Drawbars and Harmonics

2 : Overtones and Harmonics

Firstly, the answers to the Quiz in article 1 of "Drawbars and Harmonics".

Q1. C2
Q2. C3
Q3. C4
Q4. C5
Q5. C6 (Only just fitted!)

You will have noticed that the whole number drawbars are octave related, eg the 4′ drawbar provides a pitch one octave above that of the 8′ drawbar, etc.

Q6. G4 (Perfect Fifth above C4)
Q7. E5 (Major Third above C5)
Q8. G5 (Perfect Fifth above C5 and a Minor Third above E5)
Q9. G3 (Perfect Fifth above C3 and an Octave below G4)

How did you fare? There are no prizes, unfortunately. So what is the significance of all this information, then? To understand that we need to delve into the world of Overtones and Harmonics.

What is an Overtone? It's a frequency higher than that of the note being played and it's mathematically related to the frequency of that note by something called the Harmonic Series. *Hold on, what's a frequency?*

A frequency is the number of vibrations per second producing the sound. Any musical instrument playing the note A3, used to tune up an orchestra, will be producing 440 vibrations per second: the air in the flute is vibrating like this, the reed in the oboe, the string in the violin etc.

OK, so what's this Harmonic Series?

Well, we're going to have to do a little (very little, promise) Maths in order to proceed any further.

Let's take the note C3 (Middle C). Its Frequency is 256 Hz. (That's a scientific tuning fork value and it makes the Maths easier.) Frequency is often represented by the letter "f". Who'd have thought?! For **C3**, therefore;

$$f = 256 \text{ Hz}$$

Stop! What's that "Hz"?

Hz is the symbol for Hertz (pronounced "hurts" in English though in true German it should be "hairts"). Heinrich Rudolf Hertz (1857 - 1894) was a German physicist who became famous for his detailed study of waves and he is now honoured by having the unit of Wave Frequency named after him. He missed out on the car rental market, though. The unit "Hertz" used to be called "cycles per second" [c/s] which is a lot more descriptive of Frequency than Hertz. Never mind. Shall we continue?

No, what's waves got to do with it?

The vibration which causes the sound sends out that vibration as ripples through the air just like the ripples on a pond when a stone is thrown in. Those ripples produce waves on the surface of the water, so we say there are waves in the air. Will that do?

I suppose so.

OK, now let's multiply the 256 Hz by 2.

$$2f = 256 \times 2 = 512 \text{ Hz}$$

Now this is the octave above C3, ie **C4**. (Answer to Q3 !)

Let's keep this going: multiply f by 3.

$$3f = 256 \times 3 = 768 \text{ Hz}$$

Now this is a Perfect Fifth above C4, ie **G4**. (Answer to Q6 !)

Keep going:

$$4f = 256 \times 4 = 1024 \text{ Hz}$$

This is **C5** (answer to Q4 !), an octave above C4. It is also therefore twice C4's frequency, isn't it?

And again:

$$5f = 256 \times 5 = 1280 \text{ Hz}$$

This is a Major Third above C5, ie **E5**. (Answer to Q7 !)

And so it goes on. 6f is 1536 Hz, a Minor Third above E5, ie **G5** (twice 768 Hz and the answer to Q8 !).

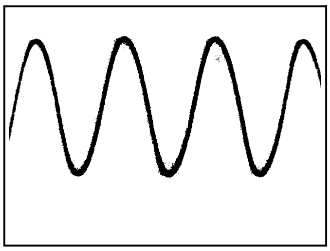
I think it's now clear that drawbars have a connection with the above calculations. But just what is the main significance of those calculations?

When you play the key C3 with just the 8′ drawbar, you hear the Fundamental Tone which is the First Harmonic in the Harmonic Series. When you set the sound to another instrument, according to the structure of the instrument, it may also sound the Second Harmonic which is the First Overtone, the Third Harmonic which is the Second Overtone, etc., all of these being captured in the Sample.

Not necessarily will all the harmonics sound but those that do will be at a lower volume than the First Harmonic and vary in volume between each other. Not necessarily would the Second Harmonic be the next loudest tone. Essentially, this is like the single note produced by an instrument sounding like a chord and each instrument differs in the number and volume of the harmonics it generates. This gives rise to the characteristic timbre of each particular instrument. A synthesiser, therefore, will try to reproduce these harmonics in the same way as a particular instrument in order to "impersonate" it.

A pure sine wave of a particular note contains only the first harmonic and each drawbar produces a pure sine wave. By using more than one drawbar at a time you are adding sine waves and therefore adding harmonics to the key you are pressing, making the sound richer. The word "Sinus" often appears in the German text to do with drawbars.

This is the shape of a pure sine wave - ripples on a pond, waves at sea??



Here is a Table of the Harmonic Series up to the 8th harmonic.

Table 1 : Harmonic Series

Harmonic	f	Musical Interval (ascending)	Note (assuming starting at Middle C)
First	f	Fundamental Tone	C3 (Middle C)
Second	2f	Octave	C4
Third	3f	Perfect Fifth	G4
Fourth	4f	Perfect Fourth	C5
Fifth	5f	Major Third	E5
Sixth	6f	Minor Third	G5
Seventh	7f	Minor Third	Bb5
Eighth	8f	Second	C6

The octave intervals above the Fundamental Tone (First Harmonic) are shown in italics in the Harmonic column. The above table is a very useful reference tool.

Let's square the circle and relate Table 1 to Drawbars, as in Table 2.

Table 2 : Drawbars related to the Harmonic Series (Names come from related pipe-organ stops)

Drawbar Footage	Harmonic	Drawbar Name
16'	Sub Octave	Bass or Bourdon
8'	1st Harmonic (Fundamental)	Neutral
5⅓'	Sub 3rd Harmonic	Quint
4'	2nd Harmonic	Octave
2⅔'	3rd Harmonic	Nazard
2'	4th Harmonic	Blockflöte
1 3/5'	5th Harmonic	Tierce
1⅓'	6th Harmonic	Larigot
1'	8th Harmonic	Sifflöte

Notice the seventh harmonic is not used - rather too discordant? Nor are harmonics higher than the eighth (though see below) because a 1′ drawbar is quite high pitched anyway (3 octaves up already from Middle C!) Top C on the Upper Keyboard at 1′ pitch has a Frequency of 16384 Hz (16.384 kHz). I can't hear it! Earlier Wersi organs and possibly some other makes as well have a tenth drawbar (see below).

Harmonics which are half the Frequency of the Fundamental or of a "normal" non-octave harmonic are called "Sub-harmonics" and there is a series of these as well, all mathematically related. The 16′ and 5⅓′ are the examples of these found in drawbars and form a section called **Sub**. Those shaded in yellow in Table 2 form the section called **Foundation** while those with no colour in the table form the section called **Brilliance**. Those which are not octave related are sometimes called Mutations, though this is essentially a pipe organ reference to the pipes of those pitches (eg the Quint stop).

The Quint drawbar provides an octave below the 2⅔′ drawbar sound. When Middle C is played using this drawbar, it produces a frequency of 384 Hz, the same as G3 (answer to Q9) which also is a Perfect Fifth above Middle C. The position of the Quint in the drawbar array differs between organ manufacturers. Some manufacturers (Hammond?) place it to the right of the 8′ drawbar.

Some organs (eg Wersi Spectra) have ten drawbars, with the tenth one being ⅔′. You will probably have noticed that an octave increase in pitch is achieved by a halving of the "pipe length". For example, one octave above an 8′ drawbar is provided by the 4′ drawbar, where 4′ is half of 8′. Therefore, as the ⅔′ drawbar is half the length of the 1⅓' drawbar it provides a sound one octave above the 1⅓' drawbar, which is G6. This note is not available as a key on the organ at 8' pitch. It is top G at 4' pitch.

This is as far as I'm going with this topic. My knowledge of using drawbars is very limited as the Verona is the first organ I've owned which has physical drawbars. I'm therefore not used to using them. They're on my "to do" list, as are so many items within the Verona, OAS-7 and the OAA.

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