On the Function of Holes and Keys on the Contrabassoon and Bassoon

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This article grew out of the project to develop the Fast System contrabassoon. One of the goals with the new register key system was to have a more logical and simple fingering system. The positions of the new register holes and the fingerings that would apply to the notes of each hole had an interdependent relationship. However, only the big picture of a fingering chart could initially be contemplated. Once the layout of the holes was determined and a new instrument was built, I was so happy to relegate the old contrabassoon fingering charts to a file drawer containing historical instrument materials. But what lay ahead was the development of a new fingering system and resource book. I had an instrument with five new fully functioning vent holes belonging to a new paradigm, plus the existing half-hole mechanism. I knew it would be a robust system. Many things were obvious because Chip Owen, head of the contrabassoon department at Fox and I had had to envision the basic fingering implications while deciding which notes of the second octave each hole would serve. But a fully developed fingering resource book could not really commence until an instrument with the new system was built. As soon as the first production instrument was finished, it was put into service in the New York Philharmonic, followed shortly by the Cleveland Orchestra and the National Symphony. This meant that fingerings had to succeed immediately at a high level.

I had already been through one systematic exploration of the vent holes on the bassoon to discover the symptoms of misplaced register holes. With the new contrabassoon I realized I could do a parallel exploration of the new system of register holes to discover fingerings based on different source notes. Then I realized I could also investigate which low note keys might be useful or necessary in the fingerings. This provided the impetus to write the initial version of this article, so I could encourage other players of the Fast System contrabassoon to discover fingerings on their own and provide feedback. What resulted was a realization that while the Fast System contrabassoon does have a more simple and logical fingering system, it is rich with possibilities for subtle alteration of the fingerings with the low note keys, just like the bassoon. These two instruments share this quality, and I hope to reveal why they are unique, as well as how fingerings can be customized for particular musical needs.

(**Editor's Note:** In order to preserve the analogous keywork and pitch relationships between the bassoon and contrabassoon, all octave designations in this article refer to *written* rather than *sounding* pitch.)

Fingerings for the notes of the bassoon and contrabassoon contain various components that can be considered and dealt with separately. In this article I will show how these components function, and this will provide a context for understanding the many fingering possibilities that exist for the bassoon and contra. Understanding the role of each component will help provide a working method for assessing whether the fingerings you are using are the very best ones for your purposes, as well as a framework for searching for new ones.

There are two basic categories of holes into the bores of bassoons and contrabassoons: tone holes and register holes.[1] Tone holes are large, and are able to produce the note desired if the pad over the hole is opened. Trill keys fall into this category, although they might be slightly smaller than a normal tone hole. In contrast to tone holes, register holes are small and they exist in the upper part of the bore (above the system of tone holes) to provide upper register notes. They do this by dividing the standing wave of a fundamental octave note into shorter segments. Some pads on the bassoon cover multiple holes. For the purposes of this article, multiple holes under one pad will be considered to be one tone hole. The multiple holes function together as they are all either opened or closed by the pad.

The Function Of Holes In The Bore

The two types of holes can serve three different functions. Tone holes serve all three of these functions in different situations, but the small register holes as defined above can serve only one. First, let's look at tone holes:

1. A tone hole serves as a genuine tone hole. Tone holes serving in this way basically produce one note or another. When playing a particular note in the fundamental octave or any of the lowest notes of the bassoon or contrabassoon, all holes above the first open tone hole in the system must be closed. I will refer to the first open tone hole as a *primary tone hole*. In upper register notes, another tone hole further up the bore may be open if it is used as a register hole. In this case, the primary tone hole will still control the note being produced. This is because both halves of the long sound wave continue to vibrate and the lower half is terminated by the primary tone hole. Thus, if the primary tone hole is opened, a different upper register note will sound. Trill keys that are used for their original function fall into this category of tone holes, since they raise the pitch of the starting note by either a half step or a whole step.[2]
2. A tone hole can serve as a register hole. A register hole functions to divide a standing wave in the instrument into shorter segments. Any tone hole in the upper half of the bore (including trill key holes) has the ability to serve this function. Most commonly, it is the holes or keys of the left hand fingers and the thumb C♯ key that function this way. Because tone holes in general are large, when they are used as register holes, they very strongly influence the pitch of the note being produced. If they are located

some distance from their theoretically correct location,[3] a different note altogether may be produced from what one would normally expect: a thirteenth rather than a twelfth, for example.

3. A tone hole can serve an auxiliary function.[4] Tone holes serving in this way do not produce the note directly, nor do they divide the sound wave into shorter segments. They only modify the sound quality of the existing note in some way. They may strengthen a note, making it more resonant or otherwise change the tone color; enable a soft delicate attack; make a note more stable or conversely, provide more flexibility; or otherwise slightly change the note's pitch. Resonance keys fall into this category. Tone holes serving this function always lie in the lower part of the bore (at the very least, two holes below the primary tone hole), and it is the right-hand fingers plus the right and left thumbs that are used for auxiliary keys. The discussion below helps explain this.

The Lattice Of Open And Closed Standing Tone Holes

On bassoons and contrabassoons, the pads on some tone holes stand open, and some stand closed when at rest. Generally, the pads that are held shut against the tone holes are for the accidentals in the scale, such as G♭, A♭, B♭, D♭, the contrabassoon's E♭ key, as well as the low C♯ and D♯ keys. When these keys were originally added to the instruments, they stood closed. The fact that they still stand closed on modern instruments is a testament to the important function they serve in the overall scheme of how the instruments are designed to play. Boehm revolutionized this aspect of the flute by making most of the accidental-note tone holes stand open (the D♯ and G♯ keys stand closed), but the application of these principles to the bassoon (around 1860) failed because it changed the tonal characteristics of the instrument so much that players did not accept it. Thus, to this day the bassoon (and the contrabassoon) play in such a way that in most cases, each note of the fundamental octave (as well as in the upper registers) has some tone holes below the primary tone hole that stand open and some that stand closed. This is what is referred to in some acoustics books as the "lattice of open and closed standing holes."[5] Exactly which holes are open or closed has some secondary effect on the note being produced: pitch can be slightly modified, tone color may be altered to fit better in the scale, or the note may be stabilized by opening or closing a tone hole down the bore. This is precisely the auxiliary function that was described above. The tone holes serving an auxiliary function are part of this lattice of open and closed standing tone holes. This will have significance later in the discussion of the function of auxiliary keys in analyzing fingerings.

I would like to take a moment to point out that the bassoon and contrabassoon are unique instruments in the woodwind family in that they have so many notes in the scale below the lowest note of the fundamental octave. Most woodwinds have two or three notes available below the lowest fundamental octave note, but bassoons and contras have seven (eight, if the instrument goes to low A). The entire long joint and bell assembly of the bassoon and the last 6-1/2 feet (1.98 meters) of the contrabassoon's bore are dedicated to these extended notes. Most of the tone holes in this extended range have pads that stand open, but the C♯ and D♯ pads stand closed. Thus the bassoon and contra have a much longer lattice of open and closed holes than most woodwinds. This provides many more possibilities for slight modification of fingerings than most woodwinds have and it helps explain why one of the fingering resources for the bassoon is a 366 page reference book.[6]

The Category of Register Holes

Register holes are any holes in the bore that divide the standing wave into shorter segments, and it is the length of these segments that determines the note produced. The small speaker holes on the wing joint and the whisper key of the bassoon, as well as the small holes on the metal pipe of the contrabassoon, are dedicated to this purpose. These holes are not large enough to serve as primary tone holes (category one above) or as auxiliary holes (category three above). With the exception of the bassoon's whisper key, they all stand closed. The whisper key is a unique key with an exceptionally small hole and the pad above it stands open. This key provides clarity of articulation on the upper notes of the second octave of the bassoon when played with third mode[7] fingerings, while leaving the middle notes in the second octave (A3, B♭3, B3 and C4)[8] vulnerable to non-musical noise in the attacks.[9] Thus it is the source of some misunderstanding and confusion.

While all of the tone holes under the left hand fingers also function as register holes on one upper octave note or other, the uppermost tone hole (for open F3) deserves special mention. On the bassoon, the open F tone hole is used in various half-hole sizes for several notes in both the second and the third octaves of the instrument. On the contrabassoon the open F tone hole is divided into two distinct holes, a larger and a smaller one. When the larger one is open, the smaller one is also open and they serve together as one tone hole. But the smaller hole may be opened independently, in which case it serves as a register hole. It is basically a half-hole with a key covering it rather than a finger, and for this the left hand first finger must be up while the second finger must be down. In cases where the fingering for a note on the contra would benefit from a slightly more open or slightly more closed half-hole, one must compensate for this need by using some other key in the fingering system.

Dividing The Standing Wave to Produce Upper Register Notes

Notes in the upper registers of conical bore double reed instruments are always derived from some source in the fundamental octave. When the standing wave of a fundamental octave note is divided into two parts, a note one octave up is produced. The register key that assists the production of this note is commonly called an *octave key*, and in order to provide good response, intonation and tone, it must be located in the vicinity of the midway point (which I will refer to as a *nodal region*) of the standing wave. For higher notes, the wave may be divided into three parts (producing the third harmonic or third mode note), resulting in two nodal regions. In this case, the register holes need to be at the one-third and two-thirds locations, not at the halfway point. Opening a register key at one of the two nodal locations will usually produce this third-mode note, but the best solution is to open two register holes, one at each nodal region. This usually provides a cleaner attack, as well as a more focused tone. Examples of this on the contrabassoon are F♯4 and G4 *(see Illustration 1).*

These notes originate from the fundamental octave notes B2 and C3, respectively, a twelfth below. For both of these notes, the lower nodal region is vented by the automatic half-hole mechanism and the upper nodal region is vented by the top vent, near the bocal socket. For higher notes yet, the standing wave may be divided into four parts, producing a fourth-harmonic note. These notes will have three nodal regions, and a register hole must be opened at either the upper or the lower of the three nodal regions in order for the note to speak. Ideally, two of the three nodal regions should be vented. This usually provides the best clarity of attack and tone. An example of this on the contrabassoon is high A4 fingered lower vent, C♯, low D, 1 2 3–1 2 *(see Illustration 2).*

This high A comes from the fundamental octave note A2 two octaves below, fingered 1 2 3–1 2. The lower vent key opens one pad (on the Fast System contra) or two pads (on the traditional contra) at the midpoint of the standing wave, producing the octave, and the C♯ key opens a tone hole functioning as a register hole lying about halfway between the octave vent and the tone hole. The remaining part of this high A fingering is the low D key, which is an auxiliary key. Most notes in the third octave of the bassoon and contrabassoon (F♯4 and above) require that one of the left-hand tone holes stand open (or be used as a half-hole), functioning as one of the venting (or dividing) points in the long sound wave.

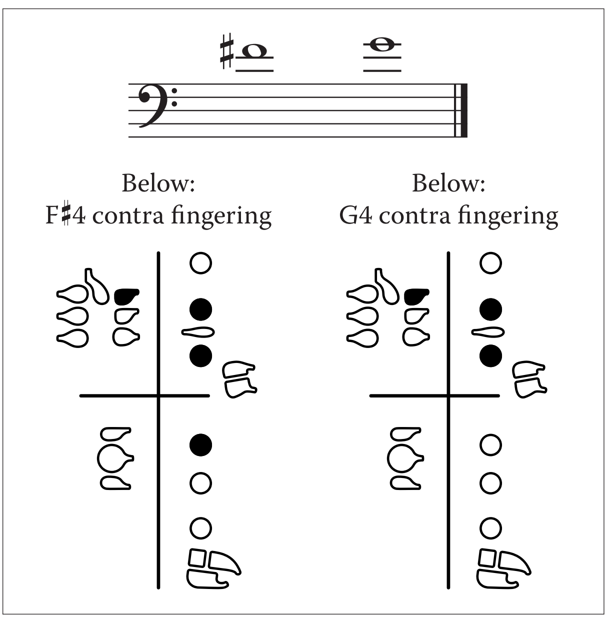


Illustration 1

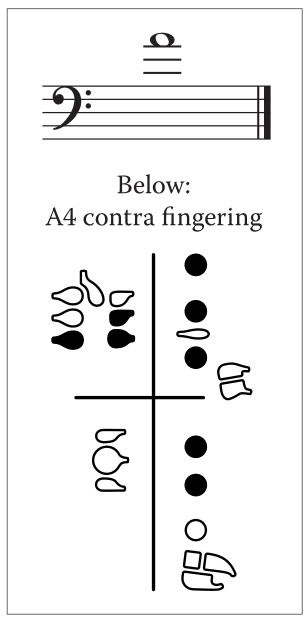


Illustration 2

A standing wave may also be divided into five parts (producing a fifth-harmonic note). Theoretically, since five is a prime number, a register hole opened at any one of the four nodal regions may produce a fifth harmonic note. But this is also where analysis of the fingerings can become tricky, since at least one tone hole must be serving as a register hole. The size of the tone hole (serving as a register hole) can influence the pitch of the note so dramatically that it may be hard to identify the note of origin.

The point of this discussion is that for upper register notes using third, fourth and fifth (or higher) harmonics, we usually need to vent at least two of the nodal regions in order to have clarity of attack at all dynamics as well as a strong tone. This principle will be useful to analyze and understand upper register fingerings, and keeping it in mind will help to facilitate the search for more suitable fingerings in the upper register if the ones you are using are not entirely to your liking.

Multiple Register Holes Open At One Time

There are two different cases to consider:

1. The first situation occurs when two holes functioning as register holes are very near each other. In most cases, they act on the same nodal region to divide the standing wave. If they are of different sizes, the larger one is dominant, and the smaller one may be thought of as acting on it. If they are the same size, their effect on the note produced depends on where they each lie in the standing wave. They may provide good response, intonation and tone for one note, but not for the next one in the scale, or they may function well on a particular note at a loud dynamic, but be troublesome at very soft dynamics. This is because each note of the scale has its nodal regions in slightly different positions on the bore.

   The following example illustrates how two register holes affect the behavior of the instrument when they are acting on the same nodal point. On the bassoon, when one plays the note C4 using the C speaker key while also leaving the whisper key open (a normal way to play this note), there are two vents open in the same vicinity, about 3-1/2 inches (8.9cm) apart *(see Illustration 3).*

   The C speaker key by itself will provide a clear attack and musically usable intonation, but it is convenient to leave the whisper key open for technical reasons.

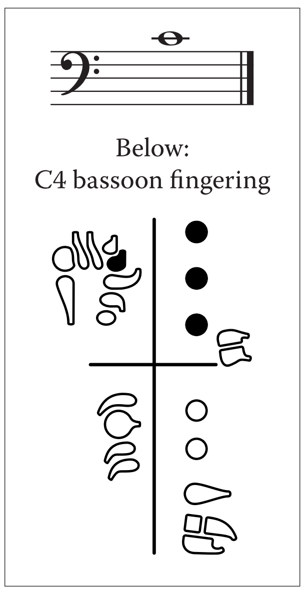


Illustration 3

The whisper key is higher on the bore but is very small, and raises the pitch very slightly. This slight rise in pitch is due to the smaller hole (higher on the bore) acting on the larger dominant vent. The pitch difference is so small that we usually adjust intuitively for it. But we can also make use of the difference to help provide the flexibility we need when we are playing the third tone of a chord that we want to sound pure.[10]

Sometimes one register hole is positioned too low on the bore to function well as an octave key for a certain note. Opening another register key a little higher on the bore can balance this out and make the two holes function as one properly placed hole. An example of this exists on the Fast System contrabassoon for the note G3, with the left first finger lifted (providing the half-hole), and the lower vent key pressed (opening the single vent on the tuning slide). This combination provides a secure and clean attack on G3, even though neither register hole is ideally located for this particular note.[11]

2. The second situation that can occur with multiple register holes open at once is that the two open holes functioning as register holes are not in the same vicinity. When the two open register holes are more than seven inches apart (on the bassoon) and fourteen inches apart (on the contrabassoon), you can be sure that they are acting on different nodal regions of the standing wave. If one of these holes is a tone hole (which it usually is), its large size will strongly influence the pitch of the note. Depending on the location of the hole, it can readily produce a note different from one that lies in the harmonic spectrum of the source note. The other (smaller) hole will further modify that, but to a lesser degree. For some very high notes, it is possible that two holes closer together than seven and fourteen inches (on the bassoon and contra, respectively) are acting on different nodal regions, but any case of this would be a rare occurrence. On the Fast System contrabassoon, even in the high fourth octave, only two notes (written B5, above the treble clef staff and C6, the next note up) have two register holes on the metal pipe open at once that are closer than 14" apart. They are 11.5" apart.

   It is possible that two holes near each other may function both ways at once. They may be positioned such that for a particular source note they can act on one nodal point or on two different ones, depending on the embouchure. This can cause uncertainties in the instrument's response, making it feel unpredictable. An example of this is the fingering for the written note C♯4 on the traditional contrabassoon *(see Illustration 4, following page).*

   With most fingerings for this note, the lower vent key is held down, opening the two vent pads on the metal pipe in the vicinity of the tuning slide. Even the upper of those two vents is positioned a little bit too low on the bore from where it should be for that C♯, and the lower of these two vents is actually low enough that if the embouchure is not exactly right,

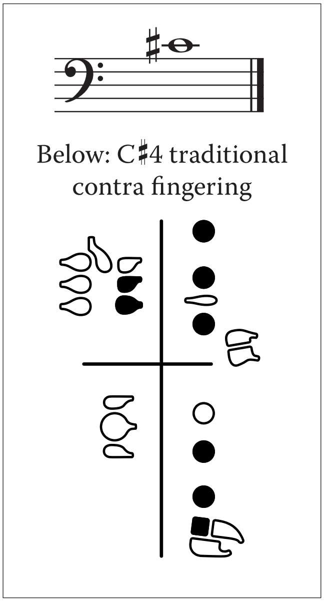


Illustration 4

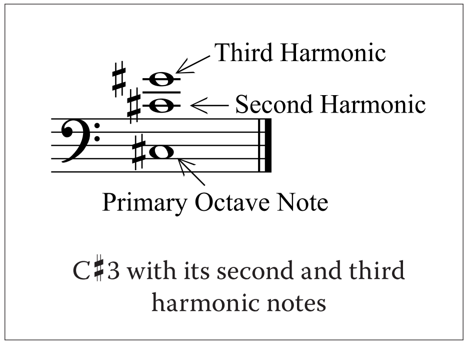


Illustration 5

the note G♯4 a fifth above can result. This happens because the lower of the two vents is near enough to the nodal region of the third harmonic of the primary octave note C♯3 *(see Illustration 5)* that it can "catch" that node if the embouchure isn't just right.

When that happens, the wave gets divided into three parts instead of two and the instrument produces a G♯4, not the desired C♯4. This occurs most easily at very soft dynamics, and in a performance it can be very embarrassing. This is one of the problems of the traditional contrabassoon that has now been eliminated. On the Fast System contrabassoon, the two pads of the lower vent system on the metal pipe never open simultaneously.

The Function Of Keys In Fingerings

When we play music, we generally associate fingerings with the notes being produced. We don't often think about exactly which holes are open and which are closed. Thus, while the previous discussion about holes in the bore is very useful to understand, it is the keys our fingers press in certain combinations that we usually concern ourselves with when solving particular fingering problems. In order to understand the fingerings we use, and to go searching for new or better ones, it is useful to think of the different components of fingerings as parts of a recipe. Much like a cooking or baking recipe has certain essential ingredients and may be modified with knowledge of the function of those ingredients, a fingering recipe has its own ingredients that may be altered to serve a particular musical purpose.

Fingering Recipes

There are three components to fingering recipes. You will notice that they are basically the same categories as the different functions that holes in the bore can serve. You can analyze your recipe by asking these three questions:

1. What is the note of origin? For notes of the fundamental octave, the note produced is essentially the note of origin. The primary tone hole determines this note. In the second octave, or mode, the sounding note has its note of origin one octave below. The primary tone hole still determines and controls the note. For third mode notes (overblowing twelfths), the primary tone hole is again the source of the note. While the contrabassoon is relatively straightforward in its tone hole design, the bassoon, with its arrangement of holes on the boot joint, can be complicated.[12] This may make the note of origin hard to identify for very high notes.
2. What are the register keys in the fingering? One needs to consider both the small register holes in the upper part of the bore and the left hand finger holes on the bassoon (left hand keys on the contrabassoon). There may be more than one register key functioning in a particular fingering. The register keys may be operating as one (on the same nodal region), or they may be acting on two different nodal regions of the third (or higher) mode note as described above.
3. What are the auxiliary keys in the fingering? Auxiliary keys in a fingering generally open and close holes in the lower part of the bore that belong to the lattice of open and closed tone holes. These always lie below the primary tone hole that produces the note. This is the aspect of fingerings that is most subject to modification to meet individual players' needs.

Understanding Auxiliary Fingerings

As mentioned above, the lower part of the bore contains tone holes that can function as auxiliary keys. There is a default starting point with the lattice of open and closed holes because some pads stand closed and some stand open. Using auxiliary keys in a fingering modifies this lattice. Pressing one key may create a longer series of open holes, or create a longer series of closed holes in the lower part of the bore. Pressing two keys may result in an open hole in the lattice being "moved" up or down the bore (opening one closed hole and closing an adjacent open hole). Sometimes two holes that normally stand open are closed and the one positioned between them is opened. This is actually the case on the contrabassoon when one uses the B♭ fingering combination in the right hand (1, 2, B♭), as an auxiliary addition to a fingering. In other cases, pressing a group of fingers such as 2, 3 and F in the right hand serves simply to close a number of the open standing holes in the lattice. This particular combination closes most of the pads in an entire region of the bore. It changes the escape possibilities for the high harmonics above the cutoff frequency[13] that permeate all the way down the bore. Auxiliary keys can function in another way: opening one key can benefit an entire series of notes. On the bassoon, we commonly use the low E♭ resonance key in all the fingerings for the upper register notes E4 to D♯5, an entire octave's worth of notes. On the Fast System contrabassoon, the low C♯ resonance key is beneficial for the series of low notes B2 down to E2. In both of these cases, opening the resonance key provides for a longer series of tone holes that are standing open in the lower part of the bore than the default lattice provides.

As I stated in the initial description of keys serving an auxiliary function, they can be used for various specific purposes: to make a note more resonant, allow a soft, delicate attack, provide for a more homogeneous sound for a series of notes, or to provide more flexibility of pitch for a chord tone. This can be achieved by either adding an auxiliary key that is normally not used, or leaving off an auxiliary key that is normally used.

Fingerings In The Fundamental Octave And The Very Lowest Notes

The fundamental octave of the bassoon and the contrabassoon is the F scale, from low F2 at the bottom of the bass clef staff to open F3. The very lowest notes are those from low E2 down to low B♭1. The fingerings for the nineteen notes of these two groups have two parts to their fingering recipes. The first is the note of origin. This is simply the note being produced, and there is generally only one fingering per note. It is worth noting that while notes of the F scale in the fundamental octave are used in producing higher notes (they get overblown), the very lowest notes (from low E on down) do *not* commonly get overblown. In other words, we don't use these lowest notes as the note of origin for producing notes in higher registers.

The second part of the recipe for these low register notes is the use of auxiliary keys. The question one can always ask is the following: Which low note keys in the fingering do not belong to the note of origin? We can only consider keys at least two notes below the primary tone hole as auxiliary keys. An example to consider is the use of the low C♯ resonance key for the low note E2 on the bassoon. One can become accustomed to using the low C♯ resonance key for low E2; this generally provides more resonance and projection to this note. However, in a soft delicate chord, this fingering may be harsh or too rigid, in terms of both pitch and tone color. Playing E2 without the C♯ resonance key may allow more flexibility of pitch, and by using that flexibility the tone may be made to fit better in certain contexts. Part of the process of evaluating which auxiliary or resonance keys to use or not use is to decide what musical result you really want.

Fingerings In The Upper Registers

Fingerings in the upper registers will always need all three fingering components to be considered in their recipe: note of origin, register key(s), and auxiliary key(s). It is useful to divide this large group of upper register notes into two categories: those notes that can only be produced by overblowing the octave (which have only one possible note of origin), and the rest of the notes, which may be produced from multiple notes of origin. The first category (notes that can only be produced by overblowing the octave) is from F♯3 to B3 *(see Illustration 6).* The register key these notes require is an octave key. While there will be essentially one octave key involved, it is possible there may be two holes open, an example of which (the note G3 on the Fast System contrabassoon) was discussed earlier. Fingerings for this group of notes are mostly subject to modification by auxiliary keys.

Illustration 6

For the notes in the second category, from C4 on up, there are at least two choices (theoretically) for how to produce them. At least one of the choices may involve two different register keys acting on two different nodal regions. The higher one plays in the scale, the more possibilities there are for where a particular note could come from. This is one reason that high notes often have numerous fingering possibilities *(see Illustration 7).*

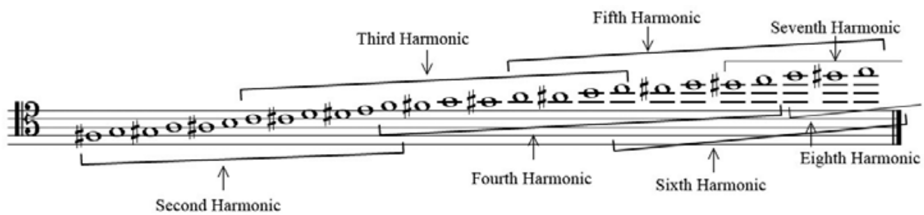


Illustration 7: Upper Register notes of the bassoon and contrabassoon, and the possible harmonics of source notes that produce them.

Searching For New Or Better Suited Fingerings

Armed with an understanding of the different components of fingerings and how they function, you can analyze any fingering. You can also search systematically for other fingerings, or modify existing fingerings to suit a particular need. The following steps can be followed individually or in any combination to find different or more suitable fingering possibilities:

1. Identify for any given note all of the possible source notes. In other words, identify all of the possible notes of origin that in combination with other register keys and auxiliary keys produce the note you are considering. The use of tone holes as register holes can produce a 13th instead of a 12th, for example. This is why the search must include other notes of origin.
2. Identify which register keys are being used. Look for a register hole higher on the bore, or which you can add to the existing register hole. A

common example of this on the bassoon would be pressing the high C *and* D keys together on the wing joint to provide a more secure attack on C♯5. Sometimes the choice of a register key becomes more obvious with a particular auxiliary fingering.

3. Examine which auxiliary keys are being used. Since the tone holes involved are primarily on the lower part of the bore, the choices will involve not only the right hand fingers but also the left little finger and the right and left thumbs. For the bassoon and contrabassoon, the auxiliary portion of the fingering recipes is the most subject to individual choice, to suit the player's needs. What works for one player on a particular instrument may be different from what another player finds useful. This is normal. Each instrument is slightly different, and the variety of reed styles (different shapes, dimensions and scrapes) interacting with different instruments and bocals makes the choice of which auxiliary fingerings to use a matter of personal choice.

There are some general principles to keep in mind. One is that creating a long row of open holes in the auxiliary key region will create a more open tone. A long row of closed auxiliary holes will create a darker, more covered tone. Another principle is that higher notes benefit from larger register holes (the third octave benefits more from larger register holes than the second, and the fourth more than the third). Since one cannot change the size of an individual hole, opening two adjacent register holes may serve the same purpose. A third principle, keeping fingerings simple and logical, can benefit from auxiliary key use. An example of this exists on the Fast System contrabassoon, where the right hand second finger key can serve as a substitute for the auxiliary C♯ key in the fingering for F4. This is useful because the second finger is also a good auxiliary key for the neighboring G4, and it is part of the basic fingerings for the next four notes G♯4, A4, A♯4 and B4. As a result, the second finger of the right hand may be held down for almost all notes between F4 and B4, serving as an anchor in the fingerings of these upper register notes. This helps make the fingerings feel more intuitive and logical.

Having said all of this, I am a firm believer in using a consistent set of fingerings when developing a technical base. I do not condone using an array of non-standard fingerings to compensate for low reedmaking standards or neglecting scales and long tones in a practice routine. But the ability to use a working knowledge of the existing keys on our instruments as tools for achieving good musical ends is invaluable. I hope that with a broader understanding of how to approach fingerings and analyze their components, each player will have the ability and freedom to assess for themselves whether the fingerings they are using are the best for their purposes.

*I would like to thank **Nora Post** for encouraging the development of this article and for her valuable perspectives on key systems of double reed instruments. I would also like to thank **Richard Bobo** for his Legni Font fingering graphics.*

Endnotes

1 I will not be considering holes covered by pads controlled by ring keys separately because they are not controlled independently.

2 Trill keys generally serve a specific purpose. Many are designed to produce a whole step trill and are less than successful when used for a half-step trill. Some are designed to produce a half-step trill and it is not practical to try to use them to produce a whole-step trill. A few can do both. The F♯ trill key on the Fox contrabassoon, for example, works well as a whole-step trill, and is reasonably good as a half-step trill from F3 or F4, if the alternations are quick.

3 Referring to a theoretical nodal point is a way to orient oneself in the consideration of a particular note. Since we are dealing with a physical instrument, we usually focus on the practical function of a register key. However, one can calculate the theoretical location of a nodal point by doing simple math.

An example of such a calculation is provided below:

Calculate the theoretical nodal point for making the oboe overblow its A=440 to the next octave A=880. Starting with the assumption that the speed of sound is 1,126' per second:

1126 ÷ 440 = 2.55909091'. This is the length of the wave, out and back, expressed in feet.

2.55909091' ÷ 2 = 1.2784' (the theoretical position of the tone hole, which is the turnaround point of the wave), again expressed in feet.

1.2784' ÷ 2 = .63977273' (the theoretical position of the register hole, midway between the reed end of the wave and the tone hole end of the wave), in feet.

.63977273' = 7.968" (feet converted to inches). The result is the position of the nodal point from the theoretical ends of the sound wave, which are beyond the end of the reed and beyond the tone hole, respectively.

4 Auxiliary function and the discussion of auxiliary keys in this article are different from the auxiliary keys that a manufacturer might list as available on an instrument. A manufacturer's auxiliary keys are usually another mechanism for opening or closing a tone hole, and may be optional when ordering an instrument.

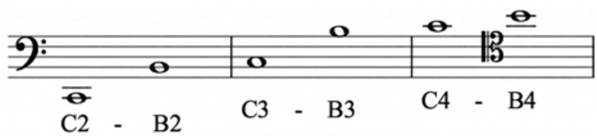
5 Arthur Benade, *Fundamentals of Musical Acoustics* (New York: Dover, 1990): 431.

6 Lewis H. Cooper, Howard Toplansky, *Essentials of Bassoon Technique* (Union, New Jersey: Howard Toplansky, 1976).

7 Conical bore instruments such as oboes and bassoons have certain patterns of vibration. They overblow the even-, as well as the odd-numbered harmonics. A higher mode note is one that is produced by dividing the sound wave of a fundamental octave note into shorter segments. On conical bore instruments, second mode means dividing the wave into two parts, producing a note one octave up. Third mode means dividing the wave into three parts, and the resulting note is an octave and a fifth higher. Fourth mode provides a note two octaves up. A fifth mode note is two octaves and a major third higher than the fundamental octave

note. This sequence continues to follow the pattern of the overtone series. For further reading, see the following webpage on the topic of conical bores: https://newt.phys.unsw.edu.au/jw/woodwind.html

8 In this article, notes of the scale are referred to by their Acoustical Society of America designations. All notes for the contrabassoon are described by their written pitch, although they sound an octave lower.



9 Also known as *dirty attacks.*

10 The major third of a chord needs to be played fourteen cents flat in order to sound pure, and a minor third needs to be played sixteen cents sharp in order to sound as pure as possible. This is commonly referred to as Just Intonation, which is a system of tuning in which the intervals are pure and have an intervallic relation to each other with ratios of small whole numbers. Major thirds have a whole number ratio of 5:4 and minor thirds have a ratio of 6:5. These tones all belong together as members of the same harmonic series. See: Chris Leuba, *A Study of Musical Intonation* (Prospect Publications, 1984).

11 This principle is the reason that the lowest vent (the one on the tuning slide) on the Fast System contrabassoon provides clean attacks on four rather than three notes.

12 Dieter Hänchen, "The Bassoon: An Acoustical Phenomenon," *The Double Reed* 37, no. 3 (Oct. 2014): 129-136. Translated by Walther Krüger and edited by James Kopp.

13 Arthur Benade, *Fundamentals of Musical Acoustics* (New York: Dover, 1990): 449.