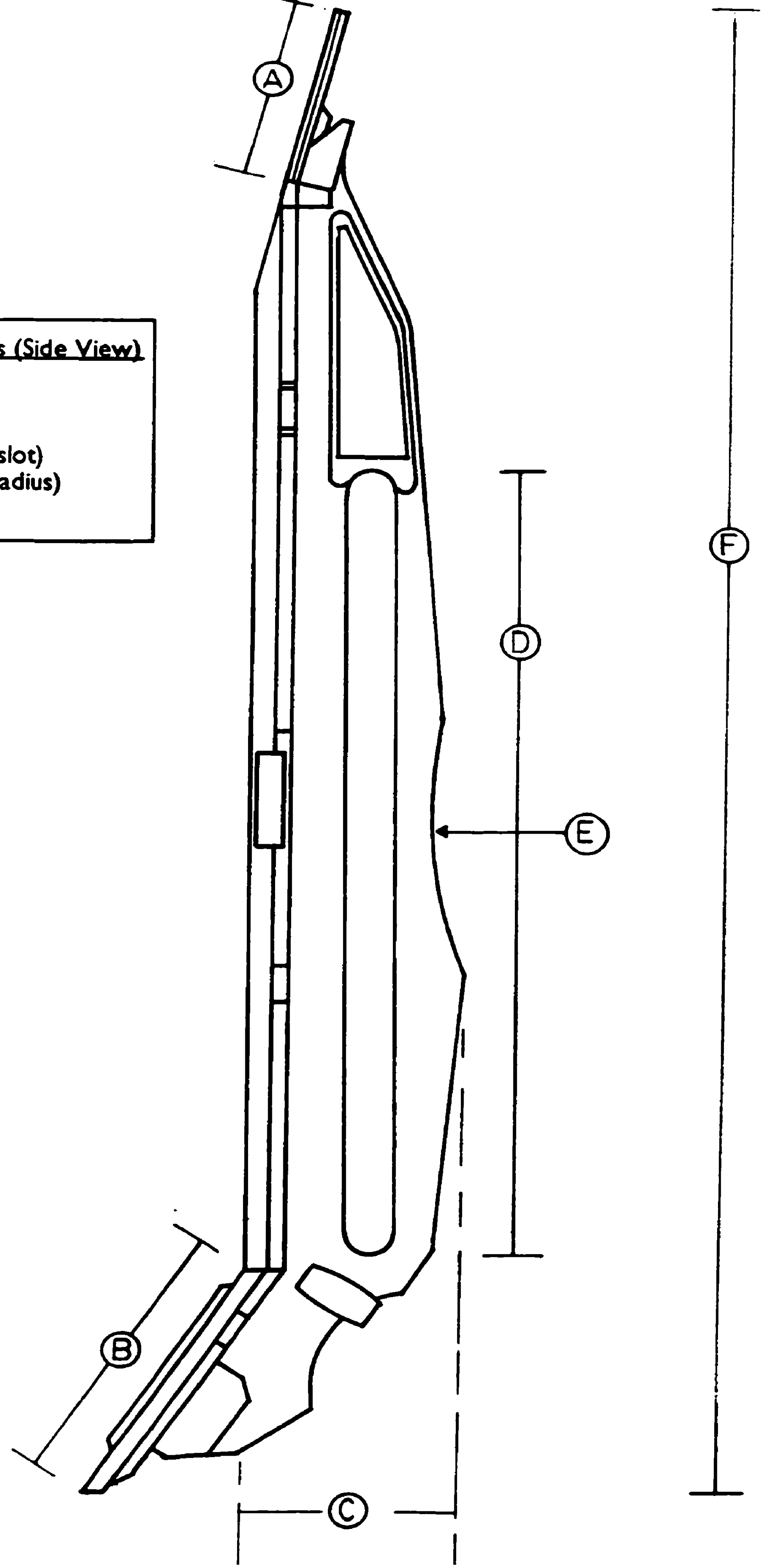
Connection
-isometric projection
-rear view
-thumb-boards and
back-boards not shown

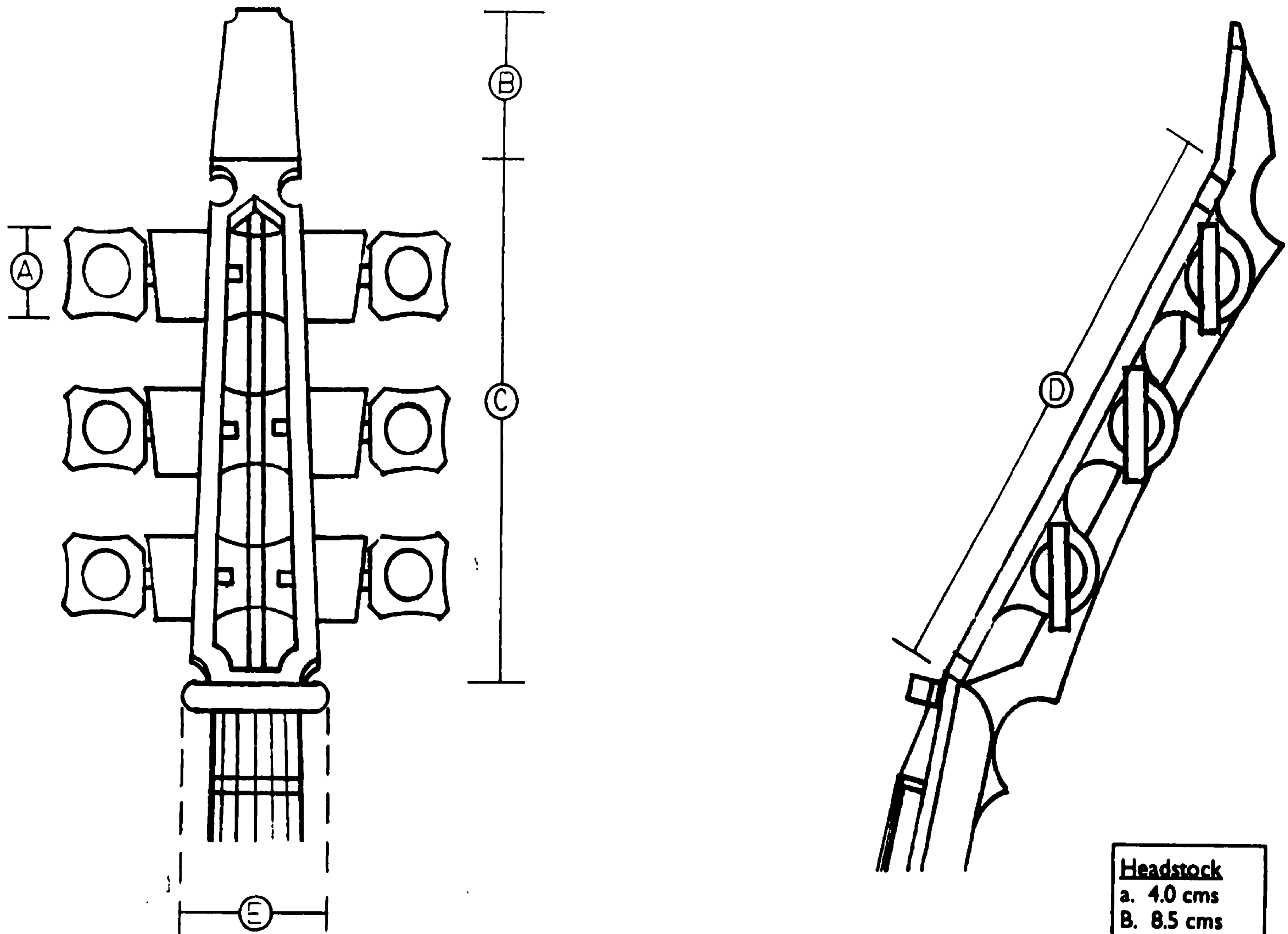
Lower Chassis (Front View)

A. 14.0 cms
B. 17.0 cms (slot)
C. 5.0 cms (pad)
D. 16.5 cms (slot)
F. 16.0 cms
G. 18.0 cms
H. 96.5 cms
I. 21.5 cms (radius)

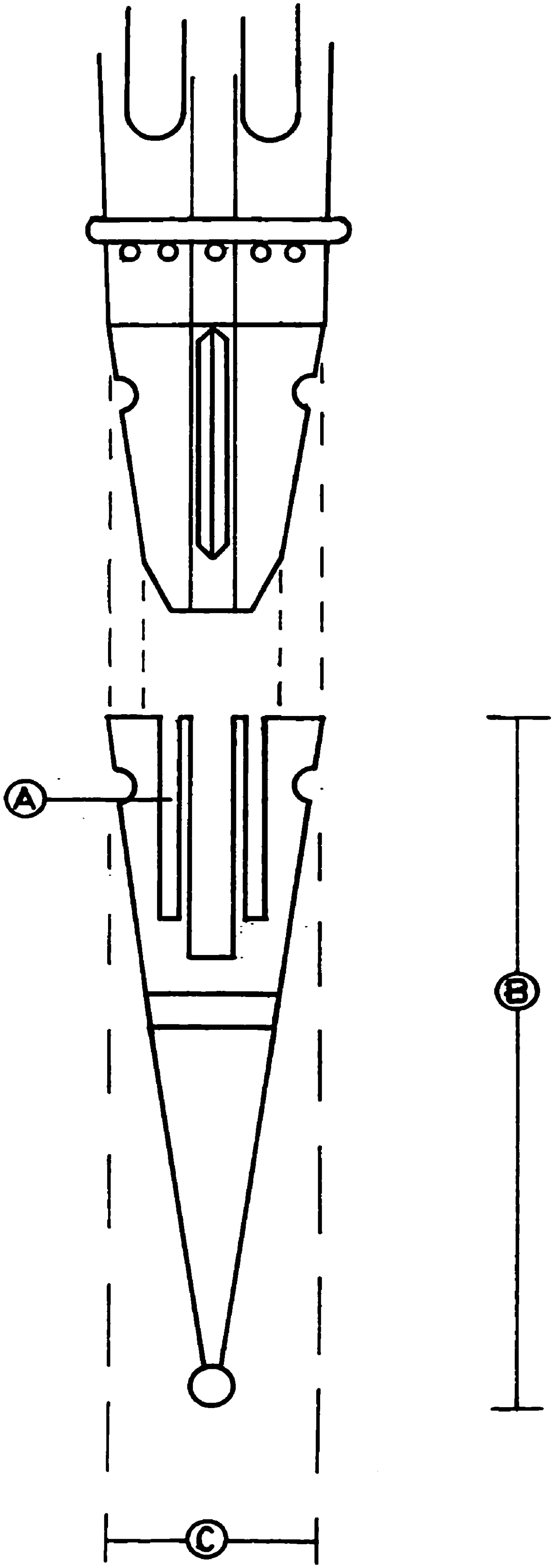


Lower Chassis (Side View)
A. 15.0 cms
B. 16.0 cms
C. 12.5 cms
D. 44.5 cms (slot)
E. 21.5 cms (radius)
F. 96.5 cms

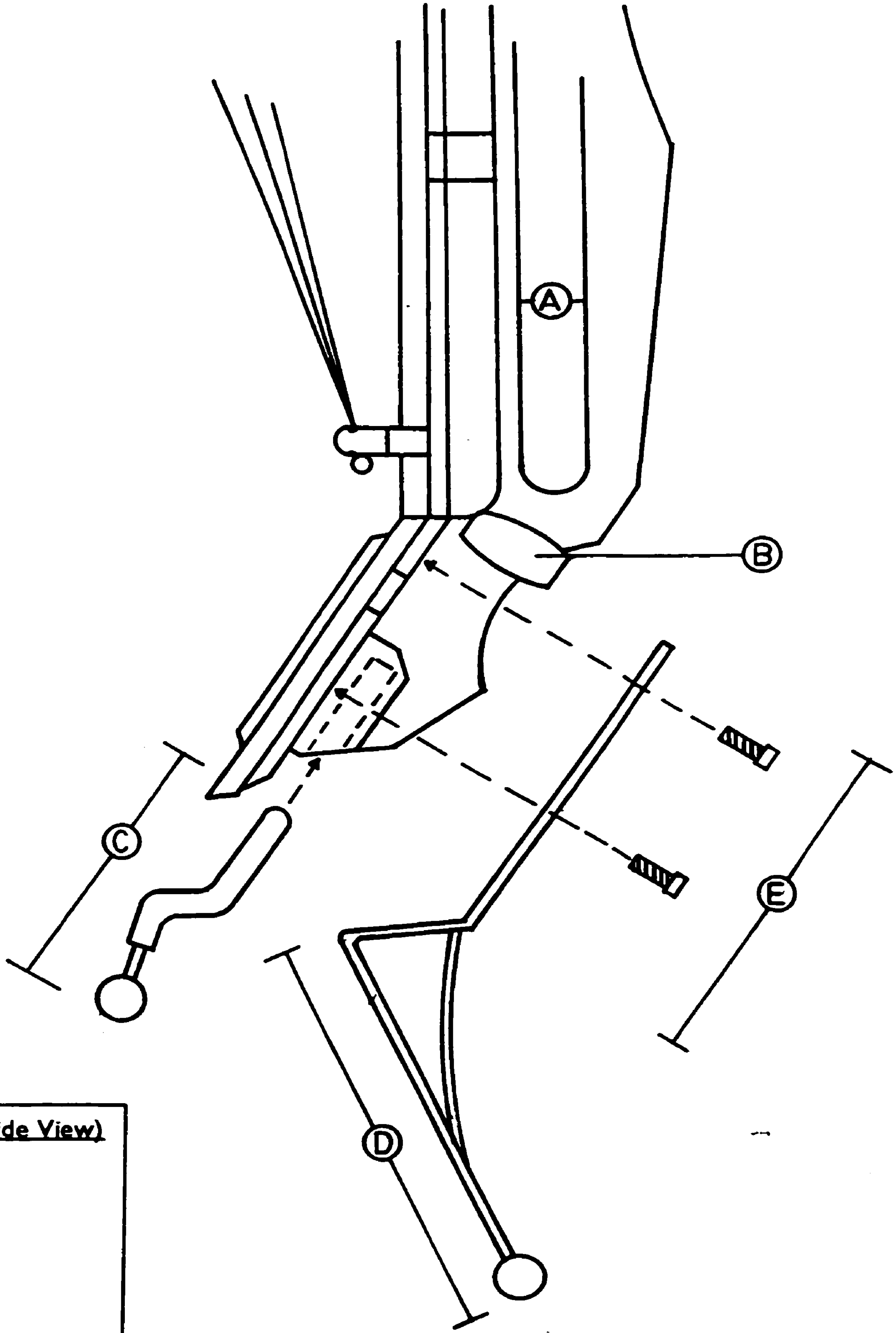




Headstock
a. 4.0 cms
B. 8.5 cms
C. 26.0 cms
D. 27.5 cms
E. 7.0 cms



Bottom/End Pin (Front View)
A. slot
-1.2 cms wide
-12.0 cms long
B. 30.0 cms
C. 8.0 cms



<u>Bottom/End Pins (Side View)</u>

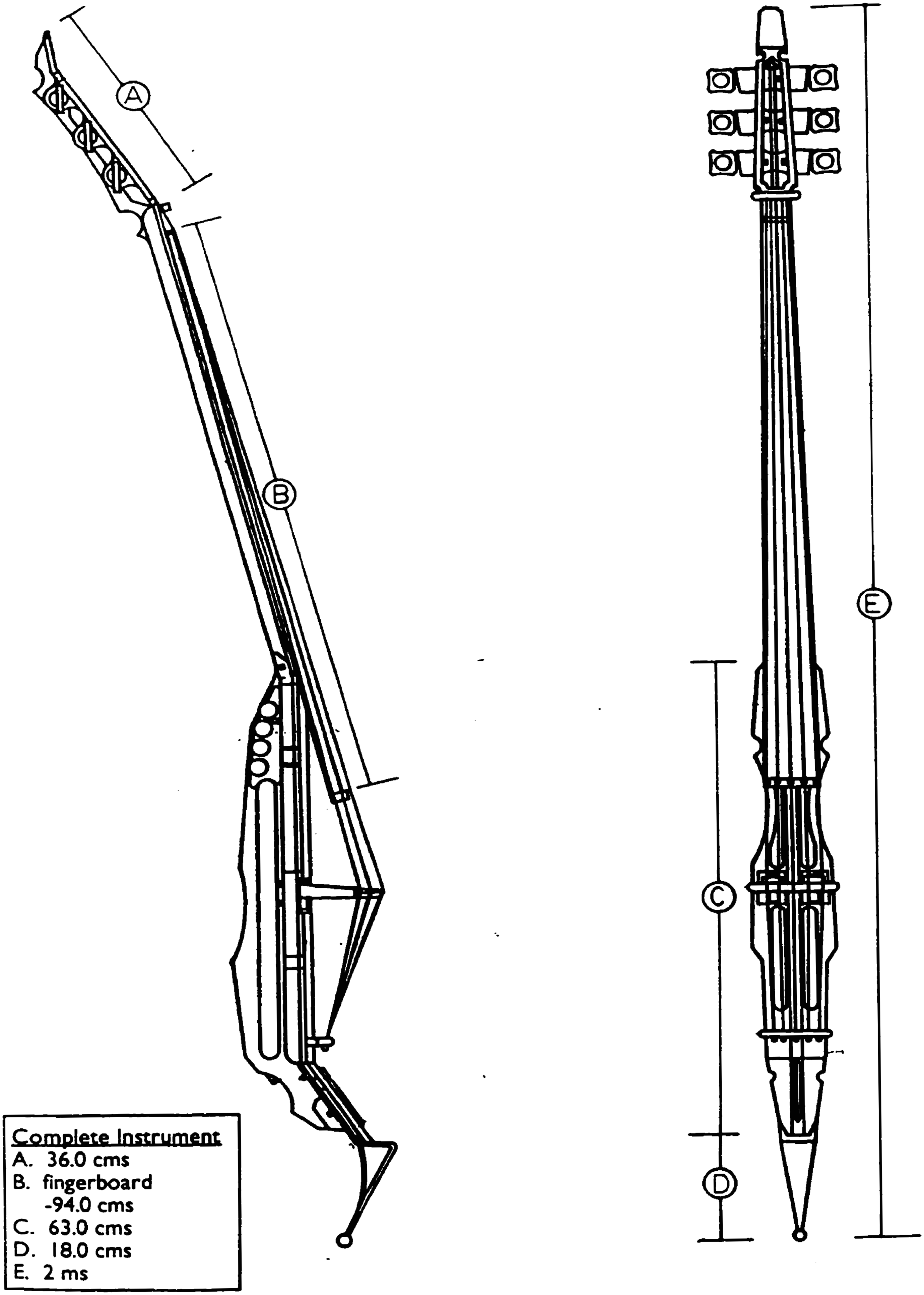
A. slot
  -3.0 cms wide

B. phono jack
  -4.5 cms long
  -3.0 cms diam.

C. short end pin
  -14.5 cms long

D. 16.0 cms

E. 13.0 cms


A
B
E
C
D
Complete Instrument
A. 36.0 cms
B. fingerboard
-94.0 cms
C. 63.0 cms
D. 18.0 cms
E. 2 ms

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