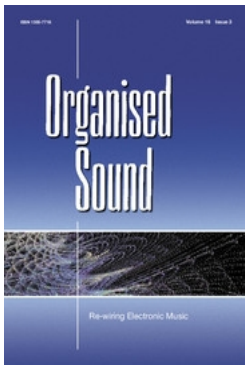

The Metasaxophone: concept, implementation, and mapping strategies for a new computer music instrument

Matthew Burtner

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The Metasaxophone: concept, implementation, and mapping strategies for a new computer music instrument

MATTHEW BURTNER

Virginia Center for Computer Music (VCCM), Department of Music, University of Virginia, Charlottesville, VA 22903, USA
E-mail: mburtner@virginia.edu

The Metasaxophone is an acoustic tenor saxophone retrofitted with an onboard computer microprocessor and an array of sensors that convert performance data into MIDI control messages. The instrument has additionally been outfitted with a unique microphone system that allows for detailed control of the amplified sound. While maintaining full acoustic functionality it is also a versatile MIDI controller and an electric instrument. A primary motivation behind the Metasaxophone is to put signal processing under direct expressive control of the performer. Through the combination of gestural and audio performance control, employing both discrete and continuous multilayered mapping strategies, the Metasaxophone can be adapted for a wide range of musical purposes. This paper explores the artistic and technical development of the instrument, as well as new conceptions of musical mappings arising from the enhanced interface.

1. INTRODUCTION. THE SAXOPHONE: FIRST PRINCIPLES, A BLESSING FROM BERLIOZ, AND NEW 'MISUSES'

Since its first appearance in public in 1842, the saxophone has proven to be a highly flexible performance interface with acoustic characteristics that have allowed its adaptation to a wide range of musical aesthetics. Hector Berlioz (1803–1869) wrote an enthusiastic first review of the new instrument in the Paris publication *Journal de Debats*. In it he declared, 'We must rejoice that it is impossible to misuse the Saxophone and thus destroy its majestic nature by forcing it to render mere musical futilities' (Rascher 1972). Berlioz had been invited by the young Adolphe Sax (1814–1894) to hear his new instrument created to have the widest possible expressive capacities and designed to bridge the divide between the many distinctive timbres and dynamic characteristics of the orchestra.

Sax intended his instrument to have the dexterous flexibility of the strings, the colouristic diversity of the woodwinds, and the dynamic power of the brass. An instrument designed to unite instrumental elements, the saxophone has also proven stylistically flexible, continually being adapted to new performance needs. It has been embraced by the orchestral, band, jazz, rock, improvised and electroacoustic music traditions. Indeed, Berlioz's quote seems prophetic of the 160-year development of the instrument, a development that has seen it successfully redefined for each musical purpose. New performance methods for the saxophone continue to evolve and this paper points to one further attempted 'misuse' of Adolphe Sax's invention.

Electroacoustic music raises new possibilities for extending the timbral range of acoustic instruments. Very often, however, the instrumental interface is not suited for direct performer control of these new timbral opportunities. A growing interest in new interfaces for gestural computer control addresses this problem (Laubier 1998, Hunt 1999, Cook 2001, Wanderley 2001). These controllers, by their nature instruments that separate sound production (synthesis) and performer gesture (control), have subsequently generated an increased interest in the study of compositional mapping strategies for computer music (Hunt, Wanderley and Kirk 2000). Such research reveals that designing good gestural capture devices is only half of the problem; how this data is used to create sound is an equally important factor (Rovan, Wanderley, Dubnov and Depalle 1997).

The Metasaxophone is part of a growing trend in instrument design using traditional instrumental performance interfaces as input devices for computer instruments (Cook, Morril and Smith 1993, Orio, Schnell and Wanderley 2001). Previous notable attempts at augmenting the saxophone have sacrificed the actual acoustic instrumental sound for MIDI controller capabilities. The first MIDI saxophone, the Synthophone, is a versatile MIDI controller marketed by Softwind Instruments (Softwind 1986). The developers of the Synthophone were interested in preserving the tactile interface of the saxophone but not its acoustic sound. The Synthophone therefore produces no sound of its own, the saxophone body being only a housing for the electronics. Retaining the true sound of the saxophone has been of primary importance in developing the Metasaxophone.

This paper discusses how a project involving music for electronics and acoustic saxophone drove the development of a human computer interface extending the expressive performance possibilities of the saxophone. While the original idea for the Metasaxophone was clear and attainable, it was impossible to foresee the effects these adaptations would have on performance and composition. Through electronic augmentations and computer mapping strategies such as those discussed in this

Figure 1. The Metasaxophone: front and back close-up views of the instrument.

paper, the saxophone has effectively been transformed into a new instrument.

2. FORMATIVE WORK

The Metasaxophone grew out of an ongoing project exploring the saxophone as an electroacoustic instrument. This project simultaneously pursues extended performance practice and the expansion of the instrument through new technologies. Compositions such as *Incantation S4* (1997), *Split Voices* (1998) and *Portals of Distortion* (1998) were fundamental in redefining the performance practice of the saxophone and suggesting the Metasaxophone controller. Performance technique took on new meaning in these pieces, becoming a means of opening the saxophone acoustically and exploring its hidden resonant characteristics. All three of these pieces were recorded and released by Innova Records on the 1999 CD, *Portals of Distortion: Music for Saxophones, Computers and Stones* (Burtner 1999). These compositions for saxophone are characterised by the aesthetic assumptions described below.

2.1. The instrument as complex acoustic filter

The saxophone was conceptually redefined as a complex acoustic filter by rethinking the performer's approach to tone, intonation, fingering and embouchure. Traditional notions of performance practice were expanded into a more open conception of the sound possibilities of the instrument. In this way an attempt was made to define a performance practice based on principles of sound synthesis rather than adopting those of jazz or classical saxophone music.

The instrument is seen as a filter into which energy is injected. The type of articulation combined with the changeable parameters of the system give the resulting sound. In this conception, there is no real 'right' or 'wrong' response from the system, only the result of the parameters (changes of the air column) and the type of articulation (embouchure and breath). The system, however, is highly complex and the sounding results are often unpredictable by the performer. But the chaotic properties of the system are allowed to sound out, and are not suppressed by the performer. A pure tone is not always desirable as the system may validly respond in a much more complex way. All fingering combinations – not just those that yield harmonic, tempered frequencies – are potentially desirable if they create a substantial change in the system. The performer's role then is seen as articulating the system rather than controlling it; changing the parameters of the filter and the type of articulations needed to allow the system to sound.

This more open approach to the instrument suits the practice of electroacoustic music well. It can most clearly be heard in *Portals of Distortion* for nine tenor saxophones, in which the ensemble is treated as a network of summed complex filters. In *Portals of Distortion*, resonances are set up in the saxophones and the performers circular breathe to sustain the sonorities. The music is highly bounded due to the static approach to parameter changes, but the resulting sound is unpredictable because the parameters themselves are unstable. The unpredictability, multiplied in the nine voices creates the sound that defines this music (audio CD Example 1: Portals of Distortion).

In this way, the complex acoustic filter metaphor brought about a new performance practice based on (i)

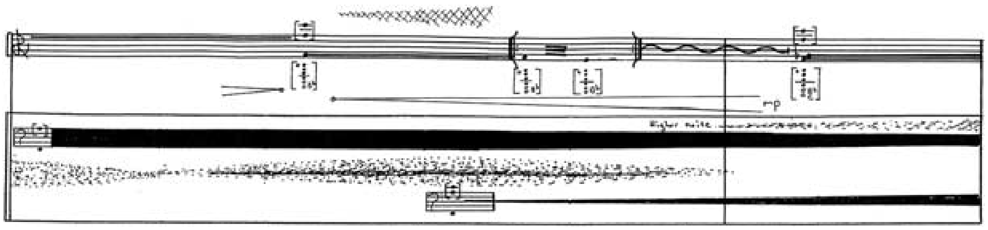

Figure 2. From the performance score of *Incantation S4* for amplified tenor saxophone and computer-generated tape.

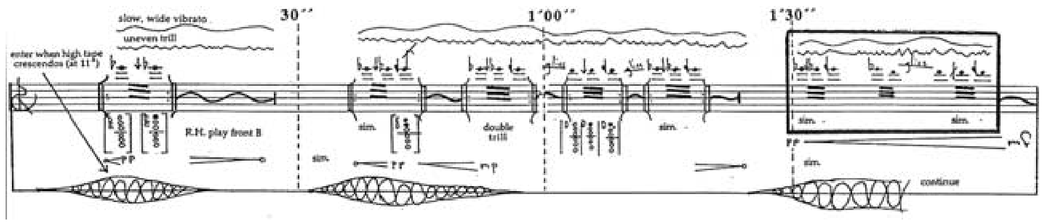

Figure 3. From the performance score of *Split Voices* for amplified tenor and soprano saxophones and computer-generated tape.

continuous and variable pressure in the air column of the horn, (ii) changing the complex properties of the tube by applying various key combinations, and (iii) embouchure changes designed to both sustain the resonance and control the spectral properties of the signal.

2.2. Signal processing as a metaphor for extended performance practice

In order to enhance the timbral relationship between the saxophone and electronics, techniques of digital audio synthesis used in the composition of the electronic parts were applied analogously to the saxophone. These included synthesis techniques such as granular synthesis, spectral mutation, convolution, distortion, ring modulation and spectral resonance. Each signal processing approach was applied acoustically, through the use of extended saxophone techniques, to the performance of the acoustic instrument. This was an attempt to form a greater unity between the electronic and acoustic instruments, allowing them to occupy a similar extended timbral space.

In *Incantation S4*, composed using Barry Truax's POD-X system for quasi-synchronous granular synthesis (Truax 1988), techniques used in the creation of the electronic part such as granular synthesis, time stretching and spectral resonance were implemented on the acoustic saxophone using *bisbigliando* trills, circular breathing, over-blowing and multiphonics.

For example, much of the granular synthesis approach used in *Incantation S4* involved high grain densities (approximately sixteen synchronous voices), and large grain durations (of the order of 100–200 ms) of harmonic material made from sampled voices and horns. The samples were time stretched and resonated at varying harmonic bands. To orchestrate the saxophone with this texture, the acoustic instrument utilises continuous microtonal trilling on 'false fingering' keys. These timbrally modificatory keys change the pitch and resonance of the horn slightly but do not drastically alter the pitch. In addition, a half-keying approach was used that introduces timbral and frequency fluctuation to the sound but does not change the pitch by step. The half keying technique is accomplished by partially closing a key. The combination of these trills was used to blend the saxophone sound with the burbling sound of granular synthesis. The performer circular breathes in order to achieve long durations, analogous to the time stretching being applied in the electronics. And finally, the embouchure is altered in order to coax out different partials of the saxophone sound, shifting the spectral energy of the sound in much the same way as the PODX digital resonators.

Similarly, in *Split Voices*, spectral modelling synthesis, spectral mutation and convolution, techniques used in creating the electronic part, were similarly applied to the saxophone through a range of multiphonics, trilled multiphonics, overblown trills and circular breathing (audio CD Example 2: Incantation S4; audio CD Example 3: Split Voices).

2.3. Continuous timbral evolution of the instrumental sound

The resulting performance practice that evolved included a body of techniques and sonorities that could be modified greatly over time through subtle embouchure changes. Circular breathing was necessary in this context to sustain the changes indefinitely. In contrast to jazz and classical performance practices, this approach favours slow, continuous development of sound, and focuses on a wide range of subtly differentiated timbral modifications. Symmetries of the horn began to function almost motivically as observations of certain harmonic

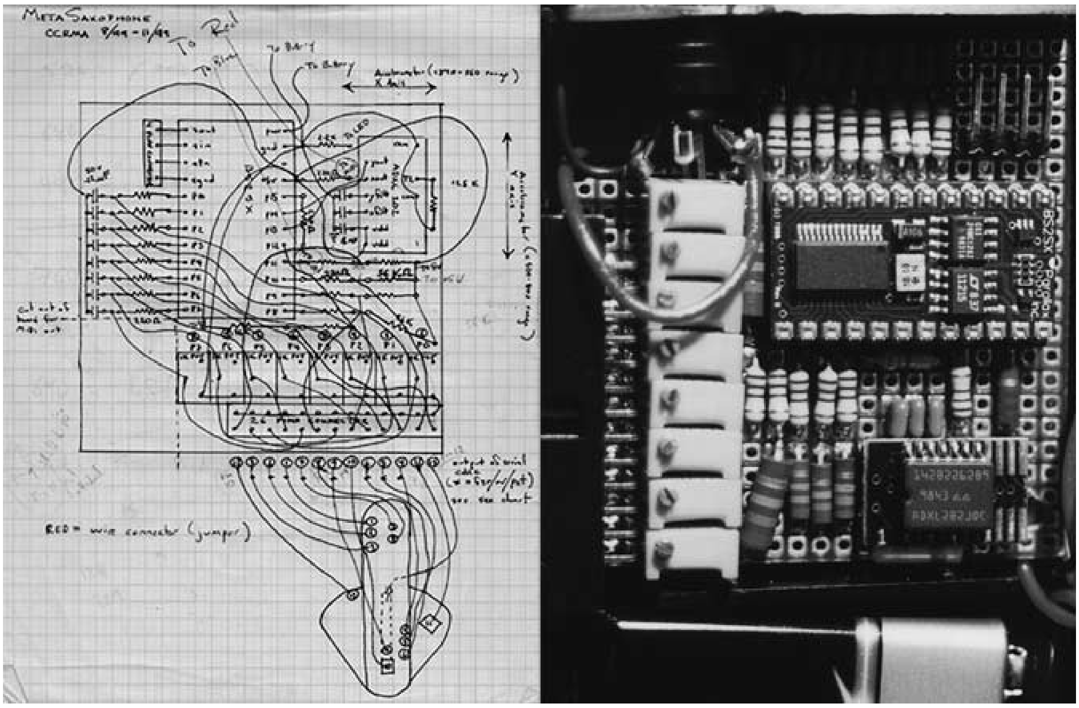

Figure 4. Original working sketch of the circuit diagram and the corresponding Metasaxophone circuit board.

coincidences became apparent. Figures 2 and 3, excerpts from *Incantation S* and *Split Voices*, show ways this music was notated for the performer.

3. REDEFINING THE FUNCTION OF A KEY

While performing compositions such as *Incantation S4*, *Portals of Distortion* and *Split Voices* it became clear that in the context of these slowly evolving musical textures a good deal of the performer's tactile sensitivity was being unused. In each of these pieces, entire minutes may pass with the performer holding down one basic fingering. In the second part of *Split Voices*, for example, the front five keys are held down for over four minutes while the performer trills other keys and changes the embouchure and air pressure.

A perceived limitation of the manual interface became apparent: while the saxophone allows for continuous control over embouchure changes and changing air pressures, the fingers of the performer have very little direct continuous control over the instrumental sound.

For all practical purposes, a saxophone key is either open or closed. As discussed above, half keying is an extended technique of some promise, and using very rapid, changing trills can give the impression of a continuously changing sound, but these both involve substantial changes in the air column that can disrupt other key work in progress. What was needed was a new level of key control that would not disrupt normal playing but could be used to substantially modify the sound.

It occurred that by giving the keys pressure sensitivity or 'aftertouch', a feature common on MIDI keyboard controllers, direct tactile control over the electronic signal processing could be given to the performer. This computer interface could be placed easily in the expressive zone left unused by the instrument, namely finger pressure on the keys. In essence, the saxophone keys, which normally execute only on and off changes of the air column, could be converted to continuous control levers. This initial realisation led to a vision of seamless integration between the instrumental acoustic and instrumental electronic worlds.

4. TECHNICAL SPECIFICATIONS: THE MIDI SAXOPHONE

4.1. Hardware

An approach was developed for retrofitting the acoustic Selmer tenor saxophone with sensors and a microprocessor that could convert the performance data into a continuous control data stream. A great deal of thought went into how and where the sensors would be attached to the instrument, and important performance considerations were contributed by Christopher Jones, Brian Ferneyhough, and Gary Scavone. It was finally decided that the microprocessor would gather performance data from six pressure sensors on the keys, two pressure sensors off of the keys, five triggers located at different points on the horn, and a sensor for measuring the movement of the instrumental body itself.

Force Sensing Resistors (FSRs), by Interlink Electronics, are located on the front B, A, G, F, E and D keys, and beside each of the thumb rests. Three triggers (also by Interlink) are located on the bell of the instrument and two are positioned on the back, below each of the thumb rests. An Analog Devices ADXL202 accelerometer IC chip on the bell measures the position of the saxophone on a two-dimensional axis – left/right and up/down.

The data from these sensors are collected via a twenty-six pin serial connector by a Parallax Inc. Basic Stamp BIISX microprocessor fixed to the bell of the instrument. Analogue pressure data from the performer is converted to a digital representation by passing each analogue signal through a resistor/capacitor (RC) circuit into the input pins on the BIISX (figure 5). Trim potentiometers calibrate the input sensitivity of each sensor. Figure 4 illustrates the original sketch of the Metasaxophone circuit, and the final circuit board.

4.2. Software

The BIISX is programmed in Parallax Basic (PBASIC) and the software converts the sensor data into MIDI messages. Analogue to digital conversion is accomplished using the PBASIC *RCTIME* (Parallax inc. 1999) function that measures the charge/discharge time of the RC circuit over time. The Metasaxophone program loops through the input pins reading the RCTIME counter of each pin.

Multiple programs can be loaded into the BIISX's EEPROM for a variety of applications. The standard Metasaxophone software sends MIDI control change messages 20–27 on channel 1 for the FSRs, MIDI note-on 1–5 on channel 1 for the triggers, and the accelerometer sends MIDI note-on messages 6–10 as the performer crosses certain thresholds of left/right, up/down tilt, and control change messages 28 and 29 for continuous control.

The continuous controller MIDI messages sent from the Metasaxophone are used to control digital signal processing and synthesis algorithms. An interactive interface programmed in Max/MSP (Ziccarelli 1989) is used. Current developments continue to use Max/MSP and are exploring interface implementations in James McCartney's SuperCollider, David Topper's GAIA Interface for RTCMIX, Max Mathews' Scanned Synthesis and Miller Puckett's Pd.

The Metasaxophone technology is a variation on a theme by Gary Scavone at Stanford University (Scavone 1999), and Perry Cook at Princeton University (Cook 1992).

5. TECHNICAL SPECIFICATIONS: THE ELECTRIC SAXOPHONE

The Metasaxophone is a fully functioning tenor saxophone, with all the flexibility and sonic capabilities characteristic of the Paris Super Action Selmer Series II. Since it was assumed that the instrument would be primarily used for electroacoustic music, however, the audio capabilities were also enhanced for electroacoustic music.

In addition to sending MIDI information, the Metasaxophone sends audio signals through small microphones located inside and around the bell. The microphone system was created uniquely for the Metasaxophone and consists of small Panasonic condenser electret cartridges fitted to the ends of bendable tubing and wrapped with the microphone wires inside heat-shrink tubing.

The microphone system is designed to attach to the back of the Metasaxophone circuit box on the top of the bell, and each microphone can be placed independently at the desired location outside or inside the instrument. In the standard configuration, one microphone is positioned deep inside the bell, without touching the inner walls of the instrument. The circuit of this microphone was modified to handle higher sound pressure levels without distortion. Two other microphones are positioned outside the horn, one on the lower half and the other on the upper half/neck area. This configuration allows for close miking of the instruments' low resonances, high frequencies, and mid-range frequencies. The microphones, however, can be placed in any configuration depending on the application needed, as they are mounted on bendable arms. Figure 7 shows the electric saxophone with all three microphones inside the bell. Each has a separate output allowing the signals to be routed to separate devices for processing or to multiple channels on a mixer. Much thought went into the acoustic design of the microphone system. Jay Kadis at Stanford University's CCRMA contributed important design suggestions.

As with the MIDI signal, the audio signal is used as a control parameter. By combining the MIDI and audio within a flexible external interface such as Max/MSP, the audio signal can be used to alter the function of the MIDI data or to control other sonic parameters.

The complete interface then allows for dynamic and flexible, multiparametric control. It includes both discrete and continuous control parameters, spatial and force feedback performer interaction with the instrument, and both gestural and audio control variables. Circular data constructs such as finger pressure controlling audio and audio controlling the effect of finger pressure are idiomatic. Multifunction mappings in which keys control a variety of inter-linked parameters were almost unavoidable due to the design of the controller. And the inseparability of the acoustic saxophone interface from either the audio sound or the MIDI control changes, due to the unavoidable changing of key positions, created a highly idiosyncratic but unified controller. The following section examines early compositional approaches to the Metasaxophone.

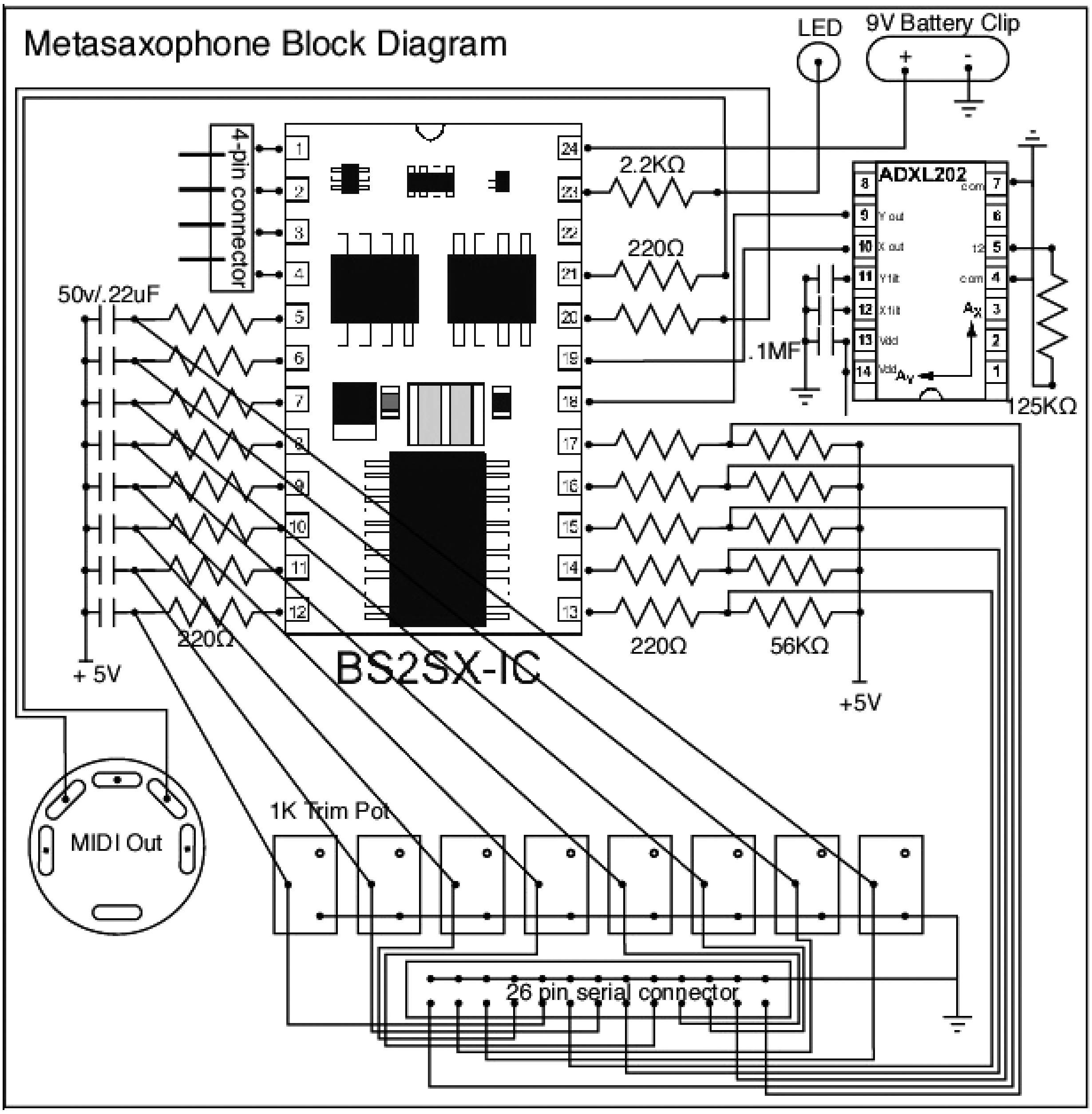

Figure 5. Block diagram of the Metasaxophone.

6. NOTATION AND MAPPING STRATEGIES

The earliest applications of the Metasaxophone involved using the after-touch capabilities to control real-time signal processing of the saxophone sound. An interface and set of signal processing networks in Max/MSP allowed the possibility of modifying the timbre of the saxophone in many ways simultaneously. For example, reverb can be controlled by finger pressure on one key, distortion can be assigned to a second, frequency modulation to a third, etc. In and of itself, this made the Metasaxophone a useful tool for the computer music performer.

6.1. Notation

Notational issues quickly arose due to the lack of a standardisation for notating multidimensional continuous control changes over time. The glissando is a useful notational paradigm for continuous frequency change, and dynamic markings express continuous changes in amplitude satisfactorily; but communicating to the performer how multiple key pressures evolve in the context of saxophone music presented a compositional problem. The notation needed to be specific enough to show pressure changes for each finger, but it could not be too specific for the performance capabilities of the instrument. For example, while it is idiomatic to specify polyphonic pressure curves over specified time periods, it is

Figure 6. Bell of the Metasaxophone showing the microprocessor casing, the front bell trigger sensor, and the Selmer Insignia.

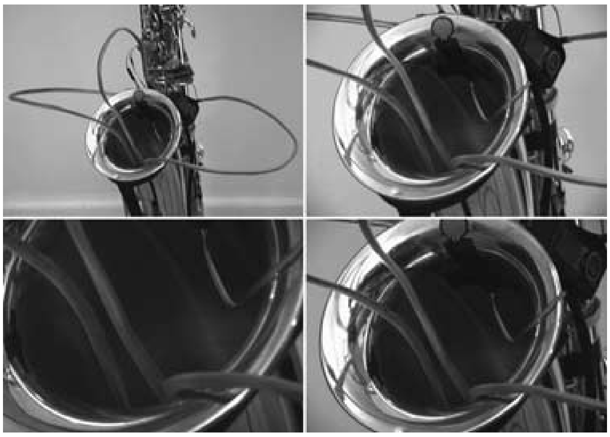

Figure 7. The Metasaxophone electric amplification system with all three microphones inside the bell.

not reasonable to notate very precise polyphonic MIDI controller values.

A system was devised in which each finger was given its own pressure staff, the total pressure of each finger occupying a space from pressure 0 (minimum) to pressure 1 (maximum) along the X axis. Contours for each finger are drawn into the space and the performer follows the contours, approximating the types of changes over time. Above the pressure staff the traditional saxophone music is written. Below the pressure staff, a third staff containing other controller information such as saxophone position and triggers is combined with a composite graphic representation of the sounding electronic part. Figure 8 illustrates a page of the new notation first used in *Noisegate 67*. The upper staff is similar to the notation used in the earlier pieces. The curved lines on the middle eight systems represent finger pressure changes for each of the six front keys and the two thumbs. The dotted line arrow just before the C♯, pointing to '1' shows a trigger being activated just before the C♯ that starts a series of delay lines. And the lowest staff is a composite of the electronic part, not unlike the graphic representation of the electronics in *Incantation S4* and *Split Voices*.

6.2. *Noisegate 67*: temporal remappings

The ability to control real-time interactive electronics from the saxophone opened new compositional and performance possibilities. Compositionally, the Metasaxophone allows the possibility for performer-controlled open form because the electronics can be triggered to modulate between sections of a piece. This allows the performer great flexibility in time.

Noisegate 67 takes advantage of the interactive nature of the instrument by exploring controlled open form. The beginning and end of the piece are notated completely in time. The middle section, however, is a network of possible paths through which the performer can freely move, dramatically shaping the time/energy structure of the composition.

The score of *Noisegate 67* is in the form of a triptych. The left and right panels of the score present the beginning and end of the piece and are notated in clock time. The performer plays the left panel first. After completing the left panel of the score, the panels are folded open exposing the inner section of the music.

The inner four panels present twenty-one systems and a network of twenty-five paths for moving between them. The duration of each system differs depending on the performance. In this way, large-scale expressive control over the inner section of the piece is given to the performer. The duration and expressive potential of this section can vary greatly. Certain paths lead to a music of drama and intensity while other paths reveal a calm and reserved music. Figure 9 is an excerpt from this section of the score. It illustrates the possible ways a performer may move between musical entities. Arrows point towards and away from boxes, showing the performer the possible ways to enter and leave each entity. The curved, numbered lines outside the boxes each represent one of the twenty-five possible paths the performer can take.

In terms of synthesis-control mappings, *Noisegate 67* explores the saxophone as a real-time, expressive noise controller. Each of the eight keys are mapped to an array of noise generators and filters. By applying pressure to the key, the amplitude of each noise generator is increased, creating an amplitude gate for the noise. By carefully controlling the finger pressure, the performer plays shifting bands of noise that are performed in counterpoint to the saxophone sound. The amplitude of the saxophone sound itself controls a ninth layer of noise. As the amplitude increases, the amplitude of the noise generator increases. Key pressures then control filter parameters. Each key has the possibility of controlling a multitude of parameters simultaneously, creating a web of interrelated actions.

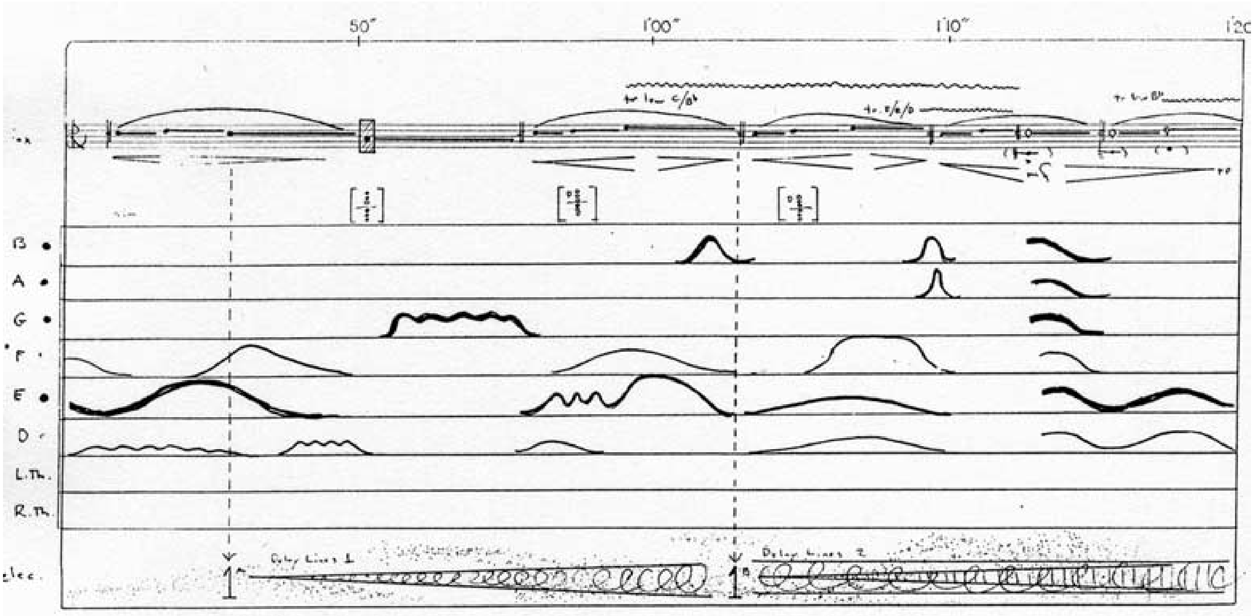

Figure 8. Metasaxophone notation excerpt showing the finger pressure changes on each key.

In this manner the dynamic of the noise system is divided into two layers: (i) a noise part independent of the saxophone audio, formed of eight key pressures, each with fixed filter coefficients, and (ii) a noise part shadowing the saxophone's audio amplitude with continuously changing filter characteristics.

Additionally, certain keys continuously control modulation of the saxophone audio signal. The E key has a fixed modulation rate of 40 Hz, and by adding pressure, the depth of the modulator is increased. The modulation rate of the D key on the other hand is determined by the saxophone's audio signal amplitude, ranging from 1 to 100 Hz. Additional keys are used to control delay lines and trigger samples from the computer (audio CD Example 4: Noisegate 67).

6.3. *S-Trance-S*: mappings for virtual instrument control

The use of the saxophone as a controller for virtual instruments has become a focus of recent developments for the instrument. The Metasaxophone, purely as a MIDI controller, is limited by the nature of the mechanical saxophone interface. This limitation is treated as an opportunity to explore instrumental remappings in combination with expressive computer instruments. One such application has been the exploration of instrument controller substitution.

Instrument controller substitution experiments with the recombination of an instrument controller interface and a physically modelled instrument of an entirely different type. In an ongoing project with Stefania Serafin, the Metasaxophone has been used as a controller for bowed string physical models (Burtner/Serafin 2000, 2001, 2002). By bowing the string from within the gestural space of a wind instrument, new expressive potentialities of the model are opened. The disembodied nature of physical models becomes a means of recombining it with other interfaces, creating extended techniques for physical models that would not be possible for the real instrument.

In the musical composition, *S-Trance-S* (2001), instrument controller substitution is explored through the metamorphosis between 'real' and physically modelled instruments. The Metasaxophone keys are mapped independently to the different physical model bowing parameters: bow force, bow position, bow velocity, frequency, two types of inharmonicity, and chaotic bow friction. Figure 10 illustrates the mappings as they occur in the piece.

This controller mapping then undergoes a series of remappings as the single virtual string grows into an ensemble of virtual strings, each one utilising a different controller mapping. With regard to the physical model, it was compositionally relevant to identify two types of control parameters, (i) those that are intrinsically tied to the propagation of sound such as bow velocity and bow pressure, and (ii) those that modify the mode of performance for expressive timbral richness such as inharmonicity, noise, bow position and frequency. This observation was an important concern when creating the performance mappings because for a generally congruous sound, certain keys must retain a propagatory role while others can be used as modifiers.

The technique of dynamically remapping the controller to the string introduced compositional and performance challenges. Figure 10 illustrates how a growing network of cross-mappings compounded the performance

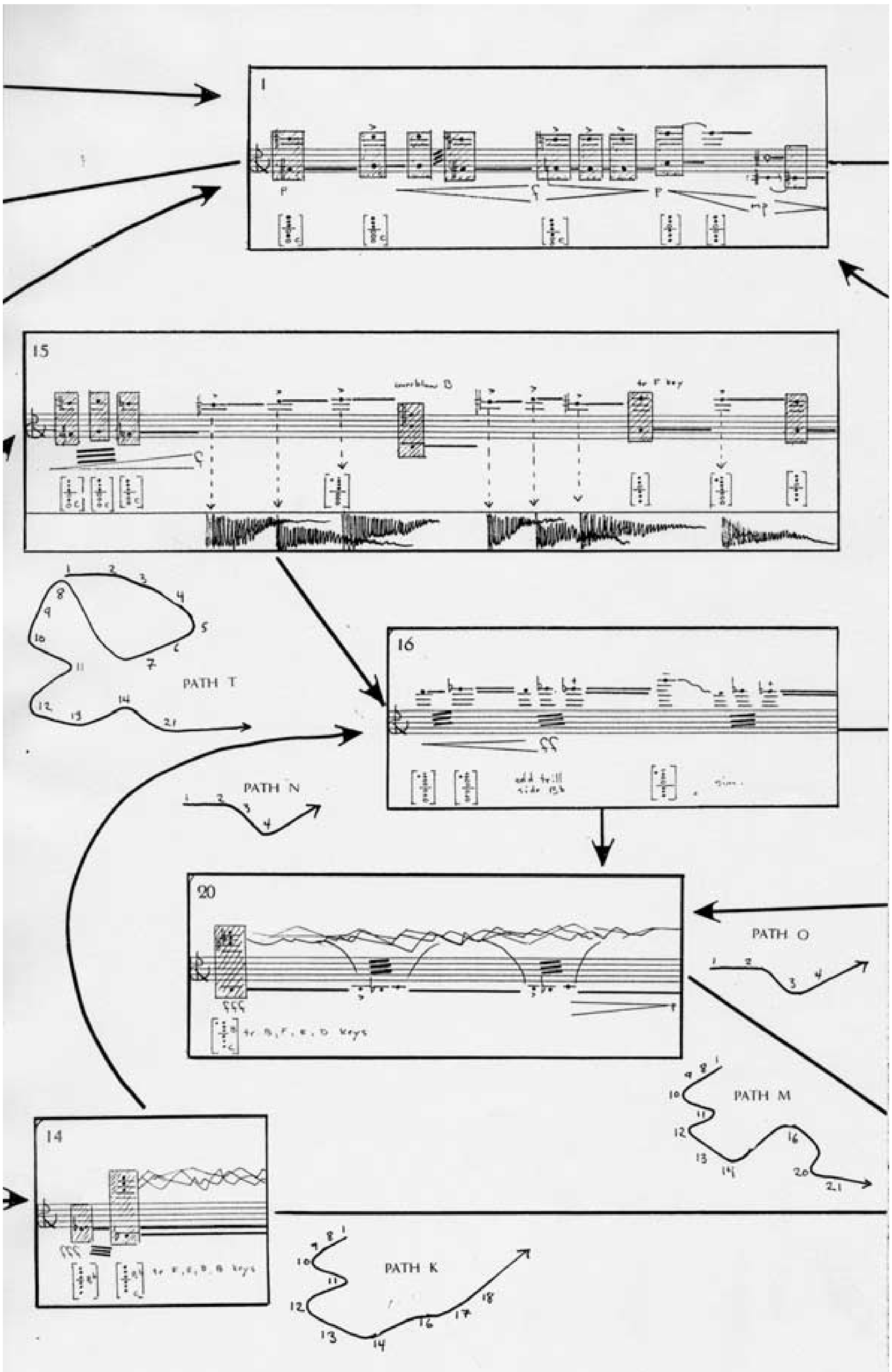

Figure 9. Detail of the inner paths of *Noisegate 67*.

complexity of the Exbow Metasax configuration. The piece begins with the Metasaxophone controlling only Exbow 1 with the keys mapped as:

B (1) to inharmonicity 1,
A (2) to bow force,
G (3) to frequency,
F (4) to bow position,
E (5) to inharmonicity 2,
D (6) to bow velocity, and
right thumb (7) to noise.

When Exbow 2 enters, the keys are dynamically remapped for this string as:

B (1) to noise,
A (2) to bow force,
G (3) to frequency,

F (4) to bow velocity,
E (5) to bow position,
D (6) to inharmonicity 1, and
right thumb (7) to inharmonicity 2.

It is worth noting the performance complexity introduced at this stage. The two Exbow strings are dynamically linked but the control parameters are reassigned. As the performer plays Exbow 1, Exbow 2 also responds but in a different way. Some keys such as A (2, bow force) and G (3, frequency) stay the same but others are changed. Thus, in order to apply velocity to either Exbow, this propagatory parameter now simultaneously alters another parameter on the opposite string. Velocity of Exbow 1 alters the inharmonicity of Exbow 2, and velocity of Exbow 2 alters the bow position of Exbow 1. Not only does complexity increase as the result of more strings, but also the articulation of those strings necessitates increasing the timbral complexity of the other strings. In this way a compositional mapping strategy was devised that forces the music to increase in timbral complexity as additional strings are added.

The situation is compounded with the addition of Exbow 3, mapped as:

B (1) to noise,
A (2) to bow velocity,
G (3) to frequency,
F (4) to bow force,
E (5) to nothing,
D (6) to nothing, and
right thumb (7) to inharmonicity 2.

It can be seen that the relative complexity of the new mappings decreases as more strings are added. In this case the E and D keys are not assigned to any parameter of the string, and the distribution of propagatory and modificatory parameters are closely observed. The A key is assigned to bow velocity, for example, and the F key to bow force, essentially switching the two propagatory parameters of Exbow 2. The B and right thumb keys are given modificatory parameters as on Exbow 1 and Exbow 2, and frequency is similarly assigned to the G key.

The final string, referred to as 'GlissDroneBow' in the diagram shares many similarities with the Exbow 1 mappings:

B (1) to inharmonicity 1,
A (2) to bow force,
G (3) to nothing,
F (4) to bow position,
E (5) to inharmonicity 2,
D (6) to nothing, and
right thumb (7) to noise.

Rather than giving the performer control over frequency, this string uses a preprogrammed frequency score, a very gradual two-octave glissando.

On a macro timbral level, the Metasaxophone controls the transformation between three instruments: the acoustic saxophone, the string physical model played by the Metasaxophone controllers, and acoustic bowed string timbres played by the computer. Two aspects of extended techniques for physical models are explored – gestural transmutation of the instrumental controller (as discussed above) and signal transmutation as a result of instrumental cross synthesis.

Through signal transmutation, the saxophone sound, the bowed string sound, and the combined Metasaxophone/string physical model sound are transformed into a series of hybrid instruments that are performed live by the saxophone and transfused into independent timbral screens. There are six such convolved timbral screens derived from the three archetypal models: (i) sax convolved with sax, (ii) string convolved with string, (iii) physical model string convolved with physical model string, (iv) sax convolved with physical model string, (v) sax convolved with string, and (vi) physical model string convolved with string.

As these hybrid timbres evolve they are continuously mutated, forming a series of transformations. Figure 11 shows the Max/MSP interactive performance interface for *S-Trance-S* (audio CD Example 5: S-Trance-S).

7. CONCLUSION

The possibilities of new applications for meta-instruments are virtually infinite, and these enhancements of the saxophone have pushed the practice of saxophone performance and composition into new areas.

Current work with the Metasaxophone involves continued exploration of extended mapping possibilities for physical models. Another project with Max Mathews involves developing real-time interactive applications for Scanned Synthesis (Mathews, Verplank and Shaw 2000). In this research, the Metasaxophone controls a variety of parameters of Scanned Synthesis strings and the saxophone keys act as complex hammers, changing the damping, length and stiffness of the strings. Additional research is exploring the behavioural characteristics of the internal resonances and pressure variations of the saxophone body through amplification. A new group of compositions, entitled Δ (2001/2002), explore the saxophone as an electric feedback instrument.

The Metasaxophone represents a further step towards formulating an integrated electroacoustic performance practice. Through the development of imbedded systems and sensor technology and the use of general communication protocols such as MIDI, direct control of digital signal processing and electronic processes can be given to the performer. The Metasaxophone has proven to be a useful tool for opening new possibilities of real-time integration of instrumental and computer music.

The Metasaxophone furthers Adolphe Sax's vision of an instrument combining the timbral and expressive characteristics of the orchestra by uniting the saxophone

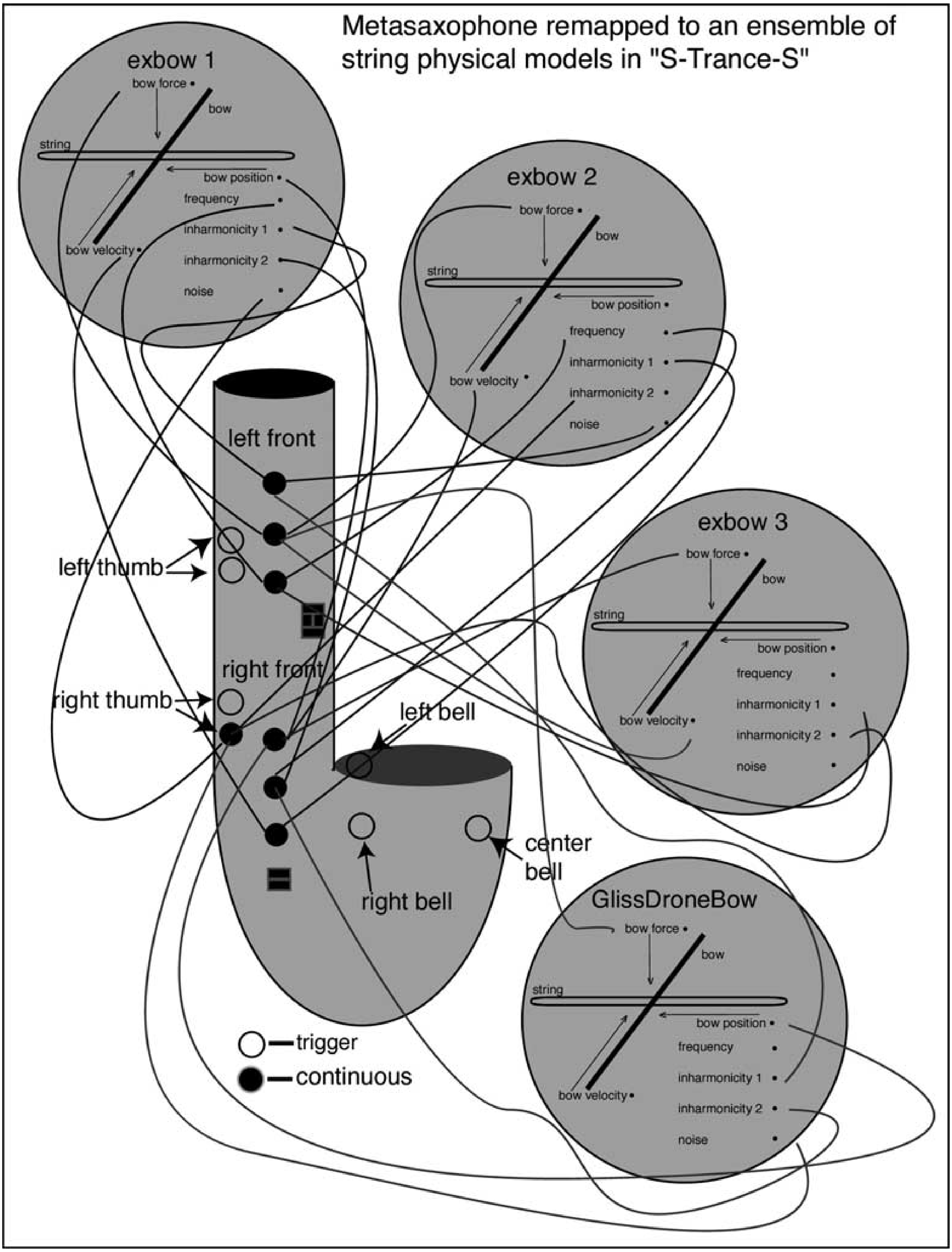

Figure 10. Metasaxophone controller mappings in *S-Trance-S*.

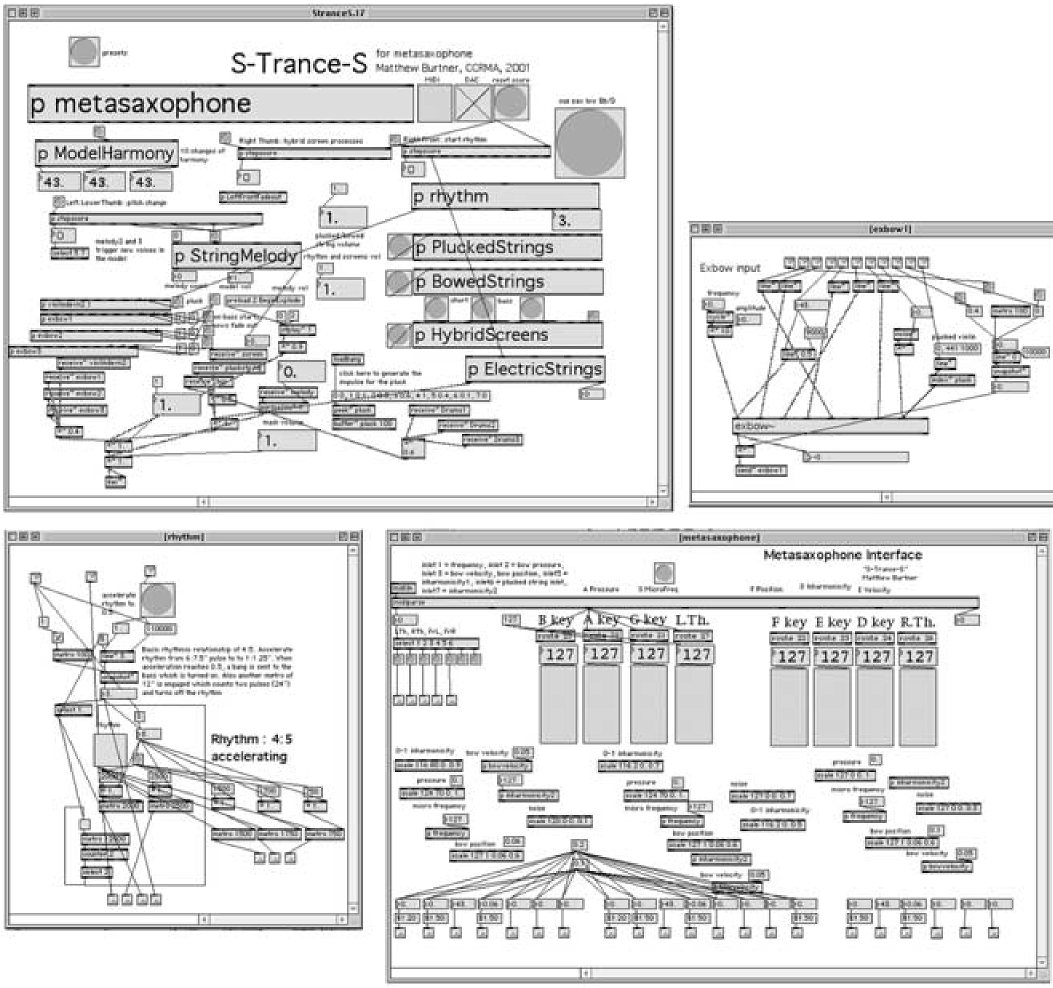

Figure 11. *S-Trance-S* performance interface, Metasaxophone interface, Exbow mappings, and rhythm subpatch.

with the world of the computer: an extended instrument for an extended orchestra. After many modifications, the Selmer instrument that became the Metasaxophone, purchased in Paris in 1990, is now covered in circuitry, sensors, serial cable and wire. And we recall the words of Berlioz 160 years ago this year: 'We must rejoice that it is impossible to misuse the Saxophone'.

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