PICKUP METHODS FOR THE ELECTRO-ACOUSTIC STEELPAN*

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ABSTRACT

This paper explores the use of strain gauge, magnetic and piezo-electric transducers for the fabrication of electro-acoustic steelpan instruments. Just like electro-acoustic guitars, electro-acoustic, pans are capable of producing audible sound with or without electronic amplification. The paper looks at the issues of pickup construction and installation.

1.0 INTRODUCTION

This paper discusses various pickup methods for the fabrication of electro-acoustic steelpan instruments. Just like electro-acoustic guitars, electro-acoustic pans are capable of producing audible sound with or without electronic amplification. We specifically discuss the use of strain gauges, piezo-electric sensors and variable reluctance electromagnetic transducers for these pickups; these transducers are applied to the basic acoustic device in order to realise the desired electro-acoustic property.

The steelpan is a percussion device whose vibration mechanism is rather different from many other instruments. Although the instrument is increasing in international popularity, it is perhaps necessary to describe some of its pertinent characteristics:

a) The pan as it is often called, was originally, and still is to a large extent, fabricated from steel drums such as those used to transport crude oil. The top of the drum is sunken, grooved, heat-treated and tuned to produce a range of musical notes [2]. (See **Figure 1**). Although there are automated processes for performing sinking and grooving functions, all pans are manually tuned.

b) Individual instruments are currently grouped in arrays which cover specific musical ranges.

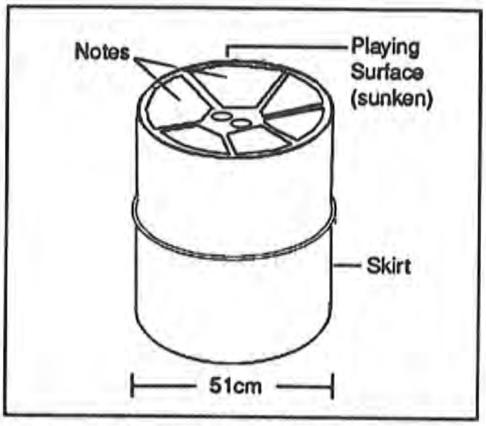

Figure 1: Typical Physical Attributes of a Cello Steelpan Component

Typically, there are seven ranges in an orchestra: bass, tenor bass, cello, guitar, double second, double tenor and tenor. The musical ranges covered by these classifications vary depending on the pan manufacturer. **Table 1** lists the ranges and note distributions for the orchestra (Carib Tokyo Steel Orchestra) upon which some of the pickup designs were tested.

c) In most musical instruments all overtones are naturally harmonically related to the fundamental component and one need only pay attention to the fundamental component in the tuning process. On the pan however, each harmonic of each note must be individually tuned while suppressing all dissonant overtones. In general, tuners arrange for no more than two components per note. In this context, the pan is perhaps most similar to, though much more versatile than, the bell. Dissonance produced by note interaction is

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CLASSIFICATION	LOWEST NOTE	NOTE DISTRIBUTION
Tenor	E^{b}_{4}	24 notes, 1 drum
Double Second	$F^{\#}_{3}$	16 + 16
Double Tenor	F_{3}	13 + 16
Double Guitar	$C^{\#}_{3}$	10 + 10
Triple Guitar (Cellos)	C_{3}	8 per drum
Tenor Bass	F_{2}	4 drums, 5 notes each
Six-Bass	E^{b}_{2}	6 drums, 3 notes each

Table 1: Table of Drum Arrays In Test Orchestra

minimised by ensuring that adjacent notes form part of a common chord. Figure 2 for example, shows a typical arrangement and the resulting power spectra for one drum of a six-bass complement. Although note arrangements vary depending on the tuner, the arrangement using the circle of fifths progression (fourths and fifths) has been adopted as the standard in the case of the tenor pan [5].

A major problem with the steelpan is its physical size. The bass range, for example, is often comprised of six drums with three notes per drum. Each drum is usually 1 metre in length. Much more unwieldy structures are sometimes used, for example 9- and 12-drum arrays are employed for more effective bass coverage. As expected, the size factor diminishes as the ranges move up the musical scale. The tenor range for example, consists of a single drum with as many as 30 to 32 notes; this drum is often cut to a length of 10 to 15 centimetres.

This paper addresses the need for direct electronic amplification of the steelpan. This need has arisen primarily because of potential benefits in reducing the effective size of bands and orchestras (these contain 45 members on average). This one factor has seriously affected the marketability of pan performances over the last few years. With direct electronic amplification, we also have the option of reducing the length of bass instruments. Moreover, with the current range of

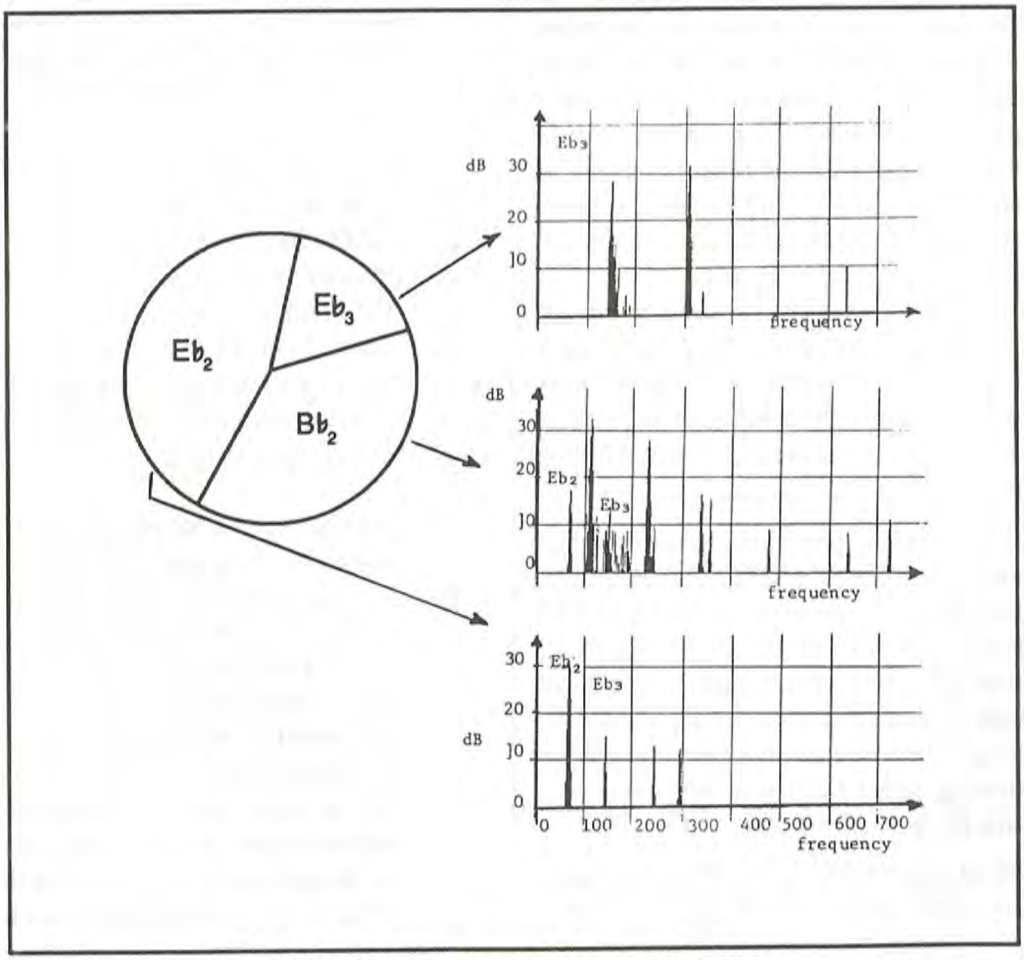

Figure 2: Measured Spectra of an Acoustic Bass

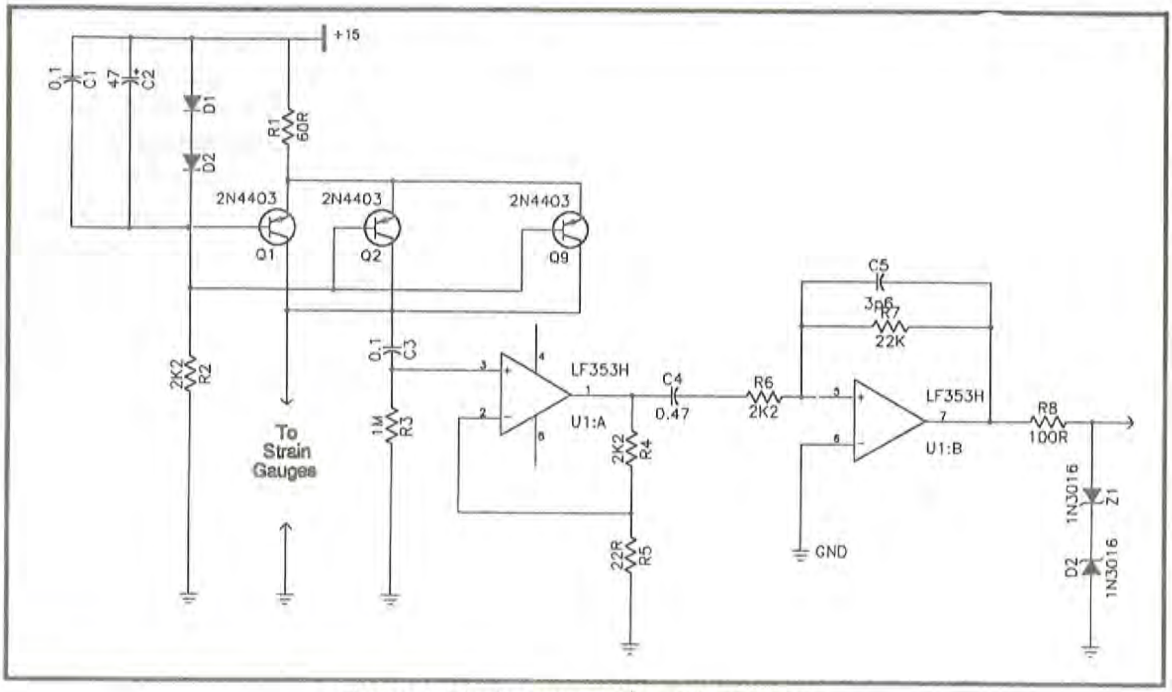

Figure 3: Strain Gauge Preamplifier Circuit

electronic accessories, various sound effects could be easily explored. The paper evaluates the proposed methods on the basis of their ruggedness, reliability, cost and fidelity.

This is not the first attempt to address the pan amplification issue. In the late 1960's, tuner Bertie Marshall amplified the pans of the now defunct Hylanders Steel Orchestra for use on the road. Little information is available on the actual methods used but indications are that he used a mix of microphones and (possible) guitar pickups. Unlike the instruments used in the current work, Bertie Marshall was said to have made pans especially for the purpose of amplification. No further work has been done until now.

The paper begins with a discussion of contact-type pickups in Section 2. In Section 3, the design and construction of proximity (non-contact) sensors is discussed. Finally, the various methods and their specific implementations are assessed in Section 4.

2.0 CONTACT PICKUPS

Two types of contact pickups were tested. The original attempt employed strain gauge pickups motivated by the encouraging report of their application in guitars [3]. Experiments were also carried out with piezo-electric transducers.

2.1 Strain Gauge Pickups

The strain gauge approach was attempted on a six-bass array. Gauges were placed on the underside of each note, one gauge per note; gauges were placed on the note centres for maximum output. Units on individual drums were wired in series and excited by a constant current source.

Spiral diaphragm gauges (type Micro Measurements EA-06-500JD-120) were selected for this particular application. Large gauge sizes were chosen because of the higher reliability and greater heat dissipation capability. This allows for higher excitation levels which in turn leads to improved signal to noise ratios [4]. The gauges used had nominal resistances of 120 Ω.

Each drum was provided with its own preamplifier and excitation unit. Although more costly, this approach was judged to be more reliable than the alternative of using a single excitation source for all drums. The preamplifiers were connected to a mixer from which the final output was derived.

The preamplifier is shown in Figure 3. It consists of a constant current source (Q1-Q10,R1,R2) and a 60dB amplifier (IC1). Parallel transistors were employed in the current source to improve noise performance. The gauge bias current was set to 20mA so that the gauge bias voltage was roughly one-half the supply voltage. This gave an acceptable compromise between power supply isolation and gauge output level.

High pass filter networks (C3,R3,C4,R6) were included to provide DC decoupling while minimising subsonic components generated by temperature variations on the drum surface.

2.2 Piezo-Electric Transducers

Over the last few years, piezo-electric transducers have grown in popularity as pickups for musical instruments. New generations of piezo-devices employing materials such as Kynar [1] are lightweight and have good wideband response. Piezo-electric transducers require no external energy source. Due to their high sensitivity, local amplification is not required. However, the low frequency response of piezo transducers is typically poor because of their capacitive Thévinin impedances. This can be compensated for by the use of high input impedance amplifiers or charge pumps.

Piezo-electric pickups can be simply bonded to the playing surface or the skirt preferably using adhesives similar to those used for bonding strain gauges. In the tests carried out, pickups were bonded to the relatively stiff regions of the playing surface between active notes. This minimised the number of transducers required; damage is also minimised during retuning.

In preliminary tests, commercial piezo speaker elements were used but these were later replaced by more rugged commercial piezo transducers. The output signal of the pickup used was of the order of 100mV or more - more than sufficient to drive commercial music amplification systems. With appropriate shielding and wiring precautions, the effects of power supply interference and other noise sources were not at all discernible.

Piezo transducers are now available with frequency responses which are flat down to 0.001Hz, thus minimising the need for external compensation.

3.0 MAGNETIC PROXIMITY SENSORS

The magnetic pickups designed employed the variable reluctance principle. Variable reluctance transducers operate by transforming changes in their magnetic fields to fluctuations in the voltage across a coil placed in that field. In other types of electromagnetic transducers, field fluctuations are caused by the relative motion of the coil and magnet. However, in variable reluctance sensors, the magnet and coil are fixed while field fluctuations result from the movement of a metallic object in the magnetic field. Electric guitars for example, employ metal strings which vibrate in the magnetic field of the pickup unit.

Pickup in the case of the steelpan can be similarly arranged by placing a sensor in close proximity to each note of the pan. However, while guitars usually have a few closely spaced strings, the steelpan can have as many as 32 notes distributed over an irregular hemispheroid surface (Figure 1). This method can, therefore, be rather expensive to implement. The following less costly approaches were tested:

- Pickup from the Playing Surface
  The idea here was to utilise a field with sufficient dispersion to cover a large area of the playing surface. It was found that by appropriately positioning the transducers, fewer pickups were required to give acceptable coverage of the entire playing surface.

- Pickup from the Skirt
  Off-the-shelf guitar pickups can be easily applied in this way.

The following issues were considered in the installation of the pickup units:-

1. The skirt of the pan vibrates in response to the impact of the playing sticks. However, the vibration modes of the skirt are invariably dissonant and unpredictable since very little attention is paid to this area during manufacture. It was therefore considered necessary to decouple these vibrations from the pickup units as much as possible. This was achieved by the use of a cinch strap tied around the skirt. However, this method was limited by the factor discusssed below.

2. Mechanical stresses applied to the skirt can easily change the characteristics of the notes on the rim of the playing surface of the instrument, thus extreme care must be exercised when installing sensor support structures or when using skirt damping mechanisms.

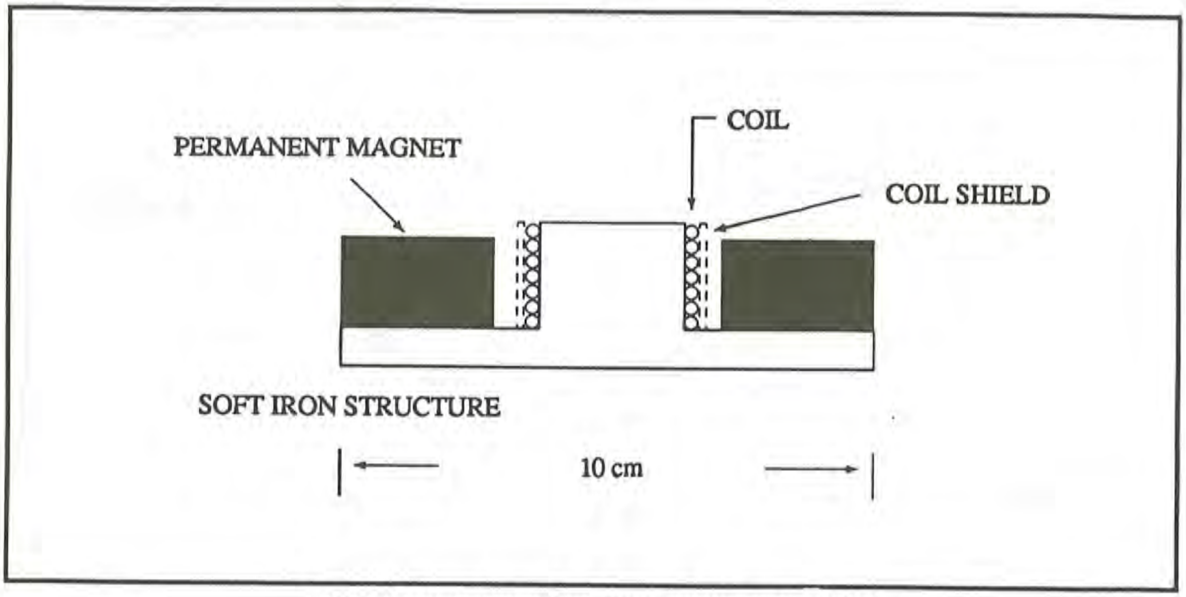

Figure 4: Transducer Construction for Sensor VR1

3. Note size and sensitivity can vary considerably over any given playing surface. In general, when attemping pickup from the pan surface, it was found necessary to place sensors in closer proximity to smaller notes in an attempt to compensate for differences in vibration amplitude levels. Significant distortion resulted when the sensor was placed too close to a note. It was felt that this was due to the inherently non-linear distribution of the magnetic field in the region of the magnetic structure, compounded by the presence of a relatively large ferromagnetic material (the playing surface). Since the note vibrations were essentially along the major magnetic axis, the inherent distortion produced by the field nonlinearity was further enhanced by excessive magnetic attraction which varied with the deflection of the relevant note.

4. The size and open construction of the instrument compounded the problem of reducing external electromagetic interference.

3.1 Transducer Construction

We now discuss the more specific details of transducer construction. Tests were carried out on two designs:

Sensor VR1: Sensors in this category employed annular ceramic magnets and former as shown in Figure 4. For test purposes, these components were obtained from commercial speaker drivers. The top soft iron pole piece used to concentrate the magnetic flux into the speaker air gap was removed; this resulted in a wider dispersion of the magnetic field. The coil was wound on the centre portion of the former using 3000 turns of 42 gauge wire. An aluminium shield was incorporated for high frequency noise suppression; suitable grounding arrangements were also made for this purpose. Flux density at a distance of 2.5cm directly above the centre pole piece was measured at 120 Gauss.

Sensor VR2: This unit was of a simpler construction and employed a single 2.5cm long, steel-slotted magnet. The coil was wound around the magnet using 2400 turns of 42 gauge wire.

3.2 Mounting and Assembly

As discussed above, two methods were used to attach the sensors to the instrument. (See Figure 5). The first method involved direct pickup from the playing surface of the instrument. VR1 pickups were favoured for this method because of their high, widely-dispersed

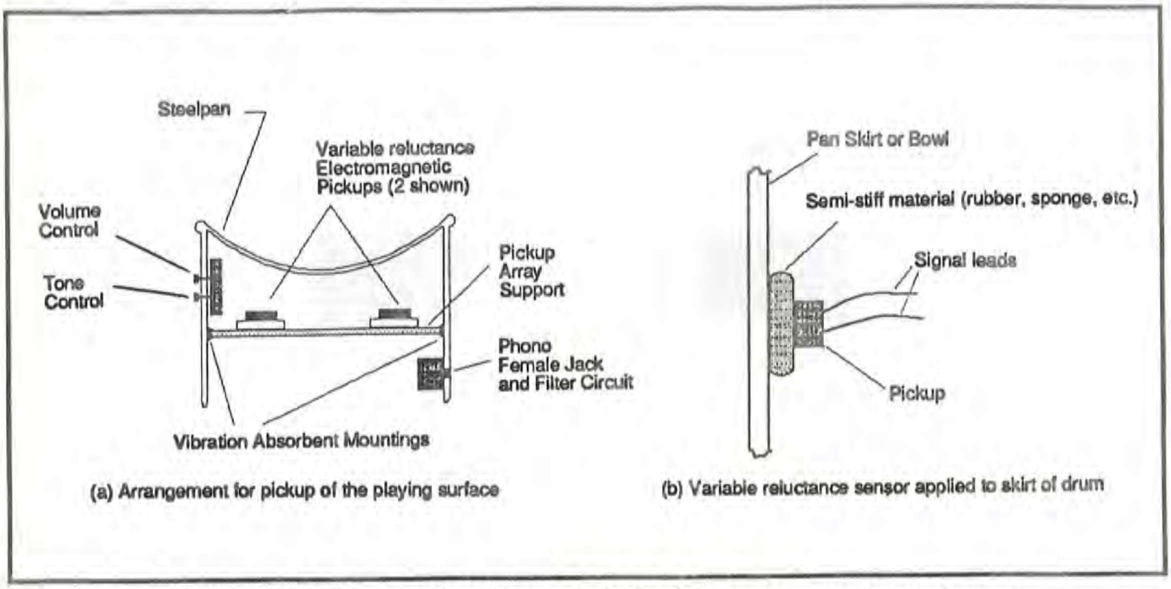

Figure 5: Possible Mounting Methods for Variable Reluctance Transducers

magnetic field strengths. This method was preferred for the higher frequency instruments such as tenors and double tenors; for these instruments, the notes towards the centre of the playing surface were not powerful enough to sufficiently excite the skirt. Figure 5(a) shows the general arrangement. Two pickup units were bolted to a frame supported from the skirt of the pan by sound absorbent material. This ensured minimum transfer of skirt vibrations to the pickups while effecting minimum restraint on the skirt itself. Sound absorbent pads were also used for attaching the sensors to the frame. The sensors were wired in antiphase so as to minimise external electromagnetic noise effects (this is what guitarists call a "humbucking" configuration). A trial-and-error process was used to find the optimal placement of the pickups along the frame. For tenors with the fourths and fifths note layout, it was found that the best results were achieved when pickups were positioned in the middle third of the pan and centred between adjacent notes. This tended to minimise gross imbalances in output levels over the full range of notes on the particular drum.

For the second method, the sensors were glued on to a semi-stiff material (such as a foam or rubber pad) which was, in turn, attached to the skirt of the drum. This method was used for the VR2 sensors because of their relatively light weight. Electrical connection was made using twinax cable and the usual headphone socket.

4.0 DESIGN EVALUATION AND CONCLUSION

Strain Gauge Pickup

The performance of the six-bass unit with strain gauge pickup was judged to be satisfactory. However, this method compared unfavourably with the other pickup methods for the following reasons:-

1) Cost of components; the main culprits here were the low noise amplifiers and the strain gauge transducers.

2) Unsatisfactory performance on mid- to high-frequency instruments. On these instruments, vibration amplitude levels are much lower than on the bass units on which the original experiment was performed. This places a greater requirement on amplifier noise levels.

3) Cost of application - strain gauges must be bonded with special epoxies. Improper application can result in loosening of the sensor and subsequent noise generation.

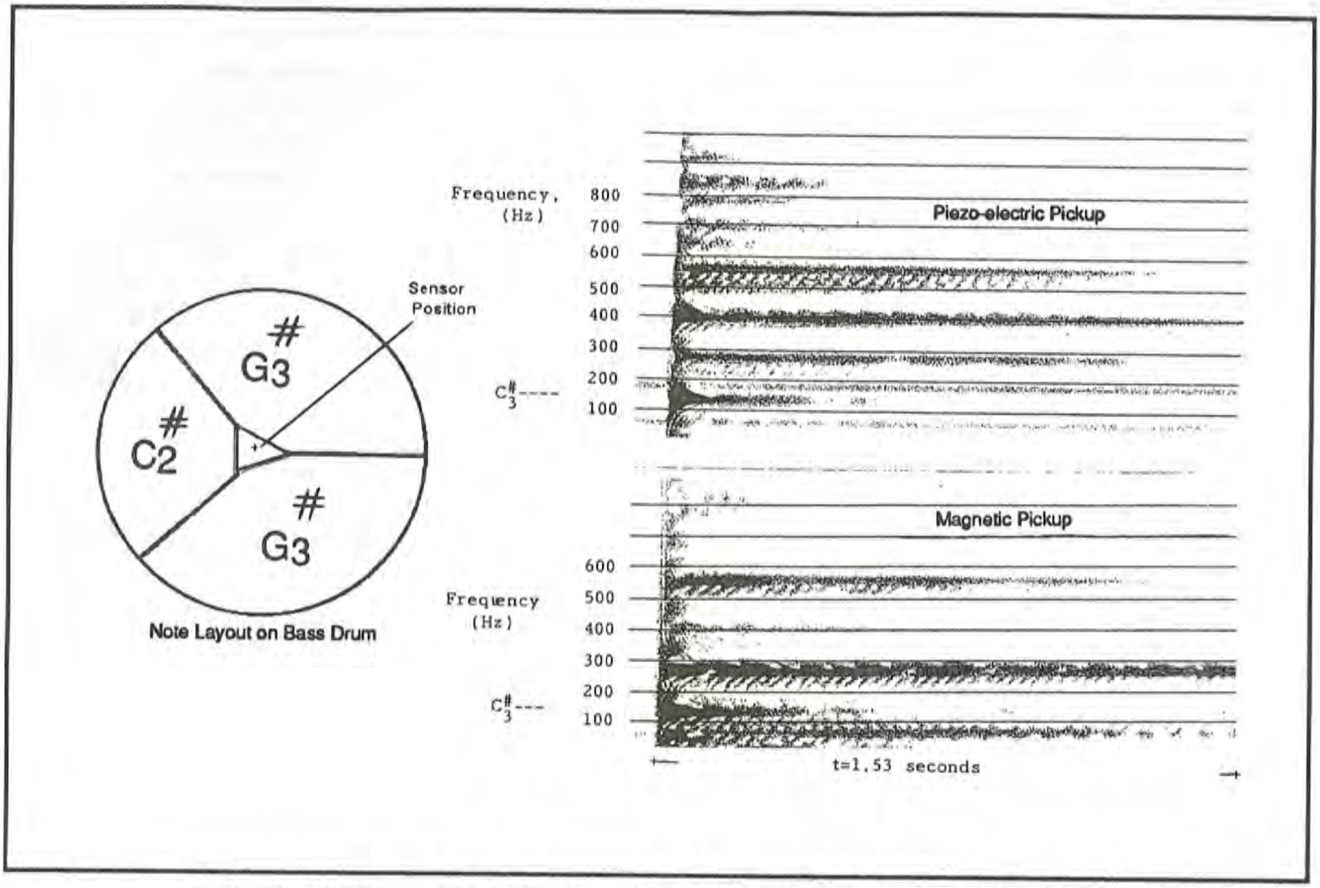

Figure 6: Sonograms of a Bass Drum using Magnetic and Piezo-Electric Pickups

4) Because this is a contact method, high recurrent costs are expected due to the possibility of gauge damage during instrument retuning. While the risk of damage can be minimised by placing the gauges between notes or on the skirt of the pan, such action will result in a significant reduction in output signal level.

Piezo-Electric Pickups

As noted previously, piezo-electric pickups boast the advantage of lightweight structure and easy applicability while generating relatively high output levels. The high output levels allow for the minimisation of pickup units by placement on the spaces between notes. Such a compromise could not have been made with strain gauges without seriously degrading the output signal/noise ratio. Moreover, although these are contact sensors, the attachment to the pan need not be permanent. Indeed, some adhesive tape for this purpose [1]. This minimises the risk of sensor damage during instrument retuning. Due to variations in which vibrations from the various notes are transmitted over the surface of the pans, suitable placement locations had to be determined by trial and error. Best performances were achieved by using multiple sensors.

Piezo-electric transducers have proven to be applicable to all instrument ranges. They were successfully used in the 1994 and 1995 Carnival performances of the Couva Joylanders Steel Orchestra.

Magnetic Pickups

Transducer units were built and installed on an ensemble of steeldrums comprising one of each of the standard ranges: tenor, double tenor, double second, double guitar, cellos, tenor bass, six bass. The instruments were field-tested by the Carib Tokyo Steel Orchestra, one of the more popular orchestras in Trinidad and Tobago. The amplified instruments were very favourably received by this group of experienced pannists.

In contrast to piezo-electric transducers and strain gauges, the magnetic pickups described are proximity sensors and are therefore not susceptible to damage whenever the instrument has to be retuned. Moreover, no local amplification or compensation is required. However, certain problems were found with the current designs:

a) The pickups tended to accentuate the initial impact of the playing stick on tenor and double tenor pans. This can be minimised by filtering. The effect is not evident on lower frequency instruments for which the head of the playing stick is made from a softer material.

b) Electromagnetic interference was evident, particularly on high frequency units. This calls for improved pickup design.

In addition, suitable pickups are not readily available and must be fabricated; indeed further work has to be done in the area of shaping the magnetic field to improve note coverage and fidelity. Finally, the frames used in **Figure 5a** adds to the financial cost of the finished product.

Frequency spectra for a drum employing the strain-gauge methodology are shown in **Figure 2. Figure 6** compares sonograms for a drum employing the variable reluctance and piezo-electric methods (using the AMP DT1 sensor). For the variable reluctance, all measurements were made using the Kay Elemetrics 7800 Sonograph.

5.0 ACKNOWLEDGEMENTS

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