Organ Tuner - ver 2.4

What is "Organ Tuner"?

Organ Tuner is a software application for the Apple iPhone, iPad, or iPod Touch that helps you to tune organ pipes, both for building and maintaining pipe organs. This app runs on Apple devices with iOS 5.0 or higher. It is available only through the Apple App Store. You can find a link to this app from our web site at **tunelab-world.com/organtuner**. This app is based on our highly-popular *TuneLab* line of piano tuning software products for Windows computers, iPhone, and Android devices.

Visual Tuning

The Organ Tuner software turns your Apple device into a precision Electronic Tuning Device especially targeted at traditional pipe organs. It provides the technician or organ builder with real-time visual guidance during tuning, along with such specialized features as temperature compensation, mutation rank multipliers, and celeste offsets. The sound of a note as it is played is picked up by the microphone in your device and analyzed. The results of the analysis are displayed in visual patterns. The Organ Tuner software displays two visual tuning patterns - the **Phase Display** and the **Spectrum Display**. Both of these displays evaluate pitch of the note, but each display has its own unique advantages. Both displays are visible simultaneously so that gives the tuner the best of both worlds.

Note Selection Terminology

In this manual we will be referring to notes on the pipe organ by note name and octave number. For example, C1 is the low C in a 16-foot rank of pipes. Each numbered octave runs from C up to the next higher B. Notes that are sharps or flats will always be designated as sharps. So, for example, we write A#0, not B*b*0. The note range of the **Organ Tuner** app is C0 to C9 (32-foot to 1/16-foot).

Notes, Partials, and Mutation Rank Multipliers

In addition to selecting the note (C0-C9) you also can select the partial and the mutation rank multiplier. The mutation rank multiplier is either 1, 3, 5, 7, 4/3, and 5/3. It multiplies the frequency by the chosen multiplier to select either a *unison*, a *fifth*, a *third*, or a *seventh*, a *fourth*, or a *sixth* mutation rank. Besides the *unison*, the most common mutation rank is the *fifth*, sometime called a *Quint* rank. When the *fifth* is selected, the calculated pitch is multiplied by 3. The result is a pitch that is a little more than an octave and a fifth above the unison pitch. So if the selected note is C3, the actual pitch is close to G4. But it is not exactly the same thing as selecting G4 because G4 is an octave and a tempered fifth above C3. But C3 with the *fifth* mutation rank multiplier selected is an octave and a just, or pure fifth above C3. That is why we don't just select G4 when tuning a *Quint* rank for C3.

Very similar to the mutation rank multiplier is the selection of the partial, which is also a pitch multiplier that ranges from 1 to 16. The purpose of the partial selection is to allow you to select a partial for a pipe if the fundamental is too low in pitch to register clearly through the microphone, or is not very strong. Most flue pipes

have a fundamental that is stronger than any of its partials, so you would want to use the fundamental most of the time. Since all the partials of organ pipes are true harmonics of the fundamental, the tuning turns out the same no matter which partial you select, as long as the partial you select is actually present in the sound of the note. So the only reason to select a different partial is if the fundamental is too low or too weak. Actually, you could get exactly the same pitch by selecting the 3rd partial as selecting the fifth (x 3) mutation rank multiplier. The difference is in how they affect automatic note switching (described later). So use the mutation rank multiplier only for pipes whose fundamental is a multiple of the selected note. Otherwise use the partial to select one of several harmonics of the selected note.

Phase Display

 The phase display is the horizontal band shown here. This display is used for fine tuning. The black squares move to the left if the note is flat and to the right if the note is sharp. The closer you get to the correct tuning, the slower the black squares will move. The goal is to make the black squares come as much to a stop as possible. When there is no note playing, or when the note being played is far from the correct pitch, the black squares will disappear or move randomly. For that situation you can use the Spectrum Display instead.

This display is called the Phase Display because it displays the phase of the sound from the microphone as compared to the phase of a virtual signal of the correct pitch. The movement of the squares can be compared to listening to beats between a tuning fork and a note on organ. For the low to midrange, when a square makes one complete trip around the display, that corresponds to one complete beat between the pipe and the correct tone. For higher notes the display is artificially slowed down in order to keep the speed of the black boxes in a reasonable range.

Multi-Pitch Display

There is an optional switch in the **Settings** to change the Phase Display into something like the picture shown
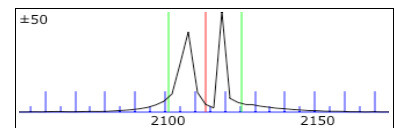
 here. Each of the 12 cells simultaneously displays the individual cents deviation of a different partial of the current note. A red bar going to the left means that partial is flat. A blue bar going to the right means that partial is sharp. The tuning error in cents in shown in the right half of each cell and the partial number is shown in the left half. For example, the picture shown here says that the fundamental is flat by 4.8 cents. And the 12th partial is sharp by 3.5 cents. While the red and blue bars extend from -20 to +20 cents deviation, the numerical cents value is accurate beyond this range. Using these displays one can tune in a multi-pitch situation (mixtures, mutations, extended choruses) by watching the partial for whichever pitch you are tuning without having to stop and switch partials manually.

Spectrum Display
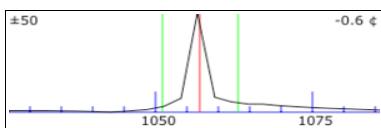
 The Spectrum Display is the graph shown here with the zoom set to ±50 cents around the desired pitch. This display can be configured for other zoom levels by using a two-fingered pinch-zoom gesture. This display shows how the sound energy is distributed across the frequency

spectrum. If the software is listening to a pure tone, then the spectrum graph will show a single peak, as shown on the left. This example was made from the note C6, and the display shows that it is 0.6 cents flat. The red line in the center of the display marks the correct pitch. The green lines nearest the center mark the points that are 10 cents above and below the correct pitch. The object in tuning with the spectrum display is to tune the note until the peak of the graph is centered on the red line. The picture on the right shows what you would get when playing a two pipes together, as in a mis-tuned mixture. Here the note C7 is being played with one pipe tuned nine cents higher than the other.

The Spectrum Display has several advantages over the Phase Display. One is that it shows where the pitch of the pipe is, even when that pitch is far from the correct pitch. The other advantage is that the Spectrum Display can show several peaks at once, as shown above in the picture on the right.
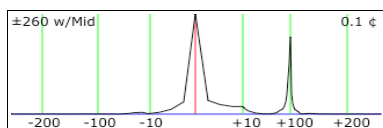
In addition to zoom levels of "**wide**", **±260 cents**, **±130 cents**, and **±50 cents,** the Spectrum Display can also be zoomed in to show and expanded view of ±10 cents around the target, while still showing ±130 cents or ±260 cents overall. When one of these "**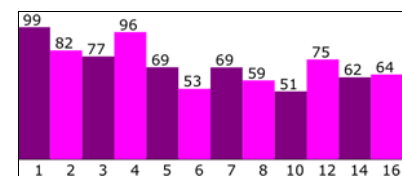dual-zoom**" modes is selected, the numbers at the bottom of the graph show offsets in cents rather than frequencies in Hz. The picture shown on the left is of one such setting of the Spectrum Display showing two simultaneous notes - one at A6 and the other at A#6. There is an option switch in **Settings** to use thicker traces for the Spectrum Display, as shown to the right. Thicker traces make the Spectrum Display easier to see. But thinner traces are slightly more precise. This graph shows the dual-zoom mode of **±130 cents /Mid.**
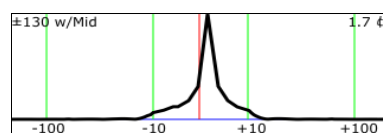

The main advantage of the Phase Display is that it generally provides more resolution than the Spectrum Display, except in the highest octave where the resolutions of the two displays are about the same. For this reason the Spectrum Display is used for rough tuning and the Phase Display is used for fine tuning But both displays are available all the time; so you can use whichever display seems to be giving the clearest indication.

Voicing Display

This display is listed as one of the zoom levels of the Spectrum Display. When selected, it appears as shown

here. The Voicing display is a bar graph showing the strength of 16 harmonics of the fundamental tone. The sound that generated the display on the left was rich in harmonics, while the sound that made the right display was a

pure flue tone with comparatively weak harmonics. By matching the strength of the harmonics you can match the voicing of one pipe to another. Normally the bar heights are auto-scaled to make the strongest harmonic register a "99". But if you want to lock the scaling at the current level to make absolute volume comparisons, tap the *LOCK* command button. The Voicing Display will appear as shown below. The bars change color to gray and brown, and any off-scale harmonics are shown in red. If you get off-

scale bars in the graph you can lock the scaling when a louder sound is present.
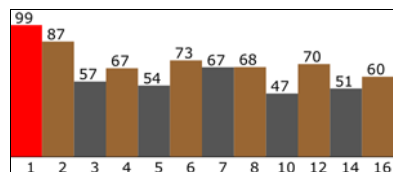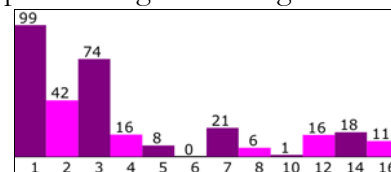
Command Buttons (main tuning page)

This button turns on **locking mode**. In this mode, the software listens to the sound from the microphone and tries to adjust the offset to match it. (You can learn more about the offset in the chapter "**All About Offsets**", later in this manual.) You can see the offset changing and you can see the Phase Display and the Spectrum Display indicating an in-tune condition. This is used for matching an offset to an existing tuning to measure an existing tuning or to establish a non-standard offset for a tuning. Be sure to turn off locking mode promptly when the sound stops, because otherwise the software will continue to try to lock to noise, resulting in a random offset. The offset produced by locking mode can be reset to zero by double-tapping on the Phase Display. When the Spectrum Display is showing the Voicing Display, the Lock button does not engage this offset pitch locking. Instead it toggles the Voicing Display auto-scaling off and on.
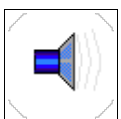
This button switches to sound-generating mode. In this mode the software generates a tone in the speaker or headphones, rather than listening to the microphone. This is not generally used for tuning, but it can be useful for comparing tones by ear.

This is the **Settings** button, and it shows a list of various settings and configuration actions, such as loading historical temperaments, doing a calibration, configuring the spectrum display, and controlling auto note switching and temperature compensation.
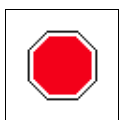
This image appears in place of a command button when a mode has been entered that needs to be able to end. This button will stop locking mode, sound-generation mode, and calibration.

Current Settings Display

At the top of the main tuning page is a display of various current settings. Some of these fields are usually blank; but here is an example all the fields shown:

Vallotti-Young well	Offset -2.67¢
	Temper 5.86¢
Quint (x 3)	TC Offset 0.00¢
Fundamental	Temperature 68.0°F
1572.65 Hz	Manual note

Here is a description of each of these fields, reading down the left column and then the right column:

Temperament Name (*Vallotti-Young well*) - the name of the un-equal temperament (if one is selected)
Mutation Rank Multiplier (*Fifth*) - if a mutation rank is selected, this indicates the multiplier.
**Tuning Partial** (*Fundamental*) - which partial (or fundamental) is used for tuning the current note
Frequency (*1572.65 Hz*) - the calculated frequency, taking into account all offsets and settings.
Offset (*-2.67*) - the main offset, if one is used. Otherwise this field is blank.
**Temperament Offset** (*5.86*) - the offset from the optional un-equal temperament in effect

TC Offset (*0.00*) - the offset due to temperature compensation
Temperature (*68.0*) - the current temperature. You set this to achieve temperature compensation.
**Note Switching** (*Manual note*) - tells which form of note switching is in effect

## Selecting Notes and Partials
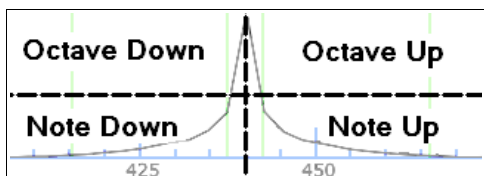
You can change the selected note one note at a time or one octave at a time by tapping on one of the four quadrants of the Spectrum Display, as
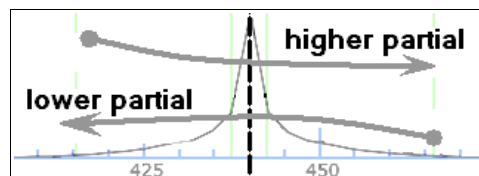
shown here on the left.   The two upper quadrants change the octave and the two lower quadrants change the note. You can also change the selected partial by swiping from one side or the other, as shown in the picture on the right.
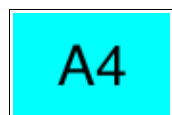
To directly select any note, first tap on the current note display as shown here on the left. That will bring up a note selection page as shown on the right. On this page you first select the octave by tapping on one of the buttons labeled "0" to "9", and then tapping on the desired note on the keyboard. Tap "Tuning" to return to the main tuning page, with the selections as they are shown. When you tap on a note, that will take you back to the tuning page immediately.
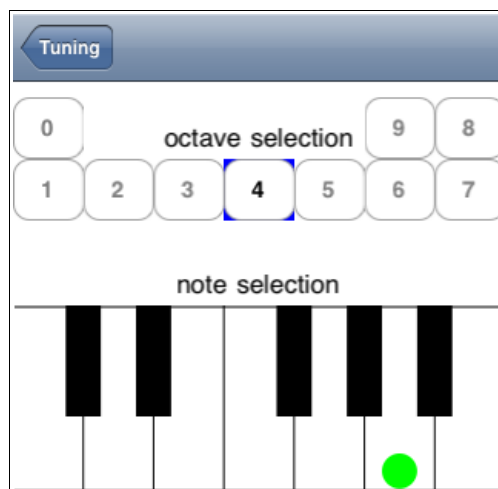
Notes may also be changed automatically if you have turned on that feature from the "Settings" page. When automatic note switching is enabled, the software listens for notes up to four notes away and switches to them when it hears them.

Calibration

The software should be calibrated before you trust its absolute pitch. Without calibration, the software assumes a nominal crystal oscillator frequency in your device's sound system and makes all pitch calculations from that assumption. By doing a calibration you are refining that nominal value based on a comparison to a trusted pitch source. You can do a rough calibration using a tuning fork, but a better calibration can be achieved by using a more precise source, such as the NIST standard frequency services described later. The result of a calibration is a knowledge of the actual sample rate of the sound system, which the software then uses to compensate for the slight deviation from the nominal sampling rate. Normally, calibration is done only once when the software is first installed on your device, but you can re-do the calibration at any time if you wish. See the chapter on calibration later in this manual for details on doing a calibration.

Automatic Note Switching

As described above, you can manually select each note. But that takes time and effort that can be avoided. By using automatic note switching, the software will switch to the next note when it hears you play it. You can configure automatic note switching to switch up, down, or in both directions. If you are tuning from low notes to high notes, then it may be an advantage to use "**Auto up**" note switching so that the note selection will not follow you down the scale as you play notes you have already tuned for test purposes. Automatic note switching may be configured from the **Settings** page. The auto note switching range is +/- 4 notes from the current note. The means it can follow you up to a major third away from the current note.

Un-Equal (Historical) Temperaments

By default, **Organ Tuner** assumes an equal-tempered scale. If you would like to tune in some unequal temperament, you can select an historical temperament to apply to your tuning. An historical temperament is defined by a list of 12 offsets for each of the 12 notes of an octave. When an historical temperament is selected, one of these 12 offsets is used, depending on which note is selected. For any given note, the same offset is used in every octave. The temperament name and the temperament offset for the selected note appear in the Current Settings box shown previously. See the chapter on historical temperaments for information on using temperaments.

Sound Generation

Although the most common use for **Organ Tuner** is in listening to notes and providing a visual tuning aid, you can also use the software as a tone generator. When the software is in sound generation mode, the pitch of the sound generated in the speaker or headphones is the same as the pitch that would have indicated correct tuning in the listening mode. The pitch is generated for whichever partial is selected - not necessarily the fundamental. Sound generation is not generally used in normal tuning, because the visual indication is more accurate than matching tones by ear.

The generated sound is nominally a single-tone sine wave with little or no harmonic content. If you would like the tone to contain harmonics, turn on the switch in **Settings** that is labeled **Generate all harmonics**.

Tuning Closeness Indicator

Just above the current note display there is a progress indicator that indicates how close your tuning is to the target pitch. Here are some examples:
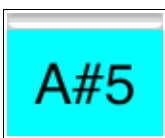
more than one cent off	slightly less than one cent off	half a cent off	nearly perfect
A#5	A#5	A#5	A#5
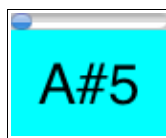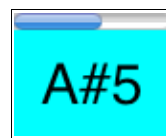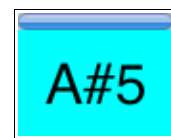
As these examples show, the progress indicator starts filling in when the tuning is within one cent of the target pitch; it fills completely when the tuning error goes to zero.

Microphone Level Indicator

To help verify that your microphone is working properly, and to help you control how loud sounds appear to the software, there is a microphone level bar graph indicator at the right edge of the spectrum display as shown here. When the vertical bar reaches the top of the spectrum display, that corresponds to a microphone level of 100%. If this indicator does not behave as expected, then you may have a problem with your microphone. The level indicator is logarithmic, not linear. That means the indication is proportional to the decibel level and is therefore more sensitive to very low sounds.
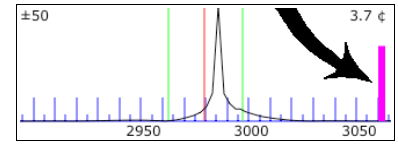
Normal Tuning Procedures

This chapter takes you step-by-step through an typical organ tuning. It also describes how **Organ Tuner** can be used by the organ builder when manufacturing and voicing pipes.

Initial Setup

Choice of Temperament - Before you begin tuning, you should decide whether or not an historical temperament is called for. The choice of historical temperaments is beyond the scope of this manual, but there are many references available. If you do not have any reason to use a specific temperament, you should probably just use equal temperament for an organ that is for general use. Historical temperaments are most often used with certain periods of music.

Temperature Compensation - Another decision to make is whether to use temperature compensation. This is the feature that includes an offset (labeled "**TC Offset**" on the tuning page) to compensate for the current temperature of the air in the pipes. This offset is automatically recalculated every time you change the **Temperature** setting, or every time an automatic temperature update is received from a remote Bluetooth temperature sensor. (See Chapter 6 for information on these sensors.) Let's suppose you want to establish 20 degrees Celsius (68 Fahrenheit) as the temperature at which the organ will be at standard pitch. Using the functions in Settings, first adjust the **Temperature** to 20 C (or 68 F). Then adjust the **TC Offset** to zero (or some other offset, if you want the organ to be at a different pitch at that temperature). Finally, adjust the **Temperature** again, this time setting it to the actual current conditions. Remember to measure the temperature of the air that goes through the pipes, not the air where you are - they may not be the same. Notice that when you make the final temperature adjustment, the **TC Offset** is automatically recalculated accordingly. The recalculation is based on the assumption that the pitch is proportional to the square root of the temperature in degrees Kelvin. In addition to this initial check of the temperature, you should check the temperature periodically while tuning so that you can adjust the **Temperature** setting accordingly.

Another way to establish a temperature compensation standard is to use the existing tuning as the standard. First set the temperature indication equal to the current temperature (or wait for the automatic wireless temperature update to occur). Then, using the locking mode or manual offset adjustments, adjust the offset to match one or more pipes in the existing tuning. Finally, use the "**Transfer offset to TC offset**" function in Settings to transfer the offset you determined from the existing tuning into the TC Offset. This is useful if you don't want to establish an arbitrary standard, and would rather use the existing tuning as the standard so you don't have to change the overall pitch of the instrument. There is more information about wireless temperature sensing later.

Beginning to Tune - the Tuning Sequence

You can tune in any order that you want. The most common sequence when tuning with an electronic aid is to start with at the lowest note of the rank and go up from there. Because of the layout of pipes, it is often the case that a row of pipes that is most easily accessible in sequence is actually every 2nd or 4th note in the chromatic scale. This sequence is easy to follow by using auto note switching, because auto note switching is capable of switching in jumps of up to four notes. Tap on the current note to start the sequence by selecting the starting note and octave.

For very low notes, the fundamental frequency may not be detected by the microphone in your device. In that case you should switch to a higher partial. Select different partials until you find one that produces a clear peak in the Spectrum Display.

The Phase Display will work even with partials that are almost too small to see in the spectrum display. Especially in the bass, feel free to select a different partial on the fly if you are having trouble getting a reasonable indication on the current partial. You can change to a different partial by swiping horizontally through the spectrum display. Swipe from the left side to the right side to go to the next higher partial. Swipe from the right side to the left side to go to the next lower partial.

We recommend that for your very first tuning with Organ Tuner you leave auto note switching disabled, and switch notes manually. That way you will not be confused by unintentional note switches. Later on, you can enable auto note switching to speed up your tuning. For now you can manually switch notes by tapping a quadrant in the spectrum display, as described in Chapter 1.

Using Auto Note Switching

You can use auto note switching to make tuning easier. To enable this feature, use the **Auto note switching** item in **Settings**. When auto note switching is enabled, the software will be constantly listening for nearby notes; and when it hears one, it will switch to it. Auto note switching can be enabled for switching up, down, or in both direction. The range of auto note switching is plus or minus 400 cents from the current note. If you use aural checks while tuning, be aware that auto note switching may occur while you are doing these checks. If an unintended auto note switch occurs, simply switch back to the correct note manually.

Coarse Tuning with the Spectrum Display

If the pitch of a pipe is too far from the target pitch, then you should use the Spectrum Display to get close to the correct pitch. You should see a peak in the graph. If that peak is to left of the red line, then the note is flat. If the peak is to the right of the red line, then the note is sharp. Make the adjustments to the pipe so as to move the peak to the red line in the center, which represents the target pitch.

Fine Tuning with the Phase Display

If the pitch of the note is already close to the target pitch, then you should see a pattern of two black boxes in the Phase Display. If the note is sharp, the boxes with be moving to the right. If the note is flat, the boxes will be moving to the left. The slower the boxes move, the closer you are to the correct pitch. It does not matter where the black boxes are within the Phase Display. All that matters is how slowly they are moving. You can judge if you are close enough by seeing how slowly the boxes are moving. Or you can use the closeness indicator above the current note display, as described in Chapter 1.

Tuning with the Multi-Pitch Display

When the Multi-pitch Display switch is turned on in Settings, the Phase Display changes to look something like the picture shown here, as described in Chapter 1. This display option is useful when tuning a

1:	-4.8	2:	-0.2	3:	-1.0	4:	-2.7
5:	-2.5	6:	-2.5	7:	-3.1	8:	-4.9
10:	1.1	12:	3.5	14:	10.8	16:	23.2

group of harmonically-related pipes, sometimes speaking together. Even if they are speaking together, Organ Tuner will usually be able to detect the pitches of individual partials in the composite sound. Each cell shows the cents deviation for its associated partial. In addition to the numerical value, a graphical indication of this same information is shown in the read and blue bars. Red means the partial is flat. Blue means it is sharp. The red and blue bars are scaled so that they are much more sensitive for deviations close to zero. By having all these partials evaluated at once, you can tune the entire set of pipes for a given note without touching the screen.

Organ Builders' Procedures

If you are an organ builder, you may want to use the **Organ Tuner** app to help you cut pipes to length. Since it is a lot easier to cut a pipe shorter than to lengthen a pipe that has been cut too short, you normally start with a pipe length that you are sure is just a little too long for the desired pitch. Then you can use **Organ Tuner** to measure the pitch error of that original cutting. Here it is desirable to know not only that the note is flat, but by how much. If this information is accurate enough, you can minimize the number of trial cuts to get the desired pitch. If the pitch is within 200 cents of the target, a fairly accurate display of the tuning error will appear in the upper right corner of the Spectrum Display.

Once you know the actual pitch error of your trial cut, you can estimate how much to cut to bring the pitch in closer to the target. Since the pitch is approximately inversely proportional to the pipe length, a close estimate of the amount to cut can be calculated using the following conversion between cents tuning error and percentage pitch error:

```
1 cent = .058%        20 cents = 1.16%      80 cents = 4.73%
2 cents = .116%       30 cents = 1.75%      100 cents = 5.95%
3 cents = .173%       40 cents = 2.34%      125 cents = 7.49%
4 cents = .231%       50 cents = 2.92%      150 cents = 9.05%
5 cents = .289%       60 cents = 3.53%      175 cents = 10.6%
10 cents = .579%      70 cents = 4.13%      200 cents = 12.2%
```

So for example, if a pipe is 1000 mm. long and is flat by 60 cents, then cutting off 35 mm. (3.53% of 1000 mm.) would reduce the pitch error to near zero. But you may not want to cut off the entire 35 mm. because that might leave the pipe too short. Your experience will tell you how close to the calculated cut-off amount you would like to go. The calculations shown here are only a rough approximation. Better methods exist which take into account the diameter of the pipe and the "end effect". These methods are beyond the scope of this manual, but it is worth pointing out that they exist.

Another organ building application is in voicing. Even before a pipe begins to speak, the Spectrum Display will show a very broad peak of filtered noise produced by a pipe that is "almost speaking". This could allow you to make a length refinement even before the pipe is fully speaking. Another aid to voicing is the display of the strength of the currently-displayed partial. This is displayed in the box to the left of the current note, and the display is in terms of decibels, so it is a logarithmic scale. The actual value displayed is arbitrary, since it depends

on many factors, including the sensitivity of your particular microphone, and the placement of that microphone. But if those factors are held constant, meaningful comparisons can be made between pipes. The most accurate measure of voicing is done with the Spectrum Display set to the Voicing Display mode, as described in the first chapter.

All About Offsets

Organ Tuner uses three kinds of cents offsets and one offset specified in beats (Celeste Tuning). The cents offsets are specified in terms of cents, where 100 cents equals the change from C to C#. The offsets in effect are all displayed on the right side of the Current Settings box, as shown to the right. The software combines these offsets to calculate the desired pitch for each note. In normal equal

Offset	-2.67¢
Temper	5.86¢
TC Offset	0.00¢
Temperature	68.0°F

temperament tuning, the first two offsets are zero. If you are using temperature compensation, then the TC Offset may be non-zero. To calculate the desired pitch, the software adds together the three offsets. If the celeste tuning option then yet another offset will affect the pitch. The Celeste Tuning option is described later in this chapter.

Main Offset

This offset shown in the upper right corner on the main tuning page. When this offset is left at zero, A4 will be 440 Hz. If you want to tune to a non-standard reference (like A-442 or A-435), then you can adjust the offset until you get the pitch that you want. You can change the offset by swiping your finger across the Phase Display, as shown here. Swiping to the right increases the offset. Swiping to the left decreases it. The first time you adjust the offset you will get a message asking you to confirm that you want to adjust the offset. This is to prevent an accidental offset adjustment if you happen to brush the Phase Display. Touch the Phase Display with two fingers to quickly reset the offset back to zero. The offset can also be modified by **locking mode**, as described later.
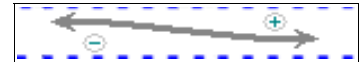
Temperament Offset

The next offset is labeled "Temper". It is the offset defined by the historical temperament you have selected. If you have not selected any historical temperament, then this "Temper" field will be blank. The temperament offset changes as you change notes. The temperament offset depends on the note name, and not on the octave. Therefore it only takes 12 offsets to completely define an historical temperament. The same 12 offsets are repeated in each octave.

TC Offset

The "TC" stands for "Temperature Compensation". This offset is much like the main offset described above, except that it will automatically change whenever you make a change to the temperature setting, which appears just below the TC Offset display. Both Temperature and TC Offset can be adjusted in much the same way as the main offset is adjusted, as described above. But first you have to enable the adjustment through the **Settings**. In the Settings there is a section dealing with temperature compensation. There you can request a change to TC Offset or Temperature. When you make this request, you will be switched back to the main tuning page, which will now have a message telling you to adjust either TC Offset or Temperature. When that message is showing, swiping through the Phase Display will change the TC Offset

or the Temperature, instead of changing the main offset. You can cancel this mode by tapping on the message that is telling you to make this adjustment. Then the message will disappear.

If you change TC Offset, then only TC Offset will change. If you change Temperature, then Temperature and TC Offset will both change. The revised TC Offset will be automatically recalculated based on the changes you make to the Temperature. If you have some way of monitoring the temperature while you are tuning, then periodically adjust the Temperature value to track those changes. The use of a Bluetooth temperature sensor (see Chapter 6) makes this job automatic. The subsequent adjustment to the TC Offset will be made assuming that pitch is proportional to the square root of the temperature in degrees Kelvin, which is a close approximation to the change in the speed of sound as a function of temperature.

The TC Offset can also be used as a general-purpose offset, much like the main offset, if you are not using it for temperature compensation.

Locking Mode

Locking mode is entered by tapping on the lock button, shown in the picture here. Then **Organ Tuner** will show a status box on the left side of the page saying "**Locking**". When you are in locking mode, the software listens to the sound in the microphone and tries to lock to it by automatically adjusting the offset. This function may be used to determine a non-standard reference to match an existing tuning. Make sure to turn off locking mode promptly when the sound is no longer available, or else the software will continue trying to lock to random noise. The locking mode can only lock on to a pitch that is already somewhere near the target pitch. If the locking mode does not appear to be capturing the pitch you want, then use manual offset adjustment to get within range and then let locking mode do the rest.

Celeste Option

A celeste rank of pipes is a rank that is tuned so that it produces a given beat rate when played along with other ranks. Usually the celeste rank is tuned sharp of normal, but sometimes it is tuned flat. When it is tuned flat then it is called "unda maris".

Since Celeste Tuning is based on beats, the celeste offset is specified in terms of beats. Historically there have been two general approaches to setting these beat rates. One is to use a constant beat rate (say, 3 beats per second) throughout the scale. The other approach is to use a gradually rising beat rate so that higher notes beat faster than lower notes. Both of these approaches are covered by the **Celeste Tuning** settings in the **Organ Tuner** app. These settings ask you to set the desired beat rate for two notes: C3 (4-foot) and C6 (1/2-foot). Based on your settings of these two beat rates the software calculates the beat rates for all the notes of the scale. If you want a constant beat rate then just set both the C3 rate and the C6 rate to the same value and that is the beat rate that will be used throughout. If you set a negative beat rate then the tuning will be "unda maris" and will be flat by that amount. The software will not allow you to set one beat rate positive and the other negative. The software will extrapolate the beat rate linearly (not exponentially) across the entire scale.

The set up **Organ Tuner** for a celeste rank go to **Celeste Tunings** in **Settings** and then make sure the switch for enabling Celeste Tuning is turned on. The screen should look like this the picture on the left.
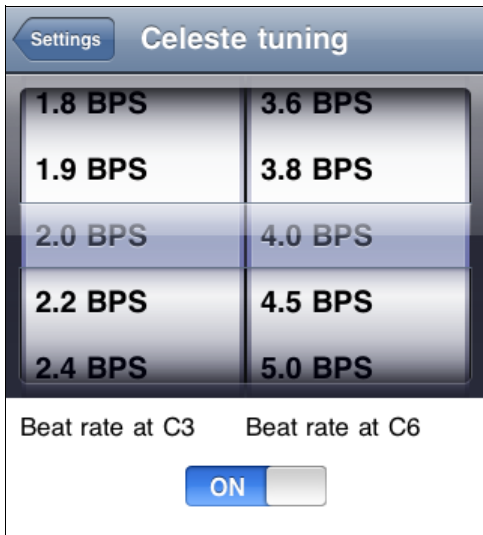
Spin the two spinners until the selected beat rates for C3 and C6 are what you want. The spinners include both positive and negative beat rates for either sharp of flat ranks. Then return to the main tuning page. When Celeste Tuning is in effect then the area around the current note display will look like this:

The yellow background is to remind you that Celeste Tuning is in effect, and the beat rate shown is the calculated beat rate for the current note. If you wish to turn off Celeste Tuning then you can go back to the **Celeste Tuning** page in **Settings** are turn of the switch, or you can simply tap on the yellow box shown above.

Historical Temperaments

Organ Tuner normally produces an equal temperament. But historically this was not always the norm. Even today there is a strong interest in non-equal temperaments. With a non-equal temperament, different key signatures have different musical characteristics. It is said that the classical composers were aware of these differences and wrote their music to take advantage of these differences. A full treatment of historical temperaments and their musical characteristics and advantages and disadvantages is beyond the scope of this manual. But if you are interested, there is a lot of literature on this subject.

For our purposes, a historical temperament is defined by a set of 12 offsets from equal temperament. These 12 offsets are repeated in every octave. **Organ Tuner** comes packaged with a set of historical temperaments that can be applied to your tuning. If you know of a historical temperament that is not included with this package, it is easy to add that temperament to your device by entering the 12 offsets, as described below.

Loading Temperament Files

To add a historical temperament to the current tuning, go to **Settings** and select **Load temperament**. This will show you the list of historical temperaments that are currently on your device. If you see one that you want to use, just tap on it. If you have an historical temperament applied and would like to remove it from the current tuning, tap on the first entry in the list of historical temperaments, which says -**Cancel temperament**-.

When an historical temperament has been added to the current tuning, then you will see the name of that temperament in the upper left of the Current Settings box on the main tuning page. Also you will see an offset for each note showing as **Temper xx.xx**. As you change notes, the "temper" offset changes.

Making Temperament Files

If you want to use a temperament that was not provided with this package, you can create your own new temperaments using **Make temperament** from **Settings**. All you need to know is the 12 offsets that define the temperament. After you enter the 12 offsets, you will be prompted to enter a name for the new or modified temperament. When you make a new temperament file, you can then select it at any later time, just like the original historical temperaments that came packaged with the software. If you want to delete a temperament from your device, just go to Load Temperament and swipe through the name of the temperament you want to delete and then tap on "**Delete**".

Calibration Procedure

This chapter takes you through the process of doing a pitch calibration. *For information on calibrating a Bluetooth temperature sensor, see Chapter 6.* Normally you need to do a calibration only once when you first install **Organ Tuner** on your device. You can check the need for a calibration by comparing **Organ Tuner** to some trusted source of pitch. If it checks out as close enough for you, then you can skip doing a calibration.

A Trusted Source of Pitch

To do a calibration you need to have a trusted source of pitch. The most accurate source of pitch that you can get is from the National Institute of Standards and Technology (NIST). This service is available by telephone and by shortwave radio on 2.5, 5, 10, 15, and 20 MHz. Another source of accurate pitch is another calibrated tuning device that can produce a tone. If no such source is available, then try using the A4 note from a high-end digital piano. **If you visit a website that claims to produce an accurate tone in your computer or if you download a file that plays a specific tone then these sources are not recommended for calibration. All of these digital forms of tones are potentially inaccurate because the actual playback pitch of digital tones is dependent on the crystal oscillator frequency in the sound system of the computer that is playing them back and is not inherent in the download.**

NIST Broadcast (and Telephone) Schedule

The NIST standard frequency service is available by telephone by calling (303) 499-7111 in Colorado. This is a very popular number. What you hear when you call this number is exactly the same as what is being transmitted by the NIST shortwave radio stations as mentioned above. NIST reports that they get over two million calls per year. In order to use these services effectively, you need to know something about the schedule for this service. The following schedule repeats each hour. It shows what tones are present during each minute of the hour. When a tone is present, it is present for the first 45 seconds of the minute and it is silent for the last 15 seconds.

|					
0: - - -	10: - - -	20: 500	30: - - -	40: 500	50: - - -
1: 600	11: 600	21: 600	31: 600	41: 600	51: - - -
2: 440	12: 500	22: 500	32: 500	42: 500	52: 500
3: - - -	13: 600	23: 600	33: 600	43: - - -	53: 600
4: - - -	14: - - -	24: 500	34: 500	44: - - -	54: 500
5: 600	15: - - -	25: 600	35: 600	45: - - -	55: 600
6: 500	16: - - -	26: 500	36: 500	46: - - -	56: 500
7: 600	17: 600	27: 600	37: 600	47: - - -	57: 600
8: - - -	18: - - -	28: 500	38: 500	48: - - -	58: 500
9: - - -	19: 600	29: - - -	39: 600	49: - - -	59: - - -

Although the 440 Hz tone in minute #2 is tempting, do not try to use it. That pitch is only present for 45 seconds each hour. The difficulty in calling at just the right time and the shortness of the tone make this choice

inadvisable. Instead you can use the 500 Hz and 600 Hz tones. The telephone service will disconnect you after three minutes, so make sure that when you call you have everything set up and time your call so that you will be assured of at least three minutes of 500 Hz or 600 Hz tones. If you happen to be closer to Hawaii than to Colorado, you can receive WWVH by shortwave radio or by calling (808) 335-4363 in Hawaii. For more information on both of these sources, see the website:

www.boulder.nist.gov/timefreq/stations/iform.html

Using NIST Tones for Calibration

To use the NIST standard frequency service to do a calibration, start by selecting **Do a calibration** from the **Settings** menu. Then select **500 or 600 Hz NIST tones** as the reference source. Do not try to make the call to the NIST with your iPhone. You need to use a different phone because **Organ Tuner** cannot be running at the same time as you are making a phone call. Position the iPhone so that its microphone is right over the speaker of the phone that is calling NIST. Follow the on-screen instructions and make sure the microphone of your iPhone is close to the telephone speaker. **Organ Tuner** will automatically determine which tone is currently sounding (500 or 600) and lock to it. When Organ Tuner has heard enough it will display a message saying that calibration is done.
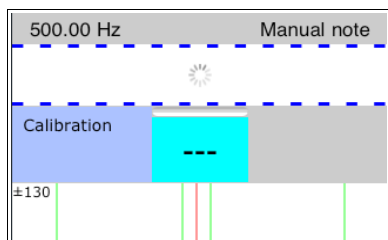
Here is what the middle of the main tuning page looks like during a calibration. It is similar to locking mode in that the offset is being adjusted automatically to lock on to the sound it hears. But unlike locking mode, there is no note displayed in the current note display, and there is an activity indicator (a spinning wheel) in the middle of the phase display. You can cancel a calibration at any time before it finishes by tapping on the stop button (red stop sign). Calibration takes about 10 to 15 seconds if the sound is clear.

Using Other References for Calibration

Besides the 500 and 600 Hz NIST tones, Organ Tuner offers other choices. If you have a precise 440 or 1760 Hz tone source, you can use that. 1760 Hz was chosen because it is the fourth harmonic of 440 Hz. Finally, there is a completely general choice where you can enter whatever frequency you like. But whatever frequency you enter, it must be the true frequency of the source that you intend to use for calibration.
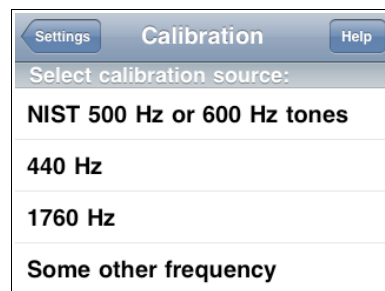
Temperature Sensors

Organ Tuner is capable of receiving temperature updates from a nearby Bluetooth temperature sensor. So far the Organ Tuner app has been verified to work with the following brands of temperature sensors:

> "**Tempo**" devices from **Blue Maestro** (**www.bluemaestro.com)**

> "**SensorBug**" from **BLEhome.com**

> "**myBlue**" temperature sensor from **WeatherHawk**

If we find other devices that work with Organ Tuners they will be listed on our website at

> **tunelab-world.com/organtuner**

These temperature sensors use Bluetooth Low Energy, also known as Bluetooth 4.0. Not all Apple devices support Bluetooth Low Energy. Support for Bluethooth 4.0 starts with the iPhone 4S, the iPod Touch 5th generation, the iPad 3rd generation, and the iPad Mini. You must be running iOS 6 or later to get Bluetooth 4.0 functionality.

Unlike older Bluetooth versions, these sensors do not require pairing with the Bluetooth device. If a supported device is powered on and within range, Organ Tuner can pick up the signal.

To use one of these sensors, just enable **Auto temperature** in Settings, and turn on the sensor according to the manufacturer's directions. The sensor detects the temperature of the air in its immediate vicinity. To get meaningful temperature data, it is important that the sensor be placed in air that is representative of the air that is in the pipes, because that is the air whose temperature is relevant to temperature-induced pitch changes.

Calibration of Temperature Sensors

Bluetooth temperature sensors have a nominal factory calibration that may be accurate enough to be used as-is, especially if the temperature sensor is only being used to register relative temperature changes. But if depend on absolute temperature standards, and you would like to calibrate your temperature sensor to a more accurate reference thermometer, the temperature calibration function in the Organ Tuner app can store a temperature offset that can be applied to all Bluetooth temperature readings.

To perform this kind of calibration the following steps must be followed exactly:

1. Turn on automatic temperature in the app.

2. Verify that temperature is being received by observing the temperature display on the main tuning screen.

3. Place the temperature sensor in the same environment as your separate reference thermometer that you want to use as a standard. Leave them there long enough for both the Bluetooth sensor and the reference thermometer to stabilize at the same temperature. This should last at least five minutes, and you should be monitoring the Bluetooth temperature in Organ Tuner during this time.

4. After a stable temperature has been reached, turn off automatic temperature in Organ Tuner to return to manual temperature mode.

5. In manual temperature mode, adjust the temperature indication manually until it reads exactly the same temperature as your reference thermometer.

6. Go to **Settings / Do a Calibration.** If you have followed steps 1-5 correctly, you will be presented with four choices for pitch calibration and two additional choices for temperature calibration in a separate section labeled **Remote Temperature**.

7. Tap on **Calibrate Temperature** in the Remote Temperature section.

8. Follow the prompt to confirm the calibrated temperature entry.

After these steps have been performed, you can turn on automatic temperature again. You should then be able to confirm that the calibration was successful by observing that the temperature reported for the Bluetooth sensor is the same as the temperature indicated on your reference thermometer.

Pipe Cutoff Calculation

Pipe cutoff mode is enabled by a switch in the Organ Tuner settings. The purpose of this mode is to provide a useful estimate to the organ builder in the first tuning of previously untuned pipes. The first cutting of the length of such pipes is always made somewhat too long so that it can be trimmed down to the correct length after testing its pitch. When pipe cutoff mode is enabled, the box on the left side of the current note display shows a calculation of how much must be cut off to bring the pipe into the correct pitch. The amount is calculated from parameters that can be set on the pipe cutoff settings page, which can be accessed by tapping on that display.

The first parameter on the pipe cutoff settings page is the number of steps in the chromatic scale in which the pipe length should be cut in half. For very thin pipes, the number of steps would be exactly 12, which represents one octave. But for any practical pipe, we know that in general the octave of a given pipe is shorter than half the lower pipe. This is due to pipe diameters (for consistent tone quality) halving on some other interval than the octave. Note that the halving interval for diameters and the halving interval for length are two different, but related parameters. The halving interval for diameters can vary from 16 step Principal halving (commonly call the Norm Measure) to 19-22 step Flute halving to 24-48 step reed halving. While this is commonly known and observed, and will not be discussed further here, this implies a variable length halving, which is less commonly known.

Specifically, narrow pipes are generally closer to a theoretical 12th step length having, and wider pipes diverge more significantly from the theoretical length halving. Experience has shown that Principal ranks (diameter halving around the 16th step) typically have a length halving around the 11.5th step. A Flute ranks (diameter halving around the 19th step) typically have a length halving around the 10.5th step. The length halving steps can be anything from 9.5 to 12.5. It need not be a whole number.

The above two examples are close enough for most practical work. A slightly more accurate way to estimate the length halving steps parameter in a specific rank is to measure two roughly tuned pipes separated by at least an octave. Measure them for both pitch error in cents and for length. Then count each chromatic step as 100 cents, adding in the cents error to get the total cents difference between the two pipes. For example, if a nominal C4 pipe is 23 cents flat and a nominal C5 pipe is 17 cents flat, the total cents difference between these two pipes would be

$$C = 12 \times 100 - 17 + 23 = 1206 \quad \text{cents.}$$

If we call this cents difference C, and the lengths of the two pipes L_1 (for C4) and L_2 (for C5), the length halving steps parameter, H, could be estimated as:

$$H = \frac{C \times \log_{10}(2)}{100 \times \log_{10}\left(\frac{L_1}{L_2}\right)}$$

For example, if L_1 = 1360 mm. And L_2 = 658 mm., we would estimate the length halving steps as:

$$H = \frac{1206 \times \log_{10}(2)}{100 \times \log_{10}\left(\frac{1360}{658}\right)} = \frac{363.04}{31.53} = 11.51$$

The "Current pipe length" entry on the settings page is the current length of the pipe that is sounding, expressed in whatever units you choose (mm., inches, etc.) The calculated cutoff amount will be in those same units, and it will be proportional to the current length.

The "Apply cutoff" button on the settings page will take the current suggested cutoff amount and subtract it from the current pipe length. Use this button if you are going to cut off the suggested amount so that that current length will show what the length should be after that portion has been removed.

On the main tuning page, tap on the pipe cutoff display to bring up a menu where you can...

1. Turn off Pipe Cutoff mode.

2. Freeze/Unfreeze the cutoff calculation. (The display will change color.)

3. Go to the Pipe Cutoff settings page.