# How to play the first bar of *Rhapsody in Blue*

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## ABSTRACT

To play the *glissando* opening Gershwin's *Rhapsody in Blue*, expert clarinettists combine unusual fingerings with even more unusual vocal tract configurations to achieve a nearly continuous rise in pitch. To study directly the player's vocal tract when performing the *glissando,* we incorporated an acoustic impedance measurement head within a clarinet mouthpiece. The player's vocal tract impedance spectra were measured and compared with the corresponding clarinet impedance spectra for the fingering used at that pitch. Partially uncovering an open finger-hole raises the frequency of clarinet impedance peaks, allowing smooth increases in resonance frequency of the downstream bore. In the clarinet's second register, however, upstream resonances in the player's vocal tract are manipulated to be comparable in magnitude with those in the clarinet. Thus, by skillfully coordinating their fingers and simultaneously coupling strong vocal tract resonances to the continuously changing pitch, experienced players facilitate a smoothly rising pitch, particularly across the *glissando*'s final octave.

## BACKGROUND

George Gershwin's *Rhapsody in Blue* opens with a solo clarinet playing a spectacular two-and-a-half octave rise, terminating in a *glissando* (Figure 1). This first bar of is one of the great icons of 20th century music and one of the best known bars in music.


**Figure 1**. Opening of Gershwin's *Rhapsody in Blue* showing the 2.5 octave run as is written – but not as is usually played.

Commissioned by Paul Whiteman and his jazz orchestra, *Rhapsody* premiered with Gershwin on the piano. It was not until rehearsals of the *Rhapsody* began that the *glissando* unintentionally came into being.

> ...as a joke on Gershwin, Gorman (Whiteman's virtuoso clarinettist) played the opening measure with a noticeable *glissando*, adding what he considered a humorous touch to the passage. Reacting favourably to Gorman's whimsy, Gershwin asked him to perform the opening measure that way at the concert and to add as much of a 'wail' as possible. (Schwartz 1979:81)

At its première on 12 February 1924 at New York's Aeolian Hall, "Ross Gorman began his *glissando* and electrified the house" (Schiff 1997:60). This performance tradition has continued to delight audiences ever since.

Replicating Gorman's 'wail' is now standard practice (Figure 2 is a spectrogram of this feat) but a difficult act to follow. To achieve this effect, expert players combine unusual fingerings with even more unusual configurations of their vocal tract to achieve a nearly continuous rise in playing pitch. To study these two mechanisms in detail, we first measure the clarinet's resonances at various fingering positions used in the *glissando*. Next we measure the player's vocal tract resonance at various stages in the *glissando*.

A clarinettist playing the clarinet can be seen as a system whereby 3 acoustic systems are coupled – the player's vocal tract upstream, the reed as a pressure-flow regulator, and the clarinet bore downstream. According to the continuity of volume flow model (Benade 1985:425), the combined acoustic impedance of the tract-reed-bore system is given by

$$Z = (Z_{Bore} + Z_{Tract}) \,//\, Z_{reed} = \frac{Z_{reed}\,(Z_{Bore} + Z_{Tract})}{Z_{reed} + Z_{Bore} + Z_{Tract}} \quad \ldots (1)$$

where $ZU = p_{\mathrm{Bore}} - p_{\mathrm{Tract}}$ are such that $U$ is the acoustic flow, $p_{\mathrm{Bore}}$ and $p_{\mathrm{Tract}}$ are the pressures in the bore (downstream) and the vocal tract (upstream) respectively. Here, the acoustic impedance of the player's vocal tract, $Z_{\mathrm{Tract}}$, is in series with that of the bore, $Z_{\mathrm{Bore}}$.

For most playing conditions, the vocal tract impedance is small compared to the bore impedance and the system can be accurately described in terms of $Z_{\mathrm{Bore}}$ and $Z_{\mathrm{Reed}}$ alone. However, should $Z_{\mathrm{Tract}}$ be large and comparable to $Z_{\mathrm{Bore}}$, the player's vocal tract can significantly influence the behaviour of the instrument.

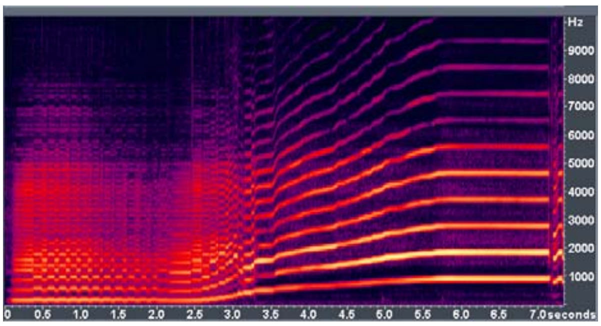


**Figure 2**. A spectrogram of the *glissando* shows the opening trill on the note G3 is executed from 0 to 2 seconds and a scale-like run at 2.5 to 3.5 seconds. Thereafter, the pitch rises smoothly over an octave from C5 (3.5 seconds) to the sustained note at C6 (beginning at 5.7 seconds). (Note names are in clarinet written pitch.)

## MATERIALS AND METHODS

### Measuring Clarinet Bore Resonance

To measure resonances in the bore for fingering positions used in the *glissando*, a standard B-flat Clarinet (Yamaha model CX) was used. The clarinet's acoustic impedance was measured by means of the 3-Microphone 2-Calibration (3M2C) technique (Dickens 2007) involving the use of two non-resonant loads for calibration. This method allows the measurement reference plane to be set at what is "seen" at the reed looking into the clarinet bore (Figure 3).

Clarinet bore impedances are then measured for various fingering positions used by clarinettists in executing the *glissando*. This involves the unusual technique of gradual uncovering clarinet finger-holes by progressively sliding one's fingers to uncover the holes and thus to raise smoothly the playing pitch, in addition to utilising standard fingerings.

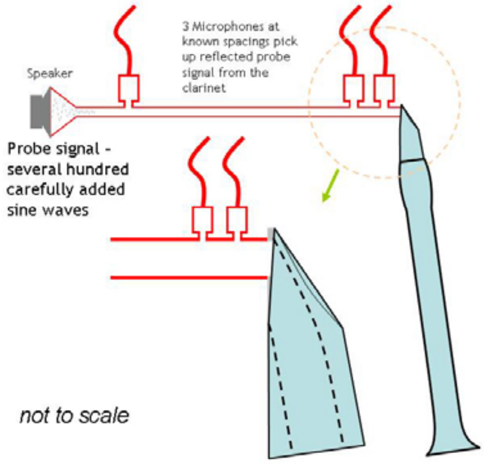


**Figure 3**. Schematic of the 3M2C technique for measuring the acoustic impedance of the clarinet bore.

### Measuring Vocal-Tract Resonance

The acoustic impedance of the player's vocal tract was measured directly during performance using a novel, non-invasive technique: capillaries for a sound source and a microphone are incorporated into a standard clarinet mouthpiece (Yamaha 4C), allowing measurements that "look" into the player's vocal tract as "seen" by the reed junction without disturbing the player (Chen 2008).

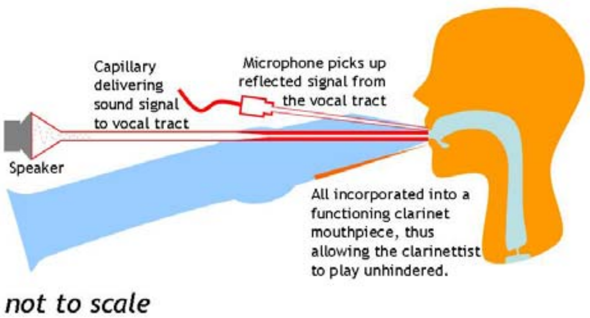


**Figure 4**. Schematic of the modified mouthpiece used in measuring the acoustic impedance of the player's vocal tract.

The clarinet is now fitted with this specially modified mouthpiece (Figure 4). Five experienced clarinettists (four professional players, one advanced student) were engaged and asked to play the *glissando*, "pausing" for a few seconds at various points in the run while their vocal tract impedance was measured for that configuration (Figure 5). One waived the anonymity automatically offered to subjects.

## RESULTS AND DISCUSSION

### Fingers and Clarinet Resonance

Seven of the tone-holes on the clarinet are covered directly by the player's fingers rather than key pads. Thus the player can gradually uncover these holes by progressively sliding the corresponding fingers off the clarinet instead of a discontinuous covering/uncovering of the tone-hole. This technique is possible in the range between the notes G3 to G4 (first register) and from D5 to C6 (second register). (Notes names discussed are in clarinet written pitch, one tone above sounding pitch.)

**Figure 5**. Francesco Celata (Sydney Symphony Orchestra) plays on the setup as we measure his vocal tract impedance. (Francesco waived anonymity for the purpose of this study.)

Acoustic impedance measurements of the clarinet for standard fingerings show well spaced maxima indicating the bore resonances at which the clarinet reed operates (Figure 6). Measurements with a tone-hole partly uncovered by a finger slide show impedance maxima at frequencies intermediate between those used for musical notes. Thus the finger slide allows the playing pitch to increase smoothly by gradually raising the bore resonance, instead of moving in discrete steps (as in a normal musical scale). Over part of the clarinet's range, this scheme contributes to the smoothly increasing playing pitch - but this is only part of the story.

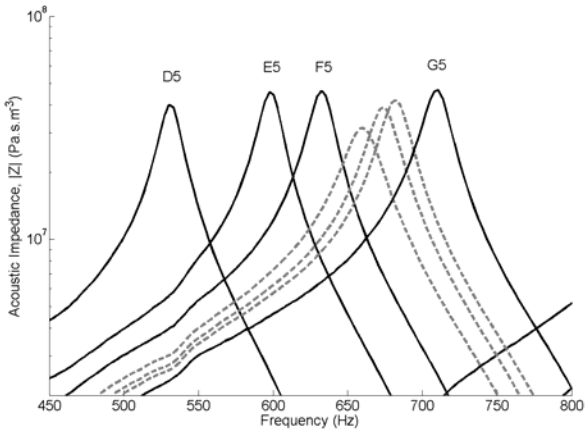


**Figure 6**. Impedance maxima measured for standard clarinet notes D5, E5, F5 and G5 (solid lines) are discretely spaced. As the player's finger gradually slides off and progressively uncovers the clarinet tone-hole that differentiates F5 and G5, however, a maximum is measured at an intermediate frequency, whose value is smoothly raised by smoothly sliding the finger (dashed lines). This allows the player to raise smoothly the operating bore resonance.

### Vocal-Tract Resonance and the Clarinettist

The frequency at which the clarinet reed vibrates determines the pitch of the note played. This frequency is determined by a maximum (usually the largest maximum) of the combined acoustic impedance of the tract-reed-bore system given by Eq. (1). Usually, the clarinet's resonances dominate and the player's tract has only a minor effect. However, the final octave of the *glissando* (from C5 to C6) lies in a range of the clarinet where the clarinet resonances are somewhat weaker than in the lower range. In this range, experienced players can produce a resonance in the vocal tract whose impedance peak is comparable with or larger in magnitude than those of the clarinet: the vocal tract can 'win' the battle to control the reed.

Figure 7 shows a comparison of the measured impedances of the clarinet (pale line) and the vocal tract (dark line). The fingered note is G5. Compared with the clarinet bore impedance, the peaks in the impedance of the vocal tract for *normal playing* are rather weaker than those of the bore. Consequently, the combined acoustic impedance for normal playing (dashed line, top) yields resulting maxima largely determined by the bore maxima: the reed vibrates at a frequency (indicated by arrow) close to the strongest peak in $Z_{Bore}$. In *glissando playing* however, a peak in the impedance of the vocal tract is measured to be much larger than those of the bore. Consequently, the maximum of the combined impedance during *glissando* playing (dashed line, bottom) is no longer determined solely by a bore maximum. Instead, it now depends on the strength and frequency of the vocal tract resonance. In this example, the resulting sounding frequency deviates by 68 cents from normal playing.

By tuning this strong resonance of the vocal tract, expert players can control the playing pitch continuously. The *glissando* in Rhapsody in Blue requires a strong vocal tract resonance and smooth control over a large pitch range. However, the playing pitch need only deviate from that of the fingered note by a semitone or so. Greater deviations are possible: in other experiments using a single fingering, we measured the resonances of the player's tracts as they shifted the sounding clarinet pitch by several notes, using the vocal tract alone.

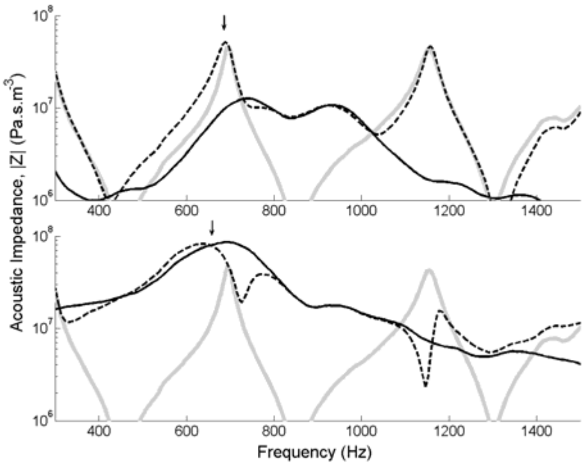


**Figure 7**. Measured impedance of clarinet (pale line), vocal tract (dark line) and combined impedance (dashed line). In both cases the fingered note is G5. Arrows indicate sounding pitch. In the top curve, the note is played normally. In the bottom curve, it is played as part of the *glissando*.

## CONCLUSION AND SUMMARY

In the clarinet, the reed's oscillation determines the sounding note. Downstream from the reed is the clarinet bore, while the player's vocal-tract is upstream. For normal clarinet playing, downstream resonances in the clarinet bore (determined by the fingering used) dominate to drive the reed to oscillate at a particular frequency. However, if the upstream resonance in the player's vocal-tract is adjusted to be strong enough and at the appropriate frequency, the vocal-tract resonance will then compete with the clarinet resonance to determine the reed's playing frequency. (Occasionally the reed resonance wins, and we hear that as a squeak!)

By skilfully coordinating the fingers to smoothly uncover the clarinet finger-holes and simultaneously tuning strong vocal-tract resonances to the continuously changing pitch, expert players are able to facilitate a smooth trombone-like *glissando*, particularly in the final octave of the run.

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### Acknowledgements

This project was supported by the Australian Research Council. Thanks to our volunteer subjects and to Yamaha for the clarinets. The first author attends the 2008 AAS annual conference on a travel award from the AAS NSW Division.