SANDERSON ACCU-TUNER®III

OPERATING MANUAL



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SANDERSON ACCU-TUNER® III
INSTRUCTION MANUAL

INTRODUCTION

The Sanderson Accu-Tuner III (Accu-Tuner III) is the latest in a line of tuning instruments that continue to be the world's finest programmable computer-controlled tuning instruments. Accu-Tuners are designed to aid the professional tuner-technician to achieve outstanding tuning results while spending less time doing so. Aural piano tuners can now "memorize" their finest tunings. The Sanderson Accu-Tuner stores the note and cents deviation as a tuning program in its memory and recreates the settings on subsequent tunings automatically. This saves a substantial amount of time without sacrificing accuracy. The built-in FAC Stretch Calculator feature automatically programs the Accu-Tuner to create a complete 88-note custom-stretched tuning.

All operations of the Accu-Tuner are controlled from the sealed membrane keyboard that tells the computer which functions to perform. Push the CENTS up button to raise the pitch; press the CENTS down button to lower the pitch. Similarly, to go up a semitone, press NOTE up, or to go down an octave, press OCTAVE down. The present pitch settings are always indicated on the pair of LCD (liquid-crystal display) windows as NOTE/OCTAVE and CENTS. Fig. 1 shows the Accu-Tuner set for the note C# in the sixth octave, 1.3 cents flat from standard pitch.



Fig. 1. Sanderson Accu-Tuner III

The pitch difference between the Accu-Tuner and the note being tuned is represented by the circle of LEDs (light emitting diodes) on the upper panel. Notes that are in tune with the pitch setting create a stationary pattern. Two to five LEDs may be on, the important factor is that the pattern is stationary. Notes that are sharp create an LED pattern that rotates clockwise, and flat notes create a pattern that rotates counter-clockwise. The center LED flashes when the note is sharp, and is not lit when the note is flat--this is very helpful when the pattern is rotating too fast to determine the direction of rotation.

Tuning with the Accu-Tuner can be thought of as a simple two step process:

1) Determining the correct settings for each note of a given instrument.
2) Tuning each note of the instrument to stop the rotation of the LED display.

Once the Accu-Tuner is mastered the investment will be well worth it in time and labor saved on each job along with increased pleasure in the tuning profession. The Accu-Tuner will help take the drudgery out of tuning yet leave the artistry intact. This is the first and only tuning instrument designed and manufactured by a professional tuner for professional tuners.

Just a quick note to let people who are familiar with Accu-Tuners know that most of the features of the Accu-Tuner III work just like the earlier versions except for memory page selection, which has been simplified. Pages of memory now have their own PAGE button in the previously empty location between OCT and CENTS buttons. It is no longer necessary to hold down the SHIFT button to access pages of memory.

The Accu-Tuner III now has a time-out circuit that turns the unit off after one-half hour if none of the keys on the keyboard have been pressed. If the new feature, Auto-Stepping, is being used to step through the tuning without pressing any button on the Accu-Tuner III for half an hour, the Accu-Tuner III will turn itself off. If the Accu-Tuner III times out, it is a Warm Stop, and when the ON/OFF button is pressed the Accu-Tuner will return to exactly where it left off. If Auto-Off is troubling, press the SHIFT or NOTE up button once in a while to reset the timer.

GETTING STARTED

The Sanderson Accu-Tuner starts in the self-calibrating state or at the exact location where the unit previously "timed out". The Accu-Tuner checks itself for accuracy during self-calibration. Two to five LEDs may be lit and any rotation shows the variation from A-440. If the LEDs are rotating please read the section below on calibration. The Accu-Tuner will also automatically shut itself off or "time out" to conserve battery power if not used for thirty minutes. The same settings it had when it turned itself off will appear when the unit is restarted.

The Accu-Tuner will be fully charged when received. The nickel-metal hydride (NiMH) battery will function for sixty to eighty hours before charging is required. This battery is tolerant of deep discharge, and the Accu-Tuner will turn itself off at a safe low-battery voltage.

LOW-BATTERY WARNING SIGNAL

A low battery warning signal will appear as "LO-BAT" in the display windows when the battery voltage is getting low. This indicates that there is approximately one-half hour of operating time left. If the unit continues to be used, the Accu-Tuner III will automatically turn off when the battery is fully discharged. If this happens in the middle of a tuning, the Accu-Tuner will continue to operate with the battery charger plugged into an AC outlet. A fully discharged NiMh battery will take about an hour and a half to recharge in the quick mode, please charge overnight to fully saturate the battery. Plugging in the Accu-Tuner III for five minutes of charging will charge the battery enough for two hours of use.

BATTERY STATUS INDICATOR

The Accu-Tuner III has the ability to display the percent of charge left in the batteries. Depending upon how much the Accu-Tuner has been used since the last charge the display will show: 100, 75, 50, and 25. When the charge gets down to twenty-five percent the LO-BATT will begin to show in the NOTE/OCTAVE display. When the indicator gets to zero the Accu-Tuner turns itself off.

To check the amount of battery charge left in the Accu-Tuner III:
1) Hold down the SHIFT 2 button.
2) Press the BAT (CENTS down) button.

The nickel-metal hydride (NiMH) battery installed in the Accu-Tuner III is capable of running the Accu-Tuner for sixty to eighty hours. If the battery charge indicator does not seem to be working, be patient, the battery is probably lasting longer than expected.

CALIBRATION

The 440 Hz crystal oscillator verifies calibration on the LED display when the Accu-Tuner is turned on in the CAL mode. If the display is stationary, the instrument is in perfect calibration. If the pattern is rotating, use the cents buttons to slow the pattern down until the display stops rotating. Then go into the TUNE mode by pressing the TUNE button. Pressing the TUNE button will store the new calibration into memory. Now the display will respond to external tones rather than the internal CAL signal.

THE THREE MODES OF OPERATION

The Sanderson Accu-Tuner has three basic modes of operation:

1) The TUNE mode.
2) The FAC (stretch mode).
3) The MEMORY mode.

Each mode is entered by pressing the appropriate button or sequence of buttons on the keyboard, which is shown in figure 2.

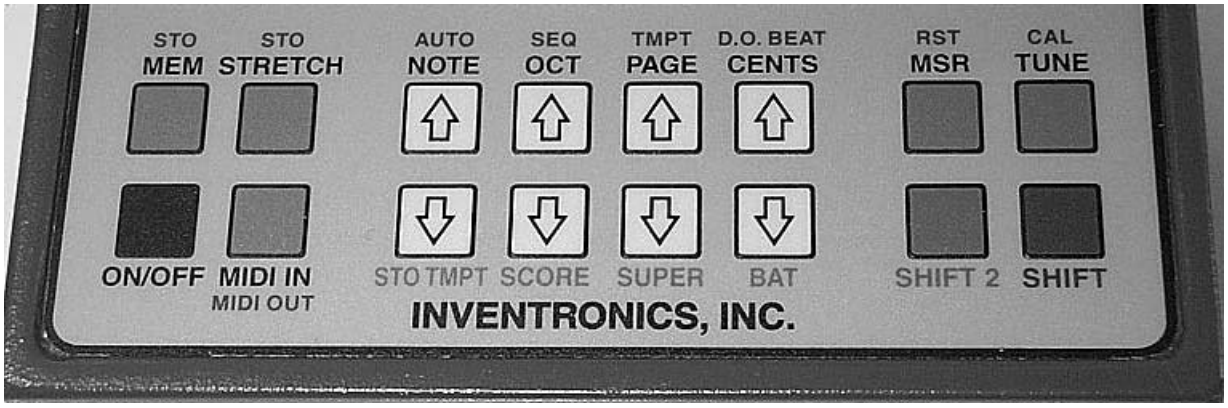


Fig. 2. Keyboard of the Accu-Tuner III.

NOTE: For the moment, disregard the SHIFT AND SHIFT 2 functions. Each will be explained later according to a specific application.

1) The TUNE mode works like most of the conventional tuning instruments already available. Only six of the white buttons in the center of the keyboard are used, and they control the note, octave, and cents deviation to which the Accu-Tuner is set. The TUNE mode is the best place to start when first learning to use the keyboard.
2) The FAC mode uses three measurements known as stretch numbers to derive a tuning based upon computer calculations and stretch tables. This tuning is a complete 88 note stretch tuning from A0 to C8. The three stretch numbers are quick and easy to measure; they are based on the inharmonicity of the notes F3, A4, and C6. Creating an FAC tuning will take a few minutes, but the Accu-Tuner will be able to retrieve that tuning at any point in the future. Tuning two or more pianos for a concert with the tuning in MEMORY is as easy as tuning them separately and individually. No longer is it necessary to have the pianos side-by-side, or even in the same room during tuning.
3) The MEMORY mode enables a tuner to store and retrieve complete 88-note tunings. The Accu-Tuner III comes with 198 pages of memory. This feature is ideal for pianos that are tuned often. Retuning a piano that is in memory consists of simply restoring each note to the pitch where the piano was previously tuned.

THE TUNE MODE

Immediately after pressing the TUNE button to exit from the CALIBRATION mode, the displays will appear as shown in Fig. 3.



Fig. 3. Accu-Tuner display after pressing TUNE.

The NOTE/OCTAVE display shows A4 indicating that the Accu-Tuner is set to A in the 4th octave. (Start counting the first A on the keyboard as A0, not A1, and the first C is C1.) The cents display shows 0.0 to indicate that the cents deviation is zero. So the Accu-Tuner is ready to tune the note A in the 4th octave at 440.00 Hz.

When ready to change the pitch settings from A4, zero cents, use the note buttons in the center of the Accu-Tuner keyboard. To go up in the note setting, press the NOTE up button (top row). Watch the display until it steps to the desired note, and then release the button. The sharps are indicated with a small square box in the top half of the display. Also, the display uses a "b" for a "B" and "d" for "D".

To step the NOTE display down, press the NOTE down button until the desired note. The OCT up and OCT down buttons work the same as the NOTE up and NOTE down buttons, stepping off the octaves to get to the desired setting. The Accu-Tuner will not step beyond its mode ranges, which are as follows:

1) C1 to B9 in the TUNE mode.
2) A0 to C8 in the FAC mode. (C3 to F6 in old stretch mode)
3) A0 to C8 in the MEMORY mode.

The CENTS buttons step differently from the other white buttons. The CENTS buttons step up or down slowly at first, and accelerates as the button is held down.

To cover a large number of cents quickly, hold down the CENTS button and watch the display as the cents change. When the correct tens digit appears, release the CENTS button. Then hold the button down again until the correct single digit appears and release. Repeat this procedure for the tenths digit.

With these six white buttons, the Accu-Tuner does everything that previous tuning instruments have been able to do. Once familiar with operation in the TUNE mode, explore the other modes of operation. If you get into an area of operation that you don't understand, just press the TUNE button and the Accu-Tuner will revert back to the TUNE mode.

THE MEMORY MODE

The Accu-Tuner is not restricted to storing or tuning only on the fundamental pitch or one specific partial of each note. The choice is left to the tuner. This flexibility is necessary to tune all types and kinds of pianos, which vary widely in the strength, and audibility of their various partials.

The complete list of storable pitches relative to a given played note is as follows:

1) Fourth below
2) Semitone below
3) Fundamental, or first partial, i.e., the note itself
4) Octave above less one semitone
5) Octave above, or second partial
6) Octave fifth, or third partial
7) Double-octave less one semitone
8) Double-octave, or fourth partial
9) Seventeenth, or octave tenth, or fifth partial
10) Nineteenth, or double-octave fifth, or sixth partial
11) Double-octave Minor seventh, or seventh partial
12) Triple-octave, or eighth partial
13) Triple-octave second, or ninth partial
14) Triple-octave major third, or tenth partial
15) Triple-octave fifth, or twelfth partial
16) Triple-octave Minor seventh, or fourteenth partial

This list includes all partials from one to ten, plus the twelfth and fourteenth; one semitone low for the first, second and fourth partials; and one subharmonic, the fourth below. This set is complete with all the notes necessary for tuning pianos at pitch or below pitch, as well as pipe organs with mixture stops. Early musical instruments can be stored one semitone low (A=415 Hz by two methods:

1) Exactly with an offset of -101.3 cents.
2) Approximately with notes stored one semitone low (on the first, second, or fourth partials.)

In general, tuning is far more accurate when done on the higher partials, specifically partials that correspond to those used by aural tuners. These vary from bass to treble with the highest partials preferable in low bass, and the fundamental in the high treble.

The tuning of a particular piano can be stored either from a written record of a tuning or from the piano itself during the tuning or immediately after completing a tuning. The Accu-Tuner will be ready to repeat the correct settings from memory whenever it is time to tune that piano again. Just go to the correct page (press PAGE to select the correct page and piano) and start to tune. Going from one note to the next is as easy as pressing the NOTE up button, using an external note switch or the automatic note stepper.

Range of Memory Mode

The range of notes covered in the MEM mode is different from the other two modes. It includes just the 88 notes on a standard piano, known to the Accu-Tuner as A0 through C8. Notice that although the three notes in octave zero can be stored in memory, they must be tuned to a partial other than the fundamental since the lowest note in TUNE mode is C1.

NOTE: Tuning the bass notes on higher partials will deliver more accurate results.

Tuning from Memory

The header list shows the tunings that are stored on the pages of memory. To set the Accu-Tuner up to reproduce a tuning, turn on the Accu-Tuner and press the TUNE button, use the PAGE buttons to step to the page number assigned to this piano. (It is not necessary to press MEM because selecting a page automatically puts the Accu-Tuner into the MEMORY mode). Press NOTE up and NOTE down to start tuning with the first note. To start with any other note, step up to the desired starting note and begin tuning.

When ready to tune the next note, just press NOTE up or down, and tune away. The notes can be tuned in any sequence (when using a sequence page the Accu-Tuner will follow any programmed tuning sequence), up, down, or by octaves, and the stored values for the selected note will appear. The fastest way to tune is with the automatic stepping, since both hands are free for tuning.

The display in MEM mode shows the note being tuned, and the cents deviation of the partial. To check the page number, press the MEM button. To check the partial, press the TUNE button and read the partial in the left display. Always remember to press the MEM button after checking the partial or the Accu-Tuner will be left in the TUNE mode and will not follow the stored tuning.

Page Number Display

In the memory mode the CENTS display doubles as the PAGE display. It displays either the current PAGE number or the current CENTS setting as required. To see how this works (turn on the Accu-Tuner, press the TUNE button) press PAGE up once. A numeral 1 will appear in the CENTS display, to indicate that storing or retrieving a piano can now be done on or from PAGE 1. To change the PAGE, press PAGE up or down. When the page number is displayed there isn't a decimal point.

NOTE: The PAGE number will step up to the number of pages selected in the Accu-Tuner. The page number in the Accu-Tuner III can be adjusted, see page 21 for more details.

Stepping down, the page numbers will stop at PAGE 0. PAGE 0 will not store a piano; it is designed into the Accu-Tuner to make it difficult to mistakenly write a new tuning on top of a valuable tuning. When the Accu-Tuner is turned on, the PAGE number is automatically set to zero. A page of memory has to be deliberately selected before storing a tuning to memory.

THE FAC MODE

Once the operation of the Accu-Tuner in the TUNE mode is mastered, it is easier to understand the operation of the tuning calculator, known as the FAC program. In this mode, the Accu-Tuner creates a tuning that is derived from the measurement of three stretch numbers on notes (F3, A4, and C6) on the piano being tuned. The FAC program includes both an optimum partial selection and a calculated cents setting for all 88 notes on the piano. Once the stretch numbers are measured and stored in the Accu-Tuner, the rest of the tuning is automatic. Every time the note or octave changes, the computer references the FAC tuning and sets the Accu-Tuner up correctly for the new note.

With an FAC tuning the NOTE/OCTAVE display shows the note on the piano that is being tuned, while the CENTS display shows the cents deviation of the particular partial being tuned. The partial that the Accu-Tuner is listening to (first, second, fourth, or sixth) does not show on the display. To view the partial the Accu-Tuner is listening to, switch to the TUNE mode, by pressing the TUNE button. Don't forget to switch back to the page in memory by pressing the MEM button before going on to the next note. If the MEM button is not pressed, the Accu-Tuner will continue in the TUNE mode, and not follow the FAC tuning.

The pitch of an FAC tuning is normally created at 440Hz pitch. A pitch correction can added or subtracted up to 150 cents flat or sharp. This is very helpful if you would like to float the pitch of the piano. If a piano is 140 cents flat, it is easy to create a tuning seventy cents flat and smoothly bring the piano halfway up to pitch today.

The FAC tunings fit the piano better than previous stretch tunings and sound better over the mid-range section as well as providing a beautiful bass and treble tuning. The high treble is tuned in double octaves, which will please many tuners, and those who prefer single octaves can easily modify the last few notes of the treble to suit your own taste. The standard FAC tuning can be altered to suit personal preference, be sure to read the section covering adjusting the double octave beat, see page 22.

MEASURING AND STORING THE FAC NUMBERS

BASIC METHOD

1) Set the Accu-Tuner to F5, zero cents in the TUNE mode. Play one string of F3 and use the tuning hammer to stop the rotation of the LEDs.

2) Press OCTAVE up to step up one octave on the Accu-Tuner to F6, and play F3 again, and use the CENTS buttons to stop the rotation of the LEDs. The cents window now displays the F3 stretch number, which is the difference in cents between the fourth and eighth partials of F3.

3) Hold the SHIFT button, press STO-STRETCH, release STO-STRETCH, release the SHIFT button last. If successful, the Accu-Tuner will jump to the correct settings for the next measurement, A5 and zero cents.

4) With the Accu-Tuner at A5 and zero cents, play one string of A4 and use the tuning hammer to stop the rotation of the LEDs. Now press OCTAVE up to step up one octave on the Accu-Tuner to A6. Play A4 again, and use the CENTS button to stop the rotation of the LEDs. The CENTS window now reads the A4 stretch number, the difference in cents between the second and fourth partials of A4.

5) Store the A4 stretch number by holding the SHIFT button, press STO-STRETCH, release STO-STRETCH, and release the SHIFT button last. The Accu-Tuner will automatically go to the correct settings for the next measurement, C6 and zero cents.

6) With the Accu-Tuner at C6 and zero cents, play one string of C6 and use the tuning hammer to stop the rotation of the LEDs. Now go up one octave on the Accu-Tuner to C7, and stop the rotation of the LEDs using the CENTS buttons. The CENTS window now reads the C6 stretch number, the cents difference between the first and second partials of C6. Store the C6 stretch number by holding the SHIFT button, press STO-STRETCH, release STO-STRETCH, release the SHIFT button last. Now that all three FAC stretch numbers are entered, the Accu-Tuner is ready to calculate the FAC tuning onto a page in piano memory. The FAC tuning cannot be used until it is calculated; if this piano is not a regular customer, then use page one for all the occasional tunings.

7) Use the PAGE buttons to select the page in piano memory that will hold this tuning.

8) To create the FAC tuning and store it in a page of memory; hold down the STRETCH button, next hold down the MEM button, release the STRETCH button, release the MEM button last. The order of holding down and releasing the buttons is critical. We refer to this procedure as rolling over from STRETCH to MEM. If correctly done, the Accu-Tuner will display “FAC” while the STRETCH and MEM buttons are held down. When the STRETCH button is released the display will show “bUSY” for five seconds as the FAC tuning is calculated and stored on the selected page. At the end of calculating the tuning the Accu-Tuner will display A0 and the page number in the CENTS window.

9) To store the serial number of the piano to identify the tuning permanently, now is the time to do it. See page 30 for instructions on storing the serial number.

To start tuning at A0, press NOTE up and NOTE down once. To start at any other note, just proceed to that note with the NOTE and OCTAVE buttons.

AVERAGING STRETCH NUMBERS FOR HIGHER ACCURACY

The above procedure applies to measuring only one open string on each note. For increased accuracy, take measurements on each string of a note individually and average the results. Another way to average out the measurements is to measure one string on two adjacent notes. Measure the inharmonicity of E3, F3 and F#3 and average for the F3 stretch number. The same method of measuring the note above and the note below can be used for A4 and C6 as well. If one of the strings disagrees badly (more than two or three cents) with the others, throw out this reading before averaging.

IF NOTHING HAPPENS

Suppose you try to store a stretch number and nothing happens? This can be disconcerting but the problem is usually very simple to solve. The FAC program is particular about being on the correct note when storing a stretch number. You must have the Accu-Tuner on F6 in the TUNE mode (by pressing the TUNE button) to store the F3 stretch number, and if not, nothing at all will happen. To store the A4 stretch number the Accu-Tuner must be on A6, and to store the C6 stretch number Accu-Tuner must be on C7. The Accu-Tuner has to be on the correct note to store a stretch number.

Another situation that can raise a problem is when the Accu-Tuner is set to page zero when trying to calculate an FAC tuning. Simply select a valid page in memory (use the PAGE buttons) and repeat the STRETCH rollover to MEM procedure.

A QUICK METHOD FOR STORING STRETCH NUMBERS

Another feature of the Accu-Tuner III is the ability to adjust and store the FAC numbers without having to follow the entire sequence outlined above. This is helpful in many situations: if the stretch numbers are already known, it is possible to enter the stretch numbers quickly.

The following procedure assumes the Accu-Tuner is off, it is not necessary to follow every step if the unit is already in use.

1) Turn on the Accu-Tuner

2) Press the TUNE button

3) Hold down the STRETCH button.

4) The left display will show F3, A4, or C6. The right display will show the current value of the corresponding stretch number. While holding the STRETCH button use the CENTS up/down to adjust the stretch number to the desired value.

5) After the stretch number is entered release the STRETCH button

6) Hold down the STRETCH button again.

7) Adjust the next stretch number by using the CENTS up/down to adjust the value.

8) Release the STRETCH button.

9) Repeat steps 6-8 until all the stretch numbers are entered correctly.

10) With the new stretch numbers properly stored. Select a page in memory, roll over from the STRETCH to MEM button, which will calculate the FAC tuning and store it in memory.

REVIEWING THE FAC NUMBERS

To review the FAC numbers for a tuning just created or about to be created, use the following procedure. Hold down the STRETCH button, while held down one of the three stretch numbers will be displayed. The left window may show F3 and the cents window will then show the F3 stretch number. Release the STRETCH button and hold it again to see the A4 stretch number. Release and hold the STRETCH button again for the C6 stretch number. The stretch numbers will continue to cycle through F3, A4, and C6 to review them again. After reviewing the stretch numbers, press the MEM button if the FAC tuning has already calculated. If the MEM button isn't pressed the Accu-Tuner will continue in the C3 to F6 stretch tuning. This will make the Accu-Tuner appear to be locked up when trying to step up from F6 to F#6 or trying to step down from C3 to B2. If this does happen, press the MEM button to get back to the page of memory, and check back over the tuning to see where the switch was made.

NOTE: Some tuners have reported that the FAC numbers tend to get better, that is, drift downwards as a piano is tuned repeatedly.

Some Accu-Tuner owners have expressed a preference for starting with the A-4 measurement vs. the sequence described above. As long as the correct partials are selected on the Accu-Tuner, the FAC measurements can begin with any of the three F-A-C notes.

The FAC numbers are automatically inserted into the header that is part of the tuning record of each piano. The header below is an example which shows page 1 has the FAC numbers of 10.2 for F3, 8.8 for A4, and 7.9 for C6:

001_____10.2 8.8 7.9 FAC 000000

The last six digits in the header listing represent the serial number.

Viewing FAC Numbers from a Page in Memory

To view or copy the three stretch numbers from an existing FAC tuning in memory, use the following procedure:

1) Turn on the Accu-Tuner.

2) Press the TUNE button.

3) Use the PAGE buttons to get to the desired page in memory to view/copy the stretch numbers.

4) Hold down the SHIFT 2 button.

5) Press the STRETCH button.

6) One of the three (F3, A4, or C6) stretch numbers will be displayed in the cents window. As the stretch numbers are reviewed, they are loaded to be able to copy the stretch tuning to a new page.

7) Release the STRETCH button.

8) Press the STRETCH button (with the SHIFT 2 button held down).

9) View the second of the three (F3, A4, or C6) stretch numbers.

10) Release the STRETCH button.

11) Press the STRETCH button (with the SHIFT 2 button held down).

12) View the third of the three (F3, A4, or C6) stretch numbers.

Now the FAC tuning can be copied to another page, following the directions below. If all that was required was reviewing the FAC numbers, press the MEM button to continue with the tuning in memory. Repeat steps 4, 5, and 6 to view the stretch numbers again.

Copying FAC Tunings to another Page in Memory

1) Use the PAGE buttons to get to the page in memory to be copied.

2) Follow the procedure above for viewing the three stretch numbers, which will load the stretch numbers for copying.

3) Use the PAGE buttons to get to the page in memory for the copy of the FAC tuning. To add a temperament or alter the double octave beat, select the desired change before calculating the FAC tuning. Select the temperament; increase/decrease the D.O.Beat or both.

4) Hold down the STRETCH button.

5) Hold down the MEM button.

6) Release the STRETCH button.

7) Release the MEM button.

8) Now the Accu-Tuner will copy the FAC tuning onto the selected PAGE in memory.

Offsetting an FAC Tuning to Non-Standard Pitch

Tuning and pitch-raising a piano to non-standard pitch is very easy with the FAC program. Prepare the Accu-Tuner with the RESET feature to get the Accu-Tuner offset to the required pitch. For instance, to tune at 442 put 8.0 cents into the CENTS window, hold down SHIFT and press RST. (Add approximately four cents for every Hz above 440 Hz, or subtract for every Hz below 440 Hz for the tuning, table and formula below.) The cents window is reset to zero, and the 8.0 cents is stored as a pitch offset. The plus sign in the note octave window indicates the pitch is offset on the sharp side. Any pitch offset up to a semitone sharp or flat can be store this way.

After the pitch offset is stored, take the FAC measurements as usual, when the tuning is stored to a page in memory, the cents offset will be included in the stored numbers.

As an example let's say we have a piano that we want to leave twenty cents flat, store an offset of -20.0 cents (hold SHIFT and press RST), then measure the F3, A4, C6 stretch numbers with the standard method. When the Accu-Tuner calculates the FAC tuning it will subtract twenty cents from all 88 notes as it stores the tuning on a page in memory. Assume the Accu-Tuner would normally store A0 as -18.2 cents it would now store the note A0 -18.2 - 20.0 (cents offset) and store the note A0 as -38.2.

Cents Offset for Hz at A4

Frequency of A4	Cents Offset
446	23.5
445	19.6
444	15.7
443	11.8
442	7.9
441	3.9
440	0.0
439	-3.9

Frequency of A4	Cents Offset
438	-7.9
437	-11.8
436	-15.8
435	-19.8
430	-39.8
420	-80.5
415.3	-100.0
415	-101.3

Formula for calculating cents offset of A4 at 420Hz: Log(420/440,2)*1200 = -80.54

"Good" FAC Numbers

You can tell a lot about a piano and its scale design from the FAC stretch numbers. The three numbers should be reasonably close to each other and lie in a reasonably straight line. For example, FAC numbers such as 10, 8, 6 or 5, 6, 7, or 8, 8, 8 represent well scaled pianos. Don't be alarmed if stretch numbers measure 25 for F3, 6 for A4, and 8 for C6, those three stretch numbers exist on a spinet piano. The mention of "good" stretch numbers is just for general information, in practice there can be a large diversity between stretch numbers. The lower the numbers, the lower the inharmonicity, so spinets tend to produce higher numbers than grand pianos.

The FAC method, or any other method, cannot produce perfectly progressing beat rates on a piano with poor scale design. Some of the less expensive spinets have measured FAC numbers of 25, 6, and 8. It is essentially impossible to create smoothly progressing beat rates across such diverse levels of inharmonicity. However, the FAC tuning will be as good as one can expect or can achieve by any method given the scale-design problems inherent in the piano itself.

One method for helping with pianos that have poor bass-tenor breaks is to use the Double Octave Beat feature to work out the scale design problems smoothly. See page

FAC Tuning from A0 to C8

After the FAC tuning has been calculated to a page in memory, tuning can start on any note. When ready to tune the next note, press NOTE up (if the automatic note stepping is not turned on) or step on the foot switch. For every semitone the Accu-Tuner will automatically update the partial and cents deviation for the next note, continue stepping and tuning this way for the entire 88 notes.

When tuning A4 the Accu-Tuner WILL NOT BE SHOWING 0.0 cents, this is normal. Behind the scenes the Accu-Tuner is tuning listening to the pitch of A6, and the cents deviation is compensated to tune A4 at 440 Hz. To double check A4 is perfectly at 440 Hz, see page 20.

Unison Tuning

Unisons may be tuned aurally along with a stretch tuning of the center string, or each string may be tuned individually to the Accu-Tuner and the unisons checked aurally later on. The Accu-Tuner will do an excellent job of tuning unisons when the strings of a given note are well matched. (They are on most notes.) The fact that some strings are mismatched makes it extremely important for the tuner to check all unisons aurally when they have been tuned with the Accu-Tuner. However, do not try to check the unisons aurally during any pitch raise. Pulling up adjacent strings affects the pitch of the strings that have already tuned. The settling process on a string is not complete until another octave or so has been tuned.

Aural unison tuners should be aware that pulling in two outside strings to the tuned center string will affect the pitch of the center string. The amount is roughly equal to one-fifth of the net pitch change. As a result, when there is more than a few cents pitch change involved, tuning unisons aurally can actually leave them out of tune in the end! To avoid getting into this situation, give the piano a quick pitch raising (or lowering) before trying to do a fine tuning. If the piano is more than five to ten cents flat, it will actually save time to do a quick pitch raise before attempting to fine-tune the piano.

ONE STRETCH NUMBER MEASUREMENT FOR TUNING

By James W. Coleman, Sr.

1. Turn on SAT III, press TUNE button to get out of Calibrate mode if LED's are stopped.
2. Tune A4 and carefully to stop display with 4 LEDs.
3. Press OCT/UP twice to get to A6
4. Hold down MSR button momentarily to stop display, trim up with CENTS buttons.
5. Multiply this cents value by .8 to get the Stretch number which works with FAC. This gives the same value as with measuring the difference between the 2nd and 4th partials of A4, but insures that the A4 fundamental will always be on target. (Or set the Accu-Tuner to multiply automatically, see instructions below).
6. Store this value by holding down blue SHIFT and pressing STO-Stretch.
7. Press PAGE/Up button once to select page 1.
8. Accept the default stretch values of F3=8 and C6=6, hold down STRETCH, hold down MEM, release Stretch, release MEM. When A0 value appears, the scaling is complete.
9. Change OCT to 4 to confirm that the fundamental and 4th partials are still correct.
10. Change to A3, Play A4 to see the 4-2 octave relationship even before A3 is tuned. If dots are stationary, use .5 DOB to get .5 bps between the 4th partial of A3 and the 2nd partial of A4 (this will give a .5 bps difference between F3-A3 and F3-A4). To invoke DOB, hold down blue SHIFT and touch CENTS/Up once for each .1 bps. If the dots are moving slightly counter-clockwise while playing A4, see how many .1 cents you need to add to make the display stop. This shows how many .1 cents narrow the 4-2 octave relationship already was. If it required .4 cents to stop the display, this means that 1.0 cents more (total of 1.4 cents) would be needed to bring the beat difference up to plus .5 HZ between the 2nd partial of A4 and the 4th partial of A3. This means that 1.4 cents adjustment needs to be made since at the pitch of A5 (the coincidence of the 2nd and 4th partials) 1.0 cents equals .5 Hz. Adding .2 DOB would stretch the A3 downward so that there would now be a .0 HZ difference between the 4th partial of A3 and the 2nd partial of A4. Then adding another .5 DOB would stretch the A3 downward another 1/2 beat to make the M3rd-M10 test (aural test for 4-2 type octave) show a stretch of 1/2 beat per second.

    Any time a DOB change is made, press note up and down for the change to take effect.

    Another way of thinking about these changes is to find out how many .1 cent changes are needed to make the LEDs rotate clockwise two lights per second while playing A4 with the program set to A3 (it listens at A5). Take one half of that needed amount and add that much in DOB control. If 0.8 cents are needed to rotate the LEDs clockwise two per second, then you need .4 DOB to stretch the A3-A4 octave that much. Thus, the 4-2 type octave aural test (F3-A3) (F3-A4) will make the M10th to be 1/2 bps faster than the M3rd. This will also stretch the double and triple octaves in both directions, Treble

and Bass. If this becomes too much in the Bass, one can decrease the DOB as needed, or one can add more DOB if the Bass needs more stretching.

11. Tune the A3 to this setting.
12. Play A3 and A4 to check the sound of the octave. Some low inharmonicity pianos cannot take as much 4-2octave stretch as others and still sound good.
13. Set auto note stepping by holding down the blue SHIFT button and pressing the NOTE/Up button once, then the NOTE/Dn button once.
14. Commence tuning downward from A4 to the lowest plain wire note. Utilize parallel aural tests along the way as a quality control method for the machine tuning.
15. Every two or three notes below A3 aurally check the sound of the octave to make sure you do not have too much stretch in the sound of the octave. The minor 3rd-M6th test is good to use (if the min 3rd is slower than the M6th, the octave is stretched beyond the 6-3 relationship). If the octave is becoming too wide, you can decrease the DOB .1 bps at a time about every 3 or 4 notes if desired.
16. Continue tuning upward from A4, tuning unisons as you go. Place 3/4" rubber wedge between L and Center strings and TUNE R string. Move wedge between C and R strings and TUNE L string. Move wedge to between the L and C of next note and TUNE the center string by ear to the previously tuned L and R strings. To insure stability, play each string at least 4 or 5 times firmly at the stopped display position. Then when all three strings are sounding together, you can get an idea how solid the unison is. Any tendency for the three strings to be at a lower pitch than the single strings can be corrected with the tuning of the middle string aurally.
17. As soon as I get to F5, I can check the relationship of the double octaves below and see that there is a slight spread of the double octave and that the octave-5th is almost pure. By the time I get to C6, I can see the relationship of the double octave, the single octave-5th, the double octave-5th, and I can listen to the parallel 17ths progression. At F6 I can play the note F3 to see how the triple octaves are matching up. If I notice the triple octave test shows the dots moving counterclockwise, I can reign in the DOB a little bit, .1 beat at a time, every two or three notes.
18. From C7 to C8 each individual string is tuned with the SAT III. The finished unisons can be listened to for clarity sake and correction if necessary. In this area, unisons are usually better tuned with the SAT than tuned strictly aurally. In this area, I can do all the tests mentioned in 18 above. If the triple octave is fairly close to my setting, the single octave-5th will usually be a little wide while the double octave-5th will be dead-on or slightly narrow. In this case, the quadruple octave will usually be a little narrow. I can tell all of this just by watching the drift of the LEDs as I play the various test notes below.
19. TUNE the unisons aurally from the lowest plain wire notes through A4. Let the SAT follow you so that you can detect any correction, which may be necessary after the firm playing of the unisons. Play repeatedly about 1 to 2 blows per second. Listen to the interplay of the highest partials you can hear and bracket in the unisons as closely as possible. On pianos, which I know to have little or no single string beating, I may elect to tune all 3 strings with the SAT.
20. Bass tuning on 7' or 9' pianos works very well with the regular measured FAC tunings. However, for medium or small pianos I like to stick to the pure 6-3 type octaves where the minor 3rd test equals the M6th test as complementary intervals of the octave. To achieve this, I use negative DOB like this: For example if I am tuning B2 to B3, I play B3 (already tuned) while the SAT is on B2. B3's 3rd partial (F#5) will probably be moving clockwise. I select enough negative DOB to cause the LEDs to stop, then I tune the B2 to this setting (remember that it is necessary to press note up then note down to get the new DOB applied). I felt strip out the Bass section while tuning these octaves. After tuning 3 or 4 notes this way, I will recheck the 6-3 octave match. If when playing the upper note of an octave to be tuned, I should notice the LEDs drifting sharp again, I will invoke additional negative DOB. When I get to the lowest few notes of small pianos, I may allow the upper note of the octave to show a slight drift in the clockwise direction to add a little more stretch (these notes always sound a little sharp anyway).
21. I TUNE out the unisons after pulling out the felt strip. I try to make the best compromise possible in the unisons. I play the notes repeatedly as in the aural unisoning of the midrange, looking for that most solid sound at impact.

PS This looks and reads much more difficult than doing it. Its advantage is that you begin tuning immediately and you need to store only 1 measurement in the process. The DOB adjustments are made "on the fly" and very few are necessary. JWC

USING THE A4 STRETCH NUMBER MULTIPLIER.

There is a new method for measuring the A4 stretch number, which is a direct method of tuning A4 to the fundamental. The newer style described above tunes A4 once instead of tuning A4 for measuring the stretch number and a second time for the FAC tuning.

Temporary changing of the A4 multiplier:

1) Turn on Accu-Tuner
2) Before pressing the TUNE button, press the NOTE up or down until the desired multiplier is shown in the CENTS window, 0.8 for the Coleman method of measuring the A4 stretch number. The A4 multiplier can be adjusted from 0.4 to 2.0.
3) Press the TUNE button and the Accu-Tuner will automatically multiply the stored A4 stretch number by the multiplier, until the Accu-Tuner is turned off with the ON/OFF button.

If you prefer to always multiply the A4 measurement by a multiplier then use the following procedure. This will alter the default multiplier from 1.0 to the selected multiplier. Every time the Accu-Tuner is turned on it will come on with the modified A4 multiplier:

1) Turn on Accu-Tuner.
2) Before pressing the TUNE button, press the NOTE up or down until the desired multiplier is shown in the CENTS window, 0.8 for the Coleman method of measuring the A4 stretch number.
3) Hold down the SHIFT button (Blue) and then press the SHIFT 2 button (Green), release the SHIFT 2 and then release the SHIFT button. This will store the multiplier as the default, and every time the Accu-Tuner III will come on with the new multiplier.
4) Press the TUNE button and the Accu-Tuner will automatically multiply the stored A4 stretch number by the multiplier, and will do so until the default multiplier is altered again with the above procedure.

AUTO NOTE STEPPING

Auto Stepping allows the technician to tune the piano without having to press the footswitch or the NOTE up/down buttons. Both halves of this feature can be toggled on or off independently. To turn on the Auto Note Stepping up feature:
1) Hold down the SHIFT button
2) Pressing the AUTO up (NOTE UP) button and the AUTO STEP UP feature will turn on.

If you were tuning A4 and had the step-up feature turned on, the Accu-Tuner III will respond to the note A4, and also A#4. If the Accu-Tuner III hears the note A#4, it will automatically step up to the note A#4. When this feature is toggled on, two bars (one in the middle and one in the top half of the display) will appear to the right of the Octave in the note/octave display. The two bars (like rungs on a ladder) illustrate the Auto-Stepping is on with a glance to the display.

To turn on the Auto Note Stepping down feature:
1) Hold down the SHIFT button
2) Pressing the AUTO down (NOTE down) button and the AUTO STEP DOWN feature will turn on.

The Auto-Stepping Down works similar to the UP feature, when tuning A4 the Accu-Tuner will also listen for the pitch of G#4. If the note G#4 is played, the Accu-Tuner will automatically step down to G#4. When auto-stepping down is toggled on two bars (one in the middle and one in the bottom half of the display) will appear to the right of the Octave in the NOTE/OCTAVE display.

If both the AUTO STEP UP and the AUTO STEP DOWN features are activated, the Accu-Tuner will be listening for three different pitches: the pitch being tuned, a pitch one-hundred cents flat and a pitch one-hundred cents sharp. And the display will show three bars to the right of the Octave number display similar to three rungs on a ladder.

Quick Note on Auto Stepping—in the bass the Accu-Tuner is set to listen to the sixth partial; on some pianos the partial can be weak on certain notes. If the Accu-Tuner is not stepping crisply, play the note an octave higher and the Auto Stepping will have a stronger signal to work with.

PITCH RAISING

The Sanderson Accu-Tuner is able to automatically calculate the overpull (anticipated drop) of a given note during the course of pitch raising. The Accu-Tuner measures the unknown pitch first, then compares it with the pitch of the selected tuning, and then calculates the pitch-raise correction. With the Accu-Tuner III the amount of pitch raise correction is selectable from either twenty-five percent or thirty-four percent.

The pitch-raise calculator is designed to be used with a tuning in memory in order to pitch raise the entire piano to the stored piano-tuning curve. Choose a page in memory with a piano similar to the one to be pitch raised, or create an FAC tuning. The pitch-raise calculator offsets the Accu-Tuner the number of cents necessary to pitch raise the piano to the stored tuning (not just to the zero-cents line).

To access a page of memory, turn the Accu-Tuner on, press the TUNE button and press PAGE up or down to the desired page.

Let's start at tuning A0, press NOTE up and NOTE down to set up the tuning, hold the MEASURE button down while striking A0 until the LEDs stop (or nearly stop). Continue to hold the MEASURE button down and press (roll over to) the SHIFT button, then release MEASURE, then release SHIFT. The Accu-Tuner will automatically offset itself by one-quarter of the measured flatness. (A note forty cents flat will automatically calculate an offset value of 10 cents sharp). Tune with the calculated offset for six to twelve notes, and then repeat the measurement on the next untuned note to get a new pitch-raise correction. The correction changes quite slowly on a normal piano, and needs to be recalculated six to ten times to cover the entire keyboard. A good place to recalculate the overpull is at the breaks in the piano scale or breaks in the plate.

When using the pitch-raising calculator the display jumps from the note being tuned to the partial that the Accu-Tuner is listening to. In our scenario above, the note A0 is listening to the partial E3. So immediately after the pitch raise calculation the Accu-Tuner will appear to jump from the note to be tuned. To verify the note being tuned, press NOTE up and then press the NOTE down.

The pitch correction factor of one-quarter is designed to work best with the "unisons-as-you-go" method of pitch raising. You can modify the number given by the Accu-Tuner. If the Accu-Tuner calculates 10 cents, but you feel 8 cents would be better, just enter -2 cents and store this offset (hold SHIFT and press RST button). The net offset will be 8 cents. Usually it is not worth the time to try to outguess the pitch-raise calculator. The Accu-Tuner III can also calculate a pitch correction factor of one-third described below.

Let's start at A0, select the correct page, press NOTE up and NOTE down. To use the pitch raise calculator for twenty-five percent overshoot:

1) Hold down the MEASURE button while striking the note (A0 in our present scenario) until the LEDs stop or nearly stop.

2) Hold down the SHIFT button.

3) Release the MEASURE button.

4) Release SHIFT button.

To use the pitch raise calculator for thirty-four percent:

1) Hold down the MEASURE button while striking the note (A0 in our present scenario) until the rotate stop or nearly stop.

2) Hold down the SHIFT 2 button.

3) Release the MEASURE button.

4) Release SHIFT 2 button.

The Accu-Tuner automatically offsets itself by one-third of the measured flatness. (For Example, a note forty-five cents below pitch will automatically result in an offset value of fifteen cents sharp). Tune with the calculated offset for half an octave or so, then repeat the measurement on the next untuned note for a new pitch-raise correction.

When using the pitch-raising calculator the display will jump from the note to be tuned to the partial that note in memory is listening to. In our scenario above, the note A0 on the page of memory is set to the partial E3. So immediately after the calculation the Accu-Tuner will appear to jump from the note to be tuned. To verify the note being tuned, press NOTE up and then press the NOTE down.

In general, 25% is adequate for wound strings. The first plain wires require 34% then 25% for unisons as you go. When pitch raising with the unisons last method, use 34% for all the plain wires.

Pitch lowering is just the reverse of pitch raising (to a piano), and the program works just as well for lowering pitch as for raising it. Just follow the above procedure; no changes have to be made.

When finished with the pitch raise, cancel the overshoot with the following: hold down the SHIFT button and press the CAL button. Keep the CAL button held down until the display jumps to A 4, 0.0 cents with two to four LED's lit. When the TUNE button is pressed to leave the CAL mode, the page of memory is still selected. Use the NOTE and OCTAVE buttons to get to the desired note and start tuning.

THE MEASURE (MSR) BUTTON

The MSR (measure) button makes it easy to measure an unknown pitch. When the LEDs are spinning around, pressing the CENTS buttons can stop the display; however, the MSR button will do the same job automatically. Simply hold down MSR and wait for the LEDs to slow down. Release the MSR button; the cents display now indicates the unknown pitch to an accuracy of one cent. After releasing the MSR button, the display may still be rotating slowly. For the quickest and most accurate results, go to within a few tenths of a cent with the MSR button, and then stop the rotation of the display with the CENTS buttons.

THE RESET (RST) BUTTON

The Reset Button has four major functions:

1) Resetting to Non-Standard Pitch.

2) Perfecting the A-440 of a Stretch Tuning.

3) Displaying the Cents Offset.

4) Measuring the Width of Musical Intervals.

Resetting to Non-Standard Pitch

The RST (reset) button is used to reset the cents display to zero without actually changing the pitch of the instrument itself. This is very useful in several ways. The first is setting the Accu-Tuner to a non-standard pitch. For instance, to tune an instrument to A at 442 Hz, which is 8.0 cents sharp, turn the Accu-Tuner on and then press the TUNE button, then step the CENTS display up to 8.0 cents as shown in Fig. 4.

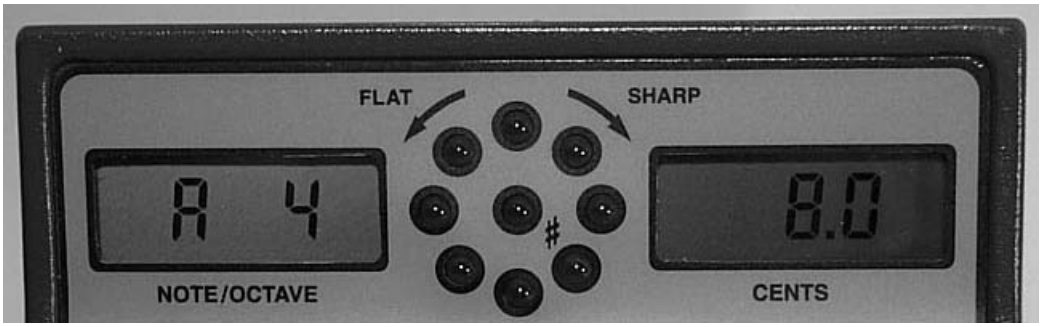


Fig. 4. Accu-Tuner just before offsetting pitch.

Now hold the SHIFT button down and press the RST button. The display will jump to zero cents as shown in Fig. 5, but will actually be at 442 Hz (8.0 cents sharp). Now the tuning can proceed exactly as it would normally, except the tuning will end up at 442 Hz. (This assumes the stored tuning is at 440 Hz.) In this frequency range, there are 4.0 cents for each 1.0 Hz pitch difference from 440.0 Hz.

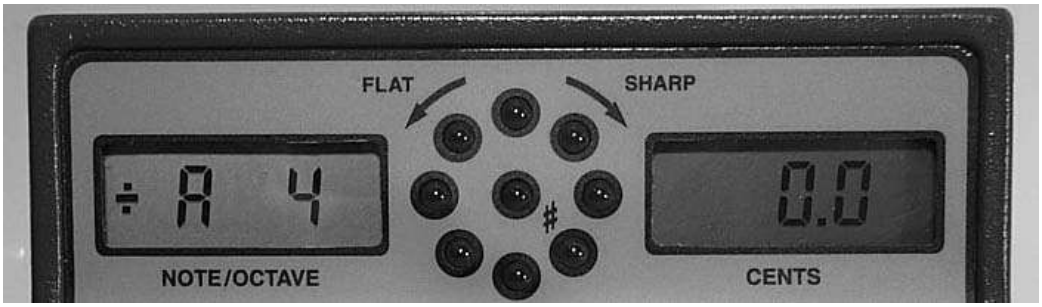


Fig. 5. Display with non-standard pitch warning.

It is also possible to tune off-pitch by accident. To help prevent this from happening, a plus sign appears in the NOTE/OCTAVE display window as shown in Fig. 5. Whenever the instrument is offset to the sharp side, a plus sign will appear. When the Accu-Tuner is offset to the flat side, a minus sign will appear.

Perfecting the A-440 of Stretch Tuning

A second use for the reset feature is to get the stretch tuning (see previous section on FAC) exactly on pitch at A-440. One of the problems with pianos is that they are rarely perfect, and the FAC stretch tuning uses the fourth partial of A4 (A6) to tune A4. This is where a slight error can occur. Sometimes the fundamental of A4 can end up a few tenths of a cent sharp. To double check the value of A-440 use the following procedure:

1) Measure the stretch numbers of the piano.

2) Store the FAC tuning to a page in memory, go straight to A4 and tune all three strings.

3) Switch to the TUNE mode by pressing the TUNE button.

4) Press OCTAVE down twice, set the cents deviation to zero, and the display should read A4 0.0

5) Play A4 on the piano.

6) If the note is right on pitch, simply switch back to the page in memory where the tuning is located. (Press MEM button, then NOTE up button). Tune the piano.

7) If the note is unacceptable, measure the pitch error with respect to A-440, and follow the instructions below.

For example: Let's assume it is 0.2 cents sharp. Store an offset that will counteract the error, namely 0.2 cents flat. Do this by putting -0.2 in the cents window, then hold down the SHIFT button and press the RST button. Now store the tuning again (roll over from the STRETCH to MEM), and tune the piano knowing that A4 will end up exactly on A-440 Hz.

Displaying the Cents Offset

The offset cents number used during a pitch raise can be displayed at any time.

Set the cents window to zero. Hold down the SHIFT button, and press RST. As long as the SHIFT button is depressed, the right display window will show the cents offset currently in use. Since the Accu-Tuner has the ability to add or subtract cents from the stored offset, the cents display must be returned to zero before viewing the cents offset.

On the other hand, to change the offset, just enter the desired difference in cents. Press SHIFT-RST and the new offset will be displayed in the cents window.

To set the cents offset back to zero, either recalibrate the instrument by holding the SHIFT and pressing the CAL button, or enter an opposite offset and store that in order to cancel the original offset.

Measuring the Width of Musical Intervals

The fourth major use for the RST button is to measure the width in cents of musical intervals. To measure the width of an interval such as a third or fourth, take the following four steps.

1) Go to the note and octave of the coincident overtones of the two notes (i.e., A5 for the F3-A3 major third).
2) Stop the LEDs using the MSR and/or CENTS buttons on the lower of the two notes.
3) Reset the CENTS display to zero with the SHIFT & RST button.
4) Stop the LEDs again on the higher of the two notes.

The width of the unknown interval now appears in the CENTS display. No addition or subtraction is necessary to make this measurement with the Accu-Tuner.

QUICK RESET OF CENTS WINDOW TO ZERO

It is often convenient to be able to reset the cents reading to zero without having to go to the trouble of counting the cents down to zero. This can be done with the CAL button. Hold the SHIFT button down, and press the CAL button quickly. The CENTS window will revert to zero cents, but the NOTE window will remain as it was. The Accu-Tuner will not go over to the CAL function if the CAL button is pressed quickly. To complete the CAL operation, hold the CAL button down instead of just giving it a quick push.

ADJUSTING THE PAGE NUMBER LIMIT

This new feature allows the user to shorten the number of pages of memory. By limiting the number of pages, the time it takes to send the tunings through the MIDI ports can be shortened. Advance to the page number to be set as the last page of memory. (The advantage to selecting the number of pages first is that the pages accelerate as the PAGE button is held down, when adjusting the page limit the pages do not accelerate. It could end up taking more than a minute to get up to page number 150 if starting at page 0.)

1) Turn the Accu-Tuner III on

2) Press the TUNE button

3) Hold down the SHIFT button (blue)

4) Hold down the SHIFT 2 button (green)

5) Set the Accu-Tuner to the desired page number stop.

6) When the SHIFT and SHIFT 2 buttons are released the page number stop will be reset.

If by mistake the page number stop was set to zero, the page number can be reset by going below page zero (with SHIFT and SHIFT 2 held down) and the index will start at the top again. To accomplish this:

1) Hold down the SHIFT

2) Hold down the SHIFT 2

3) Press the PAGE down button until the display gets to zero and the next page to appear will be page number SUP 3 (which stands for SUPertuning page 3, equivalent to page 207).

4) Release both SHIFT buttons, the memory is set to maximum pages of memory.

With the SHIFT and SHIFT 2 buttons held down the pages of memory do not accelerate. The quick way to adjust the pages is to set the page stop to SUP 3 (the top page), release SHIFT and SHIFT 2, use the PAGE button to get to the desired page limit and use SHIFT and SHIFT 2 to reset the page limit.

WARM STOP

The Sanderson Accu-Tuner III has a time out circuit that is set to half an hour. To turn off the Accu-Tuner III for a phone call without losing the settings, use the warm stop procedure. The Accu-Tuner will start up with the same settings still turned on, such as: auto-stepping, temperament, sequencing or double octave beat and the Page, Octave and Note. If the On/Off button is used to turn off the Accu-Tuner, the Accu-Tuner will turn on in the calibrate mode and when the TUNE button is pressed none of the previous settings will be preserved.

To use the warm stop feature follow the procedure below:
1) Hold down the SHIFT 2 button
2) Press the MIDI IN button

To turn the Accu-Tuner back on press the ON/OFF button the same as if the Accu-Tuner had timed out.

The Warm Stop is also a way to release an Accu-Tuner III that has hung up because the MIDI IN button was pressed accidentally.

ADJUSTING THE DOUBLE OCTAVE BEAT

First let's explain the basic outline of the Double Octave Beat (DOB). The DOB feature allows the technician to adjust the width of octaves without altering the FAC measurements. This will allow the tuning to be tailored beyond the FAC calculation to suit the preferred style of tuning or to better fit to the scaling of the piano. It is possible to adjust the D.O. beat either before or during the tuning.

The Accu-Tuner III when it is first turned on calculates one-quarter to one-half beat per second for all double octaves, as a standard FAC calculation. The D.O. Beat control allows the technician to add/subtract stretch to the tuning that the Accu-Tuner calculates. If the tuning sounds contracted in the temperament, hold down the shift and press the D.O.Beat button up. If the tuning sounds too wide in the temperament, hold down the shift and press the D.O.Beat button down. The D.O. Beat the setting will start at 0.0 and adjust up/down by tenths of a beat. The higher (positive) the D.O.Beat number is; the wider the stretch will be for each octave. The lower (negative) the D.O.Beat number is; the narrower the stretch will be for each octave.

Double Octave Test	Increase in Beats per second
A0 to A2	0.1
A1 to A3	0.2
A2 to A4	**0.4**
A3 to A5	0.8
A4 to A6	1.6
A5 to A7	3.2

If the D.O. beat were increased by 0.4 the A2 to A4 octave would be increased by +0.4 beats per second over the standard FAC stretch tuning. The amount that the D.O. beat affects the tuning will increase as the octaves increase. The table above outlines the effect of increasing the D.O. Beat by 0.4.

If the FAC tuning isn't creating the preferred tuning and would like narrower or wider octaves, then adjust the DOB before the Accu-Tuner calculates the tuning. If the FAC style of tuning normally is acceptable, but the particular piano is not passing the desired aural tests; then adjust the DOB during the tuning. The directions for adjusting the DOB before an FAC calculation are below, and just after is the description of adjusting the DOB during the tuning.

- TO ALTER THE FAC CALCULATION

If the DOB is altered before calculating the FAC tuning, the tuning will be stored to memory with the adjustments included in the tuning on that page of memory.

1) Measure and store the FAC numbers (for more information see page 10)

2) Hold down the SHIFT button

3) Press the D.O. B. (Cents) button up to increase the width of the octaves, DOB button down to decrease the width of the octaves of the tuning to be calculated.

4) Select a page in memory.

5) Hold STRETCH button.

6) Hold MEM button.

7) Release STRETCH button.

8) Release the MEM button.

When the Accu-Tuner finishes calculating the FAC tuning, the A2 to A4 double octave stretch will be altered by the amount stored for the DOB. The amount the stretch will be altered in other octaves is outlined in the table above. The amount of stretch is actually constant in terms of cents, i.e., +0.4 DOB equals 1.6 cents stretch in every double octave.

- TO ALTER THE STRETCH DURING THE TUNING

The double octave beat (DOB) is very flexible and allows a standard FAC tuning to be altered on the fly in any section of tuning the piano it is too wide or narrow. The amount that the tuning is altered is outlined above. We recommend trying out an FAC tuning by tuning a few notes to sample the tuning. For example, tune A2, A3, A4, then test the octaves and double octave to see how the tuning sounds. Adjust the DOB until the best aural results are found and then store the tuning. The directions below will describe the steps to accomplish the change:

The following directions assume a page in memory is being used for the tuning.

1) Hold down the SHIFT button.

2) Press the D.O. Beat button up or down to alter the stretch.

3) As described above the higher (positive) the D.O.Beat number is, the wider the stretch will be for each octave. The lower (negative) the D.O. Beat number is; the narrower the stretch will be for each octave.

4) Release the D.O. Beat button.

5) Release the SHIFT button.

6) Press NOTE up and then NOTE down.

The following example will give a better understanding of how the Double Octave Beat alters a tuning. The example is based on an FAC tuning with stretch numbers of F3 8.0, A4 7.0, and C6 6.0. The second line of the table has DOB of -1.0, the third line has a DOB of -0.5, the fourth line of 0.0 (unaltered FAC tuning), the fifth line is +0.5, and the last line has a DOB of +1.0. Note that A4 is not affected by altering the DOB.

DOB #	A0	A1	A2	A3	A4	A5	A6	A7
-1.0	-5.6	+1.5	+4.8	+3.2	8.7	5.7	5.6	21.0
-0.5	-9.6	-1.4	+2.9	+2.2	8.7	6.7	7.5	24.0
0.0	-13.5	-4.4	+0.9	+1.2	8.7	7.7	9.5	26.9
+0.5	-17.4	-7.3	-1.1	+0.2	8.7	8.7	11.5	29.9
+1.0	-21.4	-10.3	-3.0	-0.8	8.7	9.7	13.4	32.8

The DOB is adjustable in one-tenth of a beat increments from –2.0 to +2.0. The above table steps by half a beat increments just to demonstrate the results.

NON-EQUAL TEMPERAMENTS

Another feature of the Sanderson Accu-Tuner III is the ability to alter tunings and add different temperaments without having to physically alter all 88 notes of a tuning. The Temperament pages allow a technician to store the rules of a temperament for twelve notes and select any tuning and alter the tuning with the selected temperament automatically. If the temperament page is selected before calculating the FAC tuning, the tuning will be stored to memory with the rules of the temperament added/subtracted to each of the notes as it is stored into memory. Now it is possible to develop your own temperaments and try them out on any piano.

STORING A TEMPERAMENT

Select a TEMPERAMENT page for storage by using the PAGE buttons to go above page 198 of regular pages of memory, above Sequence pages (SE 1,2,3,4), the next page of memory displays 1-7t, and the following page (after “1-7t”) displays “8-14”. Octave 1 on PAGE 1-7t is the first temperament storage location, the chart below lists where the stored temperaments correspond to the temperament number:

	PAGE 1-7t in memory
Octave 1	Temperament 1
Octave 2	Temperament 2
Octave 3	Temperament 3
Octave 4	Temperament 4
Octave 5	Temperament 5
Octave 6	Temperament 6
Octave 7	Temperament 7

	PAGE 8-14 in memory
Octave 1	Temperament 8
Octave 2	Temperament 9
Octave 3	Temperament 10
Octave 4	Temperament 11
Octave 5	Temperament 12
Octave 6	Temperament 13
Octave 7	Temperament 14

Just to repeat and reinforce the table above:

Temperament #1 is located on page 1-7t, Octave 1 note C1 through B1.
Temperament #2 is located on page 1-7t, Octave 2 notes C2 through B2.
Temperament #3 is located on page 1-7t, Octave 3 notes C3 through B3.
Temperament # 13 is located on page 8-14, Octave 6 notes C6 through B6.
Temperament #14 is located on page 8-14, Octave 7 notes C7 through B7.

To try out a temperament, the following temperaments are stored in the Accu-Tuner on temperament pages 8 through 14. The temperaments are listed below:

Temperament 8	Kirnberger III
Temperament 9	Meantone ¼ Comma
Temperament 10	Meantone 1/6 Comma
Temperament 11	Prinz Temperament
Temperament 12	Vallotti Temperament
Temperament 13	Werckmeister Temperament
Temperament 14	Young's Temperament

The following is a step by step example of storing a temperament to temperament page 6.

1) Turn on Accu-Tuner III

2) Press TUNE button

3) Use PAGE up button until arriving at the page labeled 1 - 7 t.
(If the pages stop before the desired page: hold down the SHIFT button, hold down the SHIFT 2 button and adjust the page stop using the PAGE buttons. For full directions, see page 21.)

4) Press NOTE up button three times to get to "C1 0.0"

5) Press OCT up button five times until the display shows "C6 0.0".

6) To verify we are at the correct location press the MEM button and we should see "C6 1 - 7t" press the TUNE button and we should see "C6 0.0". For our example we will use Marpurg's temperament listed in the table below, also see page 37 for more temperaments.

7) Press the CENTS up button until the CENTS display shows 2.0 cents.

8) Hold the SHIFT button down, and press the MEM button to store (release MEM and then release the SHIFT button). Now the display will show "C#6 2.0"

9) Change the cents deviation to agree with Marpurg temperament, use the CENTS button to get the display to show "C# 6 0.0"

10) Hold the SHIFT button down, and press the MEM button to store (release MEM and then release the SHIFT button).

11) Change the cents deviation to agree with the temperament, so use the CENTS button to get the display to show "D 6 5.9"

12) Hold the SHIFT button down, and press the MEM button to store (release MEM and then release the SHIFT button).

13) Change the cents deviation to agree with the temperament, so use the CENTS button to get the display to show "D# 6 3.9"

14) Hold the SHIFT button down, and press the MEM button to store (release MEM and then release the SHIFT button).

Keep repeating the storing process until the twelve notes for the temperament are stored.

Marpurg's Temperament

Note	Cents	Note	Cents	Note	Cents
C	2.0	E	2.0	G#	2.0
C#	0.0	F	0.0	A	0.0
D	5.9	F#	5.9	A#	5.9
D#	3.9	G	3.9	B	3.9

USING A NON-EQUAL TEMPERAMENT PAGE

To convert a page in memory to a non-equal temperament, select a regular tuning in memory, then select the corresponding temperament page. The Accu-Tuner will temporarily add the selected temperament on top of the selected page of memory. If we wanted to use temperament #6 that we had just stored (in the previous section), use the following directions:

1) Turn on the Accu-Tuner

2) Select the page of memory with the piano to tune, say it is Mr. XYZ's piano on page 61. Use the PAGE buttons to select page 61.

3) Select the temperament by holding down the SHIFT button and then press the TMPT up button until the cents display shows 6t (meaning we have selected the 6th temperament).

4) Now the NOTE up button is pressed the Accu-Tuner will look up the normal settings for the next note in memory and add the temperament automatically.

It is not necessary to select the temperament page after selecting the page in memory. Select the temperament page first and then the tuning second. A sequence page can also be added to the selected features, all of the features can be added on together.

When a temperament is selected a “t” appears in the right side of the cents display. By displaying the “t” the Accu-Tuner is warning the user, trying to avoid tuning an instrument with an unwanted temperament by mistake.

To turn off the temperament feature, select temperament page zero.

1) Hold down the SHIFT button
2) Press the TMPT down button until 0 is displayed in the CENTS window.

This will turn off the temperament feature and once again tune in equal temperament.

CALCULATING AN FAC TUNING WITH A TEMPERAMENT

By selecting a temperament before creating an FAC tuning, the FAC tuning will be calculated with the rules of the selected temperament added to that page in memory. Creating an FAC tuning with a temperament selected has one disadvantage: the “t” warning does not appear when the page is selected for tuning a piano. This is not a large problem as long as noted somewhere that the tuning is calculated with a non-equal temperament. The following procedure creates a tuning with an unequal temperament:

1) Turn on the Accu-Tuner.

2) Press the TUNE button.

3) Measure and store the three FAC numbers (for more information see page 10).

4) Use the PAGE buttons to select the page in memory.

5) Hold down the SHIFT button.

6) Press the TMPT (PAGE) up button to select the temperament for the tuning.

7) Release the SHIFT button.

8) Hold the STRETCH button.

9) Hold the MEM button.

10) Release the STRETCH button

11) Release the MEM button

The Accu-Tuner will calculate the FAC tuning with the rules of the selected temperament added/subtracted to the tuning as it is stored to the page in memory.

SEQUENCING

Sequencing is the ability to program the Accu-Tuner to follow one of four programmable tuning sequences. Selecting a sequence to use is similar to selecting a page in memory. Hold down the SHIFT and press the SEQ button up or down. First to appear in the CENTS display is the SE 1 page and as the SHIFT and SEQ buttons are held down SE 2, SE 3, or SE 4. Once a sequence is selected the Accu-Tuner will be tuning in a pattern following the sequence of notes stored on the selected page. You can select the sequence page before or after selecting a regular page of memory.

Instructions below demonstrate how to store a sequence to memory, and then next how to use the stored sequence.

STORING THE SEQUENCE

The Sequence pages are located just above page 198 in memory. The four sequence pages are listed as SE 1, SE 2, SE 3, and SE 4. The Accu-Tuner III has four sequences loaded into the memory at the factory; refer to the header listing for the temperaments and their locations.

To store a sequence of your own, use the following procedure:

1) Turn on the Accu-Tuner

2) Press the TUNE button

3) Select the sequence page for storing the sequence on using the PAGE up buttons. Sequence pages are located just above page 198 in pages of memory.

4) Use the Octave and Note buttons to get to the first note to be tuned in the sequence.

5) Use the cents up/down button until number 1 is in the cents window (there will not be a decimal point when storing on a sequence page).

6) Hold down the SHIFT button.

7) Press the STO-MEM button.

8) Release the STO-MEM button.

9) Release the SHIFT button. This will store the selected note into the tuning sequence.

10) Use the Octave and Note buttons to get to the next note in the tuning sequence.

11) Use the cents up/down button until the appropriate number (2 for the second, 3 for the third and so on) is in the cents window.

12) Follow steps 6,7,8,9 to store the selected note in the tuning sequence.

Keep repeating the process (steps 6 through 12) until the entire sequence is stored, up to eighty-eight notes.

To change a note in the sequence:

1) Make sure there is not a sequence page activated. Hold down the SHIFT button and press SEQ down until the display shows SE 0 in the cents window.

2) Select the correct SEQuence page (above page 198 by using PAGE buttons).

3) Use the NOTE and OCTAVE buttons until the note to be changed is in the NOTE/OCTAVE window.

4) Change the number in the CENTS window (using the CENTS buttons) to make the correction.

5) Hold down the SHIFT button.

6) Press the STO-MEM button.

7) Release the STO-MEM button.

8) Release the SHIFT button. This will store the note to the corrected location in the tuning sequence.

One note on storing a sequence: a note can only be assigned to one place in the sequence, for example, we cannot tune A-4 as the first note in the sequence and then also store A-4 as the tenth note in the sequence.

USING THE SEQUENCE PAGE

A Sequence page is used in conjunction with a regular tuning in memory; it cannot be used in the TUNE mode. To use a stored sequence page follow the procedure listed below:

1) Hold down the SHIFT button.

2) Press the SEQ button to select the appropriate sequence. The sequences loaded in from the factory are listed at the end of the header listing. Presently sequence 1 is the Potter F-A temperament, sequence 2 is Coleman F-F temperament, sequence 3 is the European A-A temperament, and sequence 4 is Baldassin-Sanderson 2 Octave temperament.

3) Release the SHIFT button

Once the sequence page has been selected the Accu-Tuner will calculate the tuning sequence and follow the tuning pattern laid out in the sequence page. You can select a page in memory before or after selecting the sequence page, either way the sequence will be followed.

STORING AN AURAL TUNING IN MEMORY

The following description assumes the piano is tuned and storing notes from AO to C88:

1) Turn the Sanderson Accu-Tuner on and press the TUNE button.

2) Set up the correct PAGE by using PAGE up or PAGE down to get to the desired page in memory to store this piano. Press NOTE up and then NOTE down to start with AO.

3) To start with any other note, use the OCTAVE and NOTE buttons to display the note to be recorded.

4) To set the partial, press the TUNE button. Set the display for the NOTE and OCTAVE of the desired partial, such as E3 (sixth partial) or A2 (fourth partial) to record the note A0 on the piano.

5) Now measure the pitch of the note on the piano by playing the note on the piano and use the CENTS buttons to stop the LEDs.

6) To double check before storing the information press the MEMORY button, the displays will show the note and octave and the page number. Press the TUNE button to display the partial selected and the cents deviation for this partial. Make any changes necessary.

7) When the settings are all correct, store the tuning for this note by holding down SHIFT, then pressing and releasing STO-MEM.

8) The Accu-Tuner will carry along the partial and the cents deviation after storing a note. Correct the cents deviation to agree with the pitch of the note and then store the note by holding SHIFT and pressing STO-MEM. While holding down the SHIFT button just after storing a note, the display will show the note/octave of the note being stored and the page in memory. Releasing the button toggles the display back to the partial and cents deviation.

9) After storing from A0 up to around C3 the LEDs will not register as clearly. When the display starts to become less clear, it is time to lower the partial. Assume a double octave-fifth (6 partial) was the selected partial and it is time to reduce the partial. Press the TUNE button, and then use the NOTE and OCTAVE buttons to get the display to the desired partial. Next measure the cents deviation (stop the LEDs while playing the note). Now before storing, let's double check by pressing the MEM button to display the note, octave and page number. Press the TUNE button to display the partial and cents deviation. If all settings are correct, then store the setting (hold SHIFT and press STO-MEM).

10) The partial will have to be lowered at different points on different pianos. FAC tunings use the double octave-fifth (partial 6) in the bass at A0-B2, double octave (partial 4) C3-B4, octave (partial 2) from C5-B5, and fundamental (first partial) from C6 on up to C8.

11) Continue along measuring and storing until the entire piano is stored.

STORING A TUNING IN MEMORY FROM A PRINTOUT

1) Turn the Sanderson Accu-Tuner on and press the TUNE button.

2) Set up the correct PAGE by using PAGE up or PAGE down to get to the desired page in memory. Then press OCT and NOTE buttons to get to the first note for storing.

3) Press the MEM button and the Accu-Tuner will display the NOTE and OCTAVE about to be stored along with the chosen PAGE number. Make any changes necessary.

4) Press the TUNE button and the Accu-Tuner will display the partial of the note about to store and the CENTS deviation for this partial. Make any changes necessary.

5) Store this note by holding down SHIFT and then press STO-MEM.

6) The Accu-Tuner will carry along the partial and the cents deviation after storing a note to memory. Adjust the cents to agree with the cents listed on the tuning chart. Then store the note by holding SHIFT and pressing STO-MEM. While the SHIFT button is held down during storing a note, the display shows the note and octave of the note being stored and the PAGE in memory that it is being stored to. This allows the hidden information to be checked as the tuning is stored.

7) Continue along entering the cents from the printout and then storing to memory (hold SHIFT and press STO-MEM) **until there is a change in the partial to be stored**.

8) In the case of an FAC tuning chart, the partial changes occur at C3, C5, and C6. When arriving at this point in the storing the tuning press the TUNE button and then enter the correct the partial and the

cents deviation (using the OCTAVE, NOTE, and CENTS buttons). Then double check (as in steps 3, 4) by alternating between MEM and TUNE buttons to verify the information before storing it (hold SHIFT and press STO-MEM).

9) Once the partial is set up correctly, all that needs to be changed is the cents setting and store. One tip: it is easier to mark the partial changes before storing the tuning, making it harder to forget the partial change while storing the tuning. Continue until the entire tuning is stored.

UP OR DOWN MEMORY STORAGE

The direction in which the memory advances while storing a tuning can be reversed. When the Accu-Tuner is first turned on, storing a note setting will increment the note setting to the next higher semitone. This may not be convenient when tuning and storing the bass notes. To change the storage direction, hold down the MEM button, hold down the NOTE down button, then release the MEM button and then release the NOTE down button. This procedure "teaches" the STO-MEM button that it should store and decrement the note setting. To get back to the normal direction, repeat the procedure using the NOTE up button instead of the NOTE down button.

MEMORY STORAGE WITH THE FOOT SWITCH

Storing a note to memory ordinarily requires two hands, one to hold the SHIFT button, and one to press the STO-MEM button. This was done deliberately to make it difficult to store notes accidentally, possibly wiping out a valuable tuning. When storing a piano to memory from a written record, or tuning and storing a piano as you go, the foot pedal can store the information quickly.

To teach the foot pedal to store notes, hold the foot pedal down, hold down SHIFT button, hold down STO-MEM, release the foot pedal, then release STO-MEM button, then release the SHIFT button. Now be sure to use the foot pedal with care, because it will store information into memory whenever it is pressed, and over write the information that was previously stored at that location.

When it is time to stop storing to memory, teach the footswitch a different task: hold down footswitch, hold down NOTE up, release footswitch, and then release NOTE up.

UP OR DOWN NOTE SWITCH

The direction in which the foot switch progresses across the keyboard can be changed from "up" to "down" and back again at will. When the Accu-Tuner is first turned on, the foot switch moves up the keyboard. To change the direction to down, hold the foot switch down, hold the NOTE down button, release the foot switch, and then release the NOTE down button. This little procedure "teaches" the foot switch to move down the keyboard instead of up. To reverse the direction again, repeat the above procedure holding the NOTE up button instead of NOTE down.

STORING THE PIANO SERIAL NUMBER

The Accu-Tuner can store six digits of the piano's serial number along with the tuning, to identify the tuning record with the piano. Serial numbers are stored on a page beginning two note locations below the lowest note, A0, with a maximum of three digits at each location (six total). The CENTS buttons set the number and then the SHIFT and STO-MEM buttons are used to store them.

To store a serial number on a page:
Go to the bottom of the memory page with OCT down. The left window will display SEr1, short for serial number, first three digits. Use the CENTS buttons to set the right window to the first three digits of a six-digit number corresponding to the serial number of the piano. (If the number exceeds six digits, ignore digits to the left of the sixth). Then store these digits with the SHIFT and STO-MEM buttons. Now the note/octave window will display SEr2, and store the last three digits of the serial number with the CENTS buttons, and then store with SHIFT and STO-MEM. The left window will now indicate A0, the first note of the piano.

To read the serial number:
Go to a specific page, and use OCT down to get to the bottom of the page. Read the first three digits of the serial number, then press NOTE up and read the second three digits.

To search for a specific serial number:
When the page is not known, remember the first three digits of the number while searching through memory. Look at the bottom storage location of each page. On each page, press NOTE down to see the serial number, and then press PAGE up to go to the next page. Alternate between NOTE down and PAGE up until the desired serial number is found. Then press NOTE up to check the last three digits and verify the serial number of the right piano.

TRANSMITTING PIANOS FROM ONE ACCU-TUNER TO ANOTHER

No computer is necessary to transmit pianos from one Accu-Tuner III to another. Connect a MIDI cable from the MIDI OUT connector of the transmitting Accu-Tuner III to the MIDI IN connector of the Accu-Tuner III that is about to receive a piano memory transplant.

CAUTION: The receiving Accu-Tuner III's pianos in memory will be lost when the transmitting Accu-Tuner III writes information on top of them.

Press the MIDI IN button of the receiving Accu-Tuner III, and then press the SHIFT and MIDI OUT buttons on the transmitting Accu-Tuner to start the transmission. After 4 to 32 seconds, depending on the number of pianos, the transfer will be completed. The display will show bUSY while the Accu-Tuner III is sending the information over the MIDI ports. The keyboard of the transmitting Accu-Tuner III will be locked up during transmission and will release after transmission is completed.

The transmitting Accu-Tuner III will transmit piano memory up to the number of pages set for the PAGE stop. The receiving Accu-Tuner III may have the same piano memory capacity, or it may have more or less, it doesn't make any difference to the MIDI operation.

If more pianos are transmitted than the receiving Accu-Tuner III can accommodate, the pianos are received and numbered correctly up to the receiver's maximum storage capacity. The extra pianos are transmitted but ignored, and they still remain in the transmitting Accu-Tuner III's memory. See page 21 for setting the Accu-Tuner III page number stop.

In the case where the receiver has greater piano capacity than the transmitter, pianos are received and numbered correctly up to the maximum number transmitted. Higher numbered pianos in the receiving Accu-Tuner III are not disturbed. However, the keyboard of the receiving Accu-Tuner III will not unlock because it is still expecting more pianos and will wait indefinitely for them. To get out of this locked condition, use the warm stop (SHIFT 2 and MIDI IN).

TUNING WITHOUT FAC

OLD F4 STRETCH TUNINGS

The Accu-Tuner still does one-point F4 stretch tunings as before. From a cold start, press the TUNE button, set the Accu-Tuner to F5, and tune F4 with tuning hammer. Set the Accu-Tuner to F6 and play the note F4, use the cents buttons to stop the LEDs on the Accu-Tuner. Next hold SHIFT button down, and press STO-STRETCH button, release STO-STRETCH, and then release the SHIFT button. Press the STRETCH button once more to get the Accu-Tuner calculating the C3 through F6 stretch tuning. Now the Accu-Tuner will be set up at C3 and ready to tune. It is not necessary to store the F4 stretch tuning to memory before tuning.

To store the C3 to F6 tuning to memory, zero out the other two stretch numbers (A4 and C6) with the following procedure: Hold down the STRETCH button and if A4 is displayed (if F6 is displayed then release the STRETCH button and press/hold the STRETCH button a second time) use the CENTS down button to bring the A4 stretch number down to zero. Release the STRETCH button and hold down the STRETCH button a second time and use the CENTS button to bring the C6 stretch number down to zero.

The F3 stretch number will remain the same, select the PAGE of memory to store the tuning, and then calculate the tuning by rolling over from STRETCH to MEM.

DIRECT TUNING THE HIGH TREBLE

Tuning the high treble without FAC is relatively easy. Press the TUNE button to get out of the F4 stretch mode. The best tuning for each note can be determined by reference to one, two or three already-tuned notes. These notes lay one octave, octave-fifth, and two octaves lower than the note being tuned.

1) Set the Accu-Tuner to the NOTE and OCTAVE of the note being tuned (in TUNE mode).
2) Play the reference notes one at a time and see how they look on the rotating LEDs.
3) Step the CENTS up or down until a cents setting that is a good compromise between the reference notes. A cents setting where some of the reference notes rotate slowly sharp and some rotate slowly flat.
4) Then tune the note.

Tuning is more challenging in the last octave because a good compromise may be impossible to find. Decide which interval will take priority and tune mainly to satisfy its requirements. At this point many tuners stick to the single octave, but tune one or two cents wide. Others prefer to tune the double octave, which gives a sharper top end, or the octave-fifth, which is quite a bit sharper. The choice is up to personal taste and the customer preference.

DIRECT TUNING THE BASS

Tuning the bass is similar in principle to tuning the high treble. Press the TUNE button to get out of the F4 stretch mode. Set the Accu-Tuner with reference to several previously tuned notes and compromise among them to place the note being tuned.

The best reference notes lay an octave, an octave-fifth, and a double octave-fifth higher than the note being tuned. To use these reference notes, set the Accu-Tuner a double-octave-fifth higher than the note being tuned (on its sixth partial).

1) Play each reference note one at a time.
2) Step up or down with the CENTS buttons until a good compromise setting is found, one where some reference notes are rotating slightly flat, others slightly sharp.
3) Tune the note.
4) Continue this procedure all the way down to A0.

In contrast to the situation in the high treble where the three tests diverge, the three bass tests usually work nicely all the way down to A0.

PATENT NOTICE

The method of tuning a piano by measuring its inharmonicity and then creating a numerical tuning customized to fit that piano are the subject of Patent No. 5,285,711, issued to Dr. Albert E. Sanderson of Inventronics, Inc., and other patents pending.

INPUT-OUTPUT JACKS

There are six input-output jacks on the back of the Accu-Tuner that increase the versatility of the Accu-Tuner for various special purposes. The jacks on the back of the Accu-Tuner are shown in figure 6 below.



Fig. 6. Left-Side Jacks and Right-Side Jacks

AUDIO IN: An electrical audio input jack. Signals are fed into this phono jack for silent measurements of pitch, or tuning electronic musical instruments. This input is suitable for levels from 0.01 to 10 volts.

MAG IN: A miniature telephone jack for magnetic pick-ups. Magnetic microphones typically have an output of a few millivolts, and this input is designed only for such low-level signals. Connecting a large signal to this input will destroy the input circuit. Use the AUDIO IN jack for large signals.

FLTR OUT: A phono jack output from the audio filter. The audio filter amplifies sounds whose pitch corresponds to the pitch selected on the Accu-Tuner. It is useful for listening to the beats at the coincident partial of two notes forming a musical interval. This feature can be a valuable training aid for aural tuners.

OSC OUT: A phono jack, which puts out a modified sawtooth wave (one that is quite pleasant to listen to) at the pitch called for by the settings of the Accu-Tuner controls. This has a variety of uses. The frequency calibration of the instrument can be checked with this output. It can also be fed into an amplifier and broadcast, to give an aural pitch standard for any purpose. One purpose is an aid to fast piano chipping or rough pitch raising.

NOTE SWITCH: A subminiature telephone jack, that accommodates the foot switch, or thumb switch which is used for stepping up/down the NOTE settings one semitone at a time. A foot switch is supplied as standard equipment, but any switch can be used for this purpose. The contacts must be the "normally open, momentary contact" type, and each time contact is made, the NOTE setting will advance by one semitone.

BAT CHGR: Used for charging the battery. DO NOT use battery chargers other than ones recommended for the Accu-Tuner III, even when the plug is compatible with the Accu-Tuner jack, because voltage ratings differ, and too high voltage may damage the battery charger circuit in the Accu-Tuner. (The Radio Shack model 273-1770 is a compatible unit.) The battery will be eighty percent charged after a period of two hours, completely saturated after eight hours.

BATTERY CARE

NICKEL-METAL HYDRIDE

The battery used in the Sanderson Accu-Tuner III, is the nickel-metal hydride (NiMH) battery. The new NiMH will run the Accu-Tuner for 60 to 80 hours, and can be recharged hundreds of times. To achieve the longest battery life we do recommend that the Accu-Tuner be used until the "Lo-Bat" signal is displayed in the left LCD. NiMH batteries do not benefit from nightly charging, but will last longer if used to capacity before recharging.

BATTERY CHARGING CIRCUIT

The NiMH battery in the Accu-Tuner III has a large capacity and hence a larger AC adapter than previous Accu-Tuner adapters. When the Accu-Tuner charger is first plugged in both the red and green LED's near the charger jack will light up, and the two LED's indicate that the charger is working and the Accu-Tuner is charging in the high current mode. The battery will charge at high current for roughly one and a half hours before stepping down to a trickle charge stage. During the high current charging the back of the Accu-Tuner III near where the charger plugs in will get warm, this is normal. When the Accu-Tuner III

shifts down to the trickle charge stage the red LED will no longer be lit. The green LED will stay lit as long as the charger is plugged in. The battery is charged to roughly eighty percent during the high current charging and gets topped off with the trickle charging. Inventronics still recommends charging the Accu-Tuner III overnight, but the majority of the charging occurs in the first two hours.

TWO YEAR WARRANTY

INVENTRONICS offers a 2-year warranty from date of purchase*, on parts and labor. We will repair or replace the Accu-Tuner, as determined at the factory, should it be found defective. This warranty is not transferable, and applies only to the original purchaser of the equipment. Damage from the result of misuse, modification, or tampering with the equipment will void this warranty.
*The foot switch is not covered under warranty.

PTG EXAMINATION PROGRAM

Giving the Piano Technicians Guild Tuning Examination with the Sanderson Accu-Tuner III

INTRODUCTION

The Sanderson Accu-Tuner III includes a program for scoring the Piano Technicians Guild Tuning Examination quickly and easily. A section of the memory resides below Page 0 of conventional piano memory, with pages identified through three letter abbreviations that describe the pages' functions. Eight memory pages have been created as follows: Pages SUP 1, SUP 2, SUP 3, SUP 4 are for storing the master tunings or so-called SUPertunings for the test pianos. Page “EEE" stores the ExaminEE's tuning; Page "POI" stores the POInt scores for the individual notes according to the weighting (cents per point) of the PTG Tuning Examination. Page “UUU" stores a standard UntUUning based on the selected SUP page, and is used to standardize the untuned condition of the piano at the start of the test. Finally, page “DFF" stores the DiFFerence in cents between pages EEE and SUP for those who want to analyze their point scores. The following table explains the location of the PTG pages of memory.

Page -1	EEE	Examinee page
Page -2	POI	Points page
Page -3	SUP1, SUP2, SUP3 or SUP4	Supertuning page
Page -4	DFF	Cents Difference page
Page -5	UUU	Untuning page

To score the PTG tuning exam, store the supertuning on the selected SUP page of the memory, and store the examinee's tuning on page EEE. After selecting the supertuning page or the examinee page hold the SHIFT and press the STO MEM key to store the information to that page in memory.

Store the lowest note of the examinee's temperament octave by stepping to that note and octave and recording it in the computer by holding the SHIFT 2 and pressing the STO TMPT. Then hold SHIFT 2 and press SCORE to store all the calculated point scores on page POI. Before writing down the examinee’s point score be sure to verify the SUPertuning page number which is listed to the right of the cents deviation. The note and octave display will automatically jump to the starting note of the examinee's temperament octave, confirming that this note has been properly stored, and display the point score for that note. Now scan through the notes and find those which have points scored against them, and write these down on the standard PTG scoring form. Hold down the NOTE-UP or the NOTE-DOWN buttons and the Accu-Tuner will step along until it finds a nonzero point score--then it stops allowing the examiner to write down the score for that note. Then step along to the next non-zero point score by pressing NOTE UP/DOWN.

A time-saving feature is page UUU, the untuning page. To prepare the piano for the next examinee, go to this page and tune each note to stop the LEDs. Notes settings are de-tuned by an amount equal to four times the PTG tuning tolerance, alternatively flat and sharp.

STORING THE SUPERTUNING FROM THE PIANO:

Storing the SUPertuning must be done on one of the SUP pages. The procedure is exactly the same as storing a piano to regular piano memory with one very important simplification--it is impossible to store a note using the wrong partial. The PTG specifies which partial to use when storing every note of a supertuning: fourth partial in the bass, second in the midrange and the fundamental in the treble. These partials are built into the program to make it impossible to store a tuning on the wrong partial.

To store the supertuning select the appropriate SUP page in memory by holding the SHIFT 2 button and pressing the SUPER (PAGE) button. Then use the PAGE button (release the SHIFT 2 button) to get to the equivalent of Page -3 (3 steps below page zero). Set the NOTE and OCTAVE readings to indicate the note to be stored. Then play the note and stop the rotation of the LEDs with the CENTS buttons. (It isn't necessary to select the correct partial, as mentioned above.) When the LEDs are stopped, hold down SHIFT and press STO-MEM (release STO-MEM first then release the SHIFT button last) to store the setting. Then the note will automatically advance one semitone, waiting for the LEDs to be stopped and store the note. Keep going until the whole tuning is stored (C1 to B7).

STORING THE EXAMINEE'S TUNING:

Storing the ExaminEE's tuning is done on page EEE. The same as storing a super tuning except select the EEE page of memory. The PTG partials are automatically selected which make it impossible to store a tuning on the wrong partials.

To store the examinee's tuning go to page EEE in piano memory, use the PAGE buttons to go below page zero in memory, the first page below zero is EEE. Set the NOTE and OCTAVE readings to indicate the note to be stored. Then strike the note on the piano and stop the rotation of the LEDs with the CENTS buttons. When the LEDs are stopped, hold SHIFT and press STO-MEM to store the setting. Then the note will automatically advance one semitone ready to stop the LEDs and store the next note. Follow the same procedure (stop the LEDs and store the information) until the whole tuning is stored (C1 to B7).

STORING THE START-OF-TEMPERAMENT NOTE:

The examinee must state his choice of temperament octave. Set the NOTE and OCTAVE to the lowest note of that octave and store this choice by holding SHIFT 2 and pressing STO TMPT.

SCORING THE TEMPERAMENT:

To score the examinee's tuning, hold the SHIFT 2 and press the SCORE button. The display will go to the starting NOTE and OCTAVE of the chosen temperament octave, and the CENTS display will indicate the POINTS scored against that note. A zero indicates that the note is within tolerance; any other number is the point score. The absence of a sign indicates that the note is sharp, and a minus sign indicates that the note is flat.

To score the remaining temperament notes, press the NOTE-UP button and watch the CENTS window. The note will continue to advance as long as there is a zero point deduction. When a note is reached that is out of tolerance the display halts. Release the button and write down the points in the proper NOTE and OCTAVE box of the PTG Test Scoring form. After the temperament octave has been scored and verified, continue scoring the rest of the tuning. However, if a note in the temperament is found to have been measured incorrectly, or if any entry in either the supertuning or examinee's pages is changed for any reason, then the test must be re-scored before going on. Fortunately, re-scoring is just a matter of holding the SHIFT 2 and pressing the SCORE button once again.

SCORING THE REST OF THE TEST:

The rest of the test is scored the same way that the temperament was done. The notes can be scored in any order. Holding the NOTE-UP or NOTE-DOWN buttons will step the note along until a point score other than zero is encountered. Write the score down in the appropriate box of the scoring form.

The tolerances built into the Accu-Tuner for each octave are those of the PTG Tuning Exam, namely, 6 cents in octave 1, 3 cents in octave 2, 1 cent in octaves 3 and 4, 2 cents in octave 5, 3 cents in octave 6,

and 6 cents in octave 7. Notes AO, A#O, BO and C8 are not scored in the PTG exam, but may be scored with the Accu-Tuner for teachers and students at the same tolerance as their neighbors.

USING THE PAGE DIFFERENCE:

The DiFFerence page indicates the actual cents difference between the selected supertuning and the examinee's tuning, after the normal pitch adjustment of the examinee's tuning to match the pitch of the master tuning over the selected temperament octave.

This page is not used during the PTG exam, but is in the Accu-Tuner for those interested in seeing the cents difference. It can be used by teachers and students to see how close to the line a given score was, keeping in mind the tolerances above listed for each octave. The point score is calculated by dividing the cents difference given on this DFF page by the tolerance. Retain only the number before the decimal point for the point score.

PITCH CORRECTION NUMBER:

The pitch correction number is no longer used to score the examinee's pitch error (as of July 1986). However it may still be useful for some teachers and students, and is included in the program for those interested. To see the pitch correction number, hold down the SHIFT 2, press the SCORE button, and read the number in the cents windows. (When this button is released the reading will revert to a point score.) Pitch score is the pitch deviation of note A4 from 440Hz.

The pitch correction number is defined as the average of the examinee's thirteen temperament notes minus the average of the same thirteen notes of the supertuning. It therefore represents the average flatness or sharpness of the examinee's tuning, rather than the pitch of any one note. The examinee's tuning is corrected for this average discrepancy before it is scored, so that the best possible score will result, with roughly an equal number of flat and sharp notes scored against the tuner in the temperament.

UNTUNING THE PIANO FOR GIVING THE EXAM:

Before the exam is given, the piano must be untuned by a standard amount as specified by the PTG Examination Manual. This is taken care of by page UUU, which uses the supertuning page SUP to generate an untuned setting equal to the setting from page SUP plus or minus four times the tuning tolerance for that particular note. Flat and sharp deviations alternate. For example, the tolerance for C3 is one cent so C3 is tuned four cents sharp with respect to the supertuning, C#3 is tuned four cents flat, D# four cents sharp, etc. Where the tolerance is six cents, the notes are tuned alternately twenty-four cents flat and sharp.

APPENDIX A

Concise Step-by-Step Tables of Standard Routines

1. Recalibration in Tune or Stretch Mode:
SHIFT, CAL, release CAL, release SHIFT, CENTS up or down to stop LEDs, TUNE. You are at A4, 0.0 cents and calibrated to 440.00 Hz.

2. A. Auto Stepping On
Up – Hold SHIFT, press NOTE up, **Down** – Hold SHIFT, press NOTE down
B. Auto Stepping Off
Up – Hold SHIFT, press NOTE up, **Down** – Hold SHIFT, press NOTE down

3. Sequencing
On - Hold SHIFT, press SEQ to select the sequence number (one through four) desired.
Off - Hold SHIFT, press SEQ to select the sequence number zero.

4. Storing a sequence
Page up beyond page 198 to Ser 1, Ser 2, Ser 3 or Ser 4 page to store the sequence. Go to the first note to tune in the sequence. 1 in the cents window, hold SHIFT, press STO MEM, second note in sequence, 2 in the cents window, hold SHIFT, press STO MEM, continue till sequence completely stored.

5. Adjusting Double Octave Beat

On - Hold SHIFT, press the D.O.Beat until the desired additional stretch is displayed.

OFF - Hold SHIFT, press the D.O. Beat until 0.0 is displayed.

7. Measurement and Storage of FAC Stretch Numbers:

TUNE, NOTE=F, OCT=5, CENTS=0.0, tune F3 to stop LEDs, OCT up to 6, CENTS up or down to stop LEDs, SHIFT, STO-STRETCH. (NOTE=A, OCT=5, CENTS=0.0) Tune A4, OCT up to 6, CENTS up or down to stop LEDs, SHIFT, STO-STRETCH. (NOTE=C, OCT=6, CENTS=0.0) Tune C6. OCT up to C7, CENTS up or down to stop LEDs. SHIFT, STO-STRETCH. PAGE up to correct page, hold STRETCH, hold MEM, release STRETCH, and release MEM. After five seconds A0, ready to start tuning.

8. Non-440 Calibration:

TUNE, CENTS up or down to required offset (i.e., 8.0 cents = 442 Hz, 4.0 cents per Hertz), SHIFT, RST, release RST, release SHIFT. Your instrument is calibrated to non-standard A, and the NOTE/OCTAVE window shows + or - to indicate sharp or flat. (This offset is used and changed by pitch-raise calculator).

9. Storing One Note in Memory:

Press PAGE up or down to page number of desired piano. Then use the octave and note buttons to get to the correct note on the piano. To change the partial: Press the TUNE button (then the partial will be displayed), use the NOTE and OCTAVE buttons to display the desired partial, and use the CENTS button to get to the desired pitch. To store this, hold down the SHIFT button and press STO-MEM. To check that proper note has been stored, press NOTE down, TUNE, to check partial's note, octave, and cents, then MEM to see piano's note octave, and page number.

10. Storing Consecutive Notes on Same Partial:

Set up the first note and store it exactly as described above. The Accu-Tuner automatically goes to the next semitone keeping the partial relationship constant. To store the next note, press CENTS up or down to the new setting, SHIFT, STO-MEM. Repeat storing consecutive notes until the partial number changes.

11. Changing the Partial on a Page of Memory:

Press TUNE, then NOTE up or down to pitch of new partial, OCT up or down to pitch of new partial, CENTS up or down to pitch of new partial, SHIFT, and STO-MEM. You have stored one note at the new partial number, and may proceed with storing consecutive notes until the partial number changes again.

APPENDIX B

Cents Tables for Non-equal Temperaments

Pythagorean Temperament.

A	0.0	Db	-15.6	F#	5.9
A#	13.7	D	-2.0	Gb	-17.6
Bb	-9.8	D#	11.7	G	-3.9
B	3.9	Eb	-11.7	G#	9.8
C	-5.9	E	2.0	Ab	-13.7
C#	7.8	F	-7.8		

The usual practice is to use only the above flats.

Meantone Temperament

A	0.0	Db	27.4	F#	-10.3
A#	-24.0	D	3.5	Gb	30.8
Bb	17.1	D#	-20.5	G	6.8
B	-6.8	Eb	20.5	G#	-17.1
C	10.3	E	-3.4	Ab	23.9
C#	-13.7	F	13.7		

The usual sharps and flats are C#, F#, G#, Bb, and Eb.

Marpurg's Temperament 1.

A	0.0	C#	0.0	F	0.0
A#	5.9	D	5.9	F#	5.9
B	3.9	D#	3.9	G	3.9
C	2.0	E	2.0	G#	2.0

Werkmeister III, Correct Temperament No. 1

A	0.0	C#	2.0	F	9.8
A#	7.8	D	3.9	F#	0.0
B	3.9	D#	5.9	G	7.8
C	11.7	E	2.0	G#	3.9

Kirnberger III, Corrected Temperament

A	0.0	C#	2.0	F	9.8
A#	7.8	D	3.9	F#	2.0
B	0.0	D#	5.9	G	7.8
C	11.7	E	-2.0	G#	3.9

Young's Temperament No.1

A	0.0	C#	-3.9	F	3.9
A#	2.0	D	2.0	F#	-5.9
B	-3.9	D#	0.0	G	3.9
C	5.9	E	-2.0	G#	-2.0

Vallotti or Fairchild Temperament

(REF: Piano Technicians Journal, Oct. 82, p.20.)

Steve Fairchild independently developed this temperament in 1982 while looking for a temperament to smooth out the simple keys on small pianos. It greatly reduces the harshness caused by excessive inharmonicity, and for that reason could also be called the "Piano Teacher's Delight" temperament.

A	0.0	C#	0.0	F	7.8
A#	5.9	D	2.0	F#	-2.0
B	-3.9	D#	3.9	G	3.9
C	5.9	E	-2.0	G#	2.0

Cents Offset for Hz at A4

Frequency of A4	Cents Offset
446	23.5
445	19.6
444	15.7
443	11.8
442	7.9
441	3.9
440	0.0
439	-3.9

Frequency of A4	Cents Offset
438	-7.9
437	-11.8
436	-15.8
435	-19.8
430	-39.8
420	-80.5
415.3	-100.0
415	-101.3

Formula for calculating cents offset of A4 at 420Hz: Log (420/440, 2)*1200 = -80.54

APPENDIX C

Aural and Visual Tuning

(The best of both worlds)

By James W. Coleman, Sr.

Owen Jorgenson wrote the definitive work on temperaments and tuning. In his book "Tuning the Historical Temperaments" he traces the natural progress of aural tuning systems from the Pythagorean and Just Intonation systems through several Meantone temperaments to the Well temperaments and the Equal temperament. It is this last system in which most piano technicians are engaged. The basis of this system is the need or desire to be able to play in all keys with equally out of tune parallel intervals. This need was borne out of the practice of composers who became far-ranging in their tonalities of a particular composition.

The earliest popular approaches to tuning the equal temperament involved tuning a series of twelve 4ths or 5ths such that each 5th was narrowed slightly and each 4th was widened slightly in such a way that they were all equally out of tune. The difficulty with this approach was that it took 12 steps before one could tell if he was doing alright.

More recent approaches to equal temperament involve one or two test intervals for each step taken in the tempering system. More care is being given to insure that each interval (such as the minor 3rds, major 3rds, 4ths, 5ths, minor 6ths, major 6ths) is equally tempered and is compatible with all its parallel similar intervals. Some of the more popular recent temperament systems are by George Defebaugh, Bill Stegeman, Dr. Al Sanderson (2 octave A-A temp) James Coleman (F-A temp) and Mark Peele (10th temp). These may be seen demonstrated at various Piano Technician's Guild Institutes, Conferences and Seminars.

Since the Stretch Calculator tunings involve the accurate tuning of the 4th partial of each note in the F-F temperament, all the intervals which involve the 4th partials will be beautifully tempered (such as major 3rds, 4ths). Other intervals such as minor 3rds, major and minor 6ths, which are involved with higher order partials, will also be beautifully tempered. Since the greatest irregularity in partial alignments occur in the 1st, 2nd, and 3rd partials, there may be some slight unevenness heard in the octave and 5ths.

Now, by the simple practice of playing certain test intervals while tuning with the Stretch Calculator mode, one can have a double check on his aural test as well as assuring that the visual judgments are more accurate. If one tunes the stretch tuning system from top to bottom or at least from C5 down, when the 4th 1/2 step down is achieved, a major 3rd aural test is available without the upper note interfering with the LED display. In arriving at the seventh 1/2 step down, a 5th is available for aural judgment without LED interference from the upper note of the interval. This 5th interval can be followed on down to C3. One may notice a slight variation in the sound of the 5ths especially as one approaches the lower area of the scale. Sometimes this is merely due to the slipping or instability of the previously tuned upper note of the 5th. But, with the shorter scaled pianos, irregularity of the lower partials may cause the beat frequency to be greater than expected. At this point one may make a decision to alter the lower note to smooth out of the 5th interval (which of course may change the beat rate in other intervals based on this lower note). By doing this judiciously one can have a better tempering than can be had with either aural or visual methods alone.

APPENDIX D

What are Partials and Beats?

By James W. Coleman, Sr.

A piano string has a series of partials (sometimes erroneously called harmonics) which are approximately whole number multiples of the fundamental frequency (first partial). For example the 3rd A on a piano (counting from A0, A1, A2) has a theoretical frequency of 110 cycles per second (or Hertz). If it is multiplied by 2, you have 220 Hz (2nd partial). If one places his finger lightly on the middle of a string, he can force it to vibrate at its 2nd partial. If A2 is lightly touched at a distance of 1/3 the length from one end after the note is played, the string will be forced to vibrate at its 3rd partial (approximately 330 Hz which is

3 times the fundamental pitch). One can continue to divide the string by 1/4, 1/5, 1/6, 1/7, 1/8, etc. This will cause the string to sound at its 4th, 5th, 6th, 7th, and 8th partials respectively.

In order to further clarify, let me say that when a string is forced as above to vibrate in three parts by touching it at the 1/3 point, we say that this is the 3rd partial because one can see the string breakup into 3 parts with 2 nodal points in between. At the same time one notices that the pitch jumps one octave plus a 5th (19 half-steps above).

One should learn the note location for the partial series for each note of the chromatic scale. Here are the notes that correspond to the locations of the first 12 partials of the note Middle C.

C4	C5	G5	C6	E6	G6	Bb6	C7	D7	E7	F#7	G7
	Oct	5th	4th	3rd	3rd	3rd	2nd	2nd	2nd	2nd	half

When one is listening to various tempered intervals, there is at least one particular area where one can hear the beat phenomenon between coincident partials of the two notes. For example: when listening to the 5th (F3-C4), these 2 tones have partials which occur in close proximity to the note C5 (the 3rd partial of F and the 2nd partial of C). These are called the first of lowest coincident partials. If there is a slight difference in the pitch of the two coincident partials, one can hear a slight waver in the tone. This is called the beat phenomenon at the pitch of C5. It is the difference of frequency or Hz of these two partials. One can calculate the beat speed if one knows the cents reading of each of these two partials. The following formula is helpful to convert cents difference to beats per second!

Beats=ref. note Hz x 2 raised to (upper cents deviation/1200) minus ref. HZ x 2 raised to (lower cents dev./1200).

The reference note frequency can be found in charts, but it is so easy to calculate using the 1/12 root of 2, which is the half step ratio. If we need to know the Hz of C5 we merely multiply A440 times 1.0594631 three times to get 523.2251. In the process we find A# at 466.164, B 493.883. If we wish to find Hz below A440 we divide by 1.0594631. G# equals 415.305, G=391.995 etc.

Now let's use the formula above to find the beat rate of the interval F3-A3 (Major 3rd). The 5th partial of F3 is at the note location of A5. The 4th partial of A3 is also near A5. When properly tuned, on most pianos they will create a beat rate of approximately 7 beats per second. Let's say that the 4th partial of A3 reads +3.7 cents and the 5th partial of F3 reads -10 cents at the reference note of A5 (880 Hz). At A5, -10 cents is the same as G# +90 cents since we have 100 cents per half step. Now, taking the higher reading first, we have
Ref Hz 880 x (2 raised to (3.7/1200)) = 881.883
Ref Hz 830.61 x (2 to (90/1200) power) = 874.932
This leaves us with a difference of 6.95 Hz, which is the beat frequency of the lowest coincident partials of these two notes.

With the aid of a scientific calculator one can easily compute the beat rate of any interval. Dr. Sanderson has an excellent set of notes on how to tune a beautiful 2 Octave Temperament by carefully measured intervals using either aural principles or machine techniques. You may find it interesting to measure your resulting interval widths after setting a careful machine tuning or vice versa, you may find it more interesting to measure interval widths after very carefully tuning by ear.
(See Appendix E)

APPENDIX E

The Two-Octave "A" Temperament

By Dr. A.E. Sanderson

The two-octave A temperament is probably the first temperament designed to take into account the inharmonicity of pianos strings. Inharmonicity not only changes the beat rates from their theoretical values for all intervals on a piano, it also creates impossible tuning conflicts as well. The simple octave splits up into different kinds of octaves, depending upon which pair of coincident partials are tuned to zero beat. Even the single, double, and triple octaves are incompatible intervals on a piano, and can only be tuned to sound "as good as possible," not perfect, because inharmonicity makes perfection literally unattainable.

The two-octave A temperament is tuned from the "outside in." That is, the wide intervals, two octaves and the double octave, are tuned first. This is done so that octave tuning problems with a piano will show up at the earliest possible stage when they are relatively easy to correct with small compromises. Many pianos have, unfortunately, incompatible tuning requirements, and by tuning the three A's first, we can establish a double octave and two octaves that fit as well as is possible both with each other and with the scale of the given piano.

Next we subdivide this wide interval into six equal parts by tuning six contiguous major thirds that fit between the three A's perfectly. Finally, with every fourth note already tuned, we fit the three missing notes within each major third primarily by tuning a pattern of thirds and fourths.

Tuning wide intervals first and then subdividing them has important advantages over the usual methods of building up wide intervals by tuning a succession of narrow ones. In the first place, it guarantees that the wide intervals will be as harmonious as possible, and that the narrow intervals will be adjusted or forced to be compatible with them. Secondly, small errors in tuning narrow intervals cannot add up to become large errors in the wide intervals, no matter how difficult the scale of the piano. This not only leads to greater accuracy on well-scaled pianos, but also greatly reduces the number of problems associated with tuning poorly scaled pianos.

Direct-Interval Tuning

Direct-interval tuning is a way of using the Sanderson Accu-Tuner that exactly simulates the way fine aural tuners tune by ear. Each interval is tuned by setting its width to a specified number of cents, which is verified by a direct measurement. Hence the term "direct-interval tuning". The sequence of intervals followed is circular, just as in aural tuning, and this makes it quite easy for the tuner to check each interval aurally as it is tuned. (If you are not familiar with measuring the width of intervals in cents, refer to the section entitled "Measuring the Width of Musical Intervals").

First, two single octaves and the double octave are tuned using direct-interval measurements. Second, the double octave is subdivided in six equal parts with a set of contiguous major thirds that mathematically fit this span perfectly, as determined by direct interval measurements. This leaves every fourth note tuned, and the three untuned notes within each major third are then tuned with fourths and thirds, again by direct interval measurements. Follow the step by step procedure below, and be sure to check all intervals aurally as you tune:

Step 1. Tune A4 to zero cents, and A3 from A4 as a 2-4 octave 1 cent wide. (Refer to Appendix H if you are not familiar with the different kinds of octaves.)

Step 2. Tune A2 from A3 as a 3-6 octave 1 cent wide. Check the A2-A4 double octave, and if it is more than 4 cents wide, divide the excess by three and narrow both octaves by this amount. (E.g., if double octave is 5.5 cents wide, 5.5-4 is 1.5, divide by 3, and narrow both octaves .5 cent.)

Step 3. Tune three major thirds of equal cents width between A2 and A3. You must first guess how wide to tune them and then see how the guess works out and revise it if necessary. A good first guess is 13.5 cents. So tune F3 from A3 13.5 cents wide, then C#3 from F3 13.5 cents wide. Measure the width of the A2-C#3 third. If it is also 13.5 cents wide, you were lucky and these three thirds are the correct width on the first guess. If you were not so lucky, average the three thirds (two of which were 13.5 cents wide), and tune all three to this average value by retouching C#3 and F3.

Step 4. Now tune C#4 from A3, and F4 from C#4, as thirds of this same value. You have now tuned five contiguous thirds all the same width, a width that fits exactly the A2-A3 octave. To see whether this width fits the A3=A4 octave, measure the width of the last third, F4-A4. If this agrees with the other thirds, you were lucky again and these six thirds are all tuned. If you weren't lucky, take the discrepancy of the last F4-A4 third, divide it by 3, and move F4 by this amount in the direction that will reduce the discrepancy. (E.g., if you had five thirds at 13.5 cents, and the last was 12 cents the discrepancy is 1.5 cents. Take one-third of this, 0.5 cents, and move F4 flat by this amount. This leaves you with four thirds at 13.5, one at 13, and one at 12.5. This is quite reasonable on that "inharmonic instrument," the piano).

Step 5. Now every fourth note is tuned from A2 to A4. Fill in the missing notes between F3 and C#4 to get a nine-note mini-temperament. You must now take a guess at the width of the fourths, try it on the mini-

temperament, and revise it as necessary to make the fourths fit with the thirds, whose width you already know. A good first guess for fourths is 2.5 cents. Tune up a fourth from F3 to A#3 down a third from A#3 to F#3, up a fourth from F#3 to B3 and stop. Now tune down a fourth from C#4 to G#3, up a third from G#3 to C4, down a fourth from C4 to G3 and stop. You have filled in the six missing notes of the mini-temperament, now you can tell whether your guess on the width of the fourths was correct from the width of the G3-B3 third, which is the check interval.

Step 6. Measure the width of the G3-B3 third and compare it to what it should be. If it is smaller than the other thirds, your fourth guess was also too small, and vice versa. The size of the error in the fourths equal one-quarter the error in the G3-B3 check interval because four fourths were tuned to get to the check interval.

Step 7. Retune the mini-temperament as in Step 5 with the new correct value for the widths of the fourths. Check it aurally to see that you have five perfectly rising thirds, and four equally good fourths. This result can always be achieved even on the most poorly scaled piano, since we have not been asked to make any compromises up to this point.

Step 8. Tune outwards from the mini-temperament with major thirds down to A2 and up to A3. The thirds tuned downwards are constant width but the thirds tuned upwards may have to be calculated if their width varies. Use straight-line interpolation based on the three known thirds in the A3-A4 octave, to get numbers for the missing thirds. (E.g., in Step 4 these three thirds, A3-C#4, C#4-F4 and F4-A4 were 13.5, 13, and 12.5 cents, respectively. Straight-line interpolation gives values of 13.4, 13.3, and 13.1 for A#3-D4, B3-D#4 and C4-E4, and 12.9, 12.8, and 12.6 for D4-F#4, D#4-G4 and E4-G#4, respectively).

Step 9. The electronic tuning of the two octaves A2-A4 is now complete. A very careful aural check is advisable at this point. Pay particular attention to the fourths, which are wider than theoretical owing to the effects of inharmonicity. The fifths are purer than theoretical for the same reason, and rarely cause any trouble.

Aural Tuning

The two-octave "A" temperament may be tuned aurally with exactly the same note-tuning sequence. This makes it easy to check an electronic tuning aurally at every step--very helpful in avoiding errors. Aural tuners can study and possibly improve their tuning by using the Accu-Tuner to measure the width of tuned intervals after setting this two-octave temperament very carefully by ear.

Step 1. Tune A4 to 440 Hz. Use F2 as test note, 17th to fork should beat same as 17th to A4. Tune A3 from A4 as a 2-4 octave, 1\2 beat wide. That is, the tenth should beat 1\2 beat per second (bps) faster than the third.

Step 2. Tune A2 from A3 as a 3-6 octave 1\2 beat wide. That is, the major sixth should beat 1\2 bps faster than the minor third.

Step 3. Check the double octave, a 1-4 interval to be less than 1 beat wide. That is, the 17th beat should be less than 1 bps faster than the third. If the double octave is too wide, compromise both octaves slightly to get and acceptable double octave.

Step 4. Divide the A2-A3 octave into three equal parts by tuning C#3 and F3. These thirds can be tested very accurately with the contiguous thirds test. This test states that two contiguous thirds must have relative beat rates in the ratio of 4 to 5, that is 4 beats of the lower one require the same amount of time to complete as 5 beats of the upper one. This test then does not require knowledge of beats per second, only a good sense of rhythm or tempo. In this case, C#3 and F3 are correctly tuned when 4 beats of A2-C#3 occur at the same tempo as 5 beats of C#3-F3, and in addition, 4 beats of C#3-F3 occur at the same tempo as 5 beats of F3-A3.

Step 5. Now tune C#4 and F4 to divide the A3-A4 octave into three equal parts with thirds. You may have to taper the width of the thirds downwards slightly in the upper octave on account of the inharmonicity of the piano.

Step 6. Check that the three major tenths formed on the seven notes tuned so far also in the ratio of 4 to 5. Also check the C# and F octaves with both the third-tenth and minor-third-sixth tests. Scale problems will show up at this stage, and it may be necessary to compromise slightly the perfectly rising thirds to get satisfactory octaves and tenths.

Step 7. Fill in the six untuned notes between F3 and C#4 to get a nine-note mini-temperament, but be sure not to change already tuned notes. Tune up a fourth from F3 to A#3, down a third from A#3 to F#3, up a fourth from F#3 to B3 and stop. Then tune down a fourth from C#4 to G#3, up a third from G#3 to C4, down a fourth from C4 to G3 and stop. Check the G3-B3 third, which is the test interval for this tuning. If it is too small, you must expand your fourths, and vice versa. With just nine notes to worry about, it is always possible to get five perfectly rising thirds and four matched fourths no matter how poorly scaled the piano may be. The beat rates may not be very close to theoretical, but they will be right for the given piano and its inharmonicity characteristics. So tune the piano, and let the beat rates fall where they may!

Step 8. Tune down to A2 and up to A4, and use the contiguous third test to place each note initially. Check each note with the fourth and fifth, and then the major sixth and octave as they become available. The final result should be two octaves tuned with rising thirds all the way, with all fourths quite even and acceptable, and with all fifths nearly pure.

APPENDIX F

Contiguous-Interval Tuning Tests for Electronic Piano Tuners

By Dr. A.E. Sanderson

Two contiguous musical intervals are intervals that touch each other, in other words, share the note in the middle. Tests that use contiguous intervals are easy to learn and use, and tell the tuner explicitly which notes are at fault and what to do to correct them.

Contiguous major thirds will beat in the ratio of four to five because the major third itself consists of two notes whose frequencies are in the ratio of four to five. Displacing any interval up the keyboard will speed it up theoretically in the ratio of the frequencies of the two root notes involved. Therefore two contiguous major thirds should beat in the ratio of four to five, two contiguous minor thirds in the ratio of five to six. Similarly, two contiguous fourths should beat in the ratio of three to four and two contiguous fifths in the ratio of two to three. However, on the piano this theoretical relationship holds well only for the major and minor thirds. The fourths and fifths are so strongly affected by inharmonicity that these contiguous intervals beat at almost the same speeds.

Using the above facts, we can develop a test for one note of the piano at a time. Take C4 for example. Play down a third and up a third G#3-C4 and C4-E4, keeping time at the rate of four beats of the lower one, and then at five beats of the upper one. Think of it as four beats to the measure, followed by five beats to the measure. The tempo of the two kinds of measures should agree. If the upper beat rate is too fast, it indicates that C4 may be flat, and vice versa.

Before moving C4, we need more evidence. Play down a fourth and up a fourth, G3-C4 and C4-F4, and listen for near equality of the beat rates, or an upper beat rate just slightly faster than the lower. If C4 is flat the upper fourth will be faster than the lower, and vice versa. If both the fourth test and the third test indicate the C4 is flat, this is very strong evidence that C4 should be moved. But to nail down your decision, you can add a contiguous fifth test as well.

To check contiguous fifths, play down a fifth and up a fifth, F3-C4 and C4-G4. If C4 is flat, the lower fifth will beat faster than the upper.

In our example, we have now used three tests, and six other notes to check up on one note. If all the tests indicate that C4 is flat, then it is a good idea to move C4. If some tests say flat and some say sharp, then leave C4 where it is and go on to test other notes. Eventually you will find the main culprit or culprits, the notes for which all three tests say the same thing. Move these notes without hesitation. Your temperament will improve steadily as you find and correct each note that fails all three contiguous tests.

The range of this contiguous-interval test is at least from C3 to C5, a two-octave span. After tuning the whole piano, unisons and all, start applying this test at C3. Move up one semitone at a time, and correct any note that fails all three tests before moving on. Go up to C5 this way. If you like, you may make a second pass from C3 to C5 and polish your tuning even more. Eventually you will reach the point where no notes can be improved upon, and at that point you will have an extremely fine tuning. A supertuning if you will!

APPENDIX G

Octave Tuning

By Rick Baldassin

Tuning octaves with the Accu-Tuner can be directly related to tuning octaves aurally with specific interval tests. These interval tests and electronic setting instructions have been included here for three primary reasons: 1) So that aural tuners will know which Accu-Tuner settings correspond to the interval tests they have been using. 2) So that Accu-Tuner users may expand their aural tuning abilities by checking aurally with interval tests, and 3) To raise in general the level of knowledge relating to octave tests, electronic setting instructions, and their use in piano tuning.

Knowing that there are several types of octaves, aural tests and electronic setting instructions are necessary to insure that the appropriate type is being tuned in a given area of the piano. Since only one type is in tune at a time, and so rare is the exception, the tests and setting instructions for one type only should be used at a time. The exception, of course, would be in a transitional area, changing from one type to another.

Two different aural tests along with the electronic setting instructions have been provided so that the findings may be double checked. Since the aural tests employ the use of intervals for comparison, both expanded and contracted, and either the upper note or lower may be the reference to which we are tuning, four classifications of aural tests result. Be sure to note the Classification for each test so as to correctly interpret the findings and make the proper adjustments in tuning the octave.

CLASS A: Lower note is the reference note. If the beat rate between the test note and the upper note is *too slow* as compared to the beat rate of the test note and the reference note, *raise the upper note*. If the beat rate with the upper note is *too fast, lower the upper note*.

CLASS B: Upper note is the reference note. If the beat rate between the test note and the lower note is *too slow* as compared to the beat rate of the test note and the reference note, *raise the lower note*. If the beat rate with the lower note is *too fast, lower the lower note*.

CLASS C: Lower note is the reference note. If the beat rate between the test note and the upper note is *too slow* as compared to the beat rate of the test note and the reference note, *lower the upper note*. If the beat rate with the upper note is *too fast, raise the upper note*.

CLASS D: Upper note is the reference note. If the beat rate between the test note and the lower note is *too slow* as compared to the beat rate of the test note and the reference note, *lower the lower note*. If the beat rate with the lower note is *too fast, raise the lower note*.

The object in each case is to obtain an equal beat rate between the upper and lower notes of the octave, and the test note. Each test is given a name corresponding to the intervals employed in the test. In naming the intervals, "P" denotes a so-called "Perfect" interval, "M" denotes a "Major" interval, "m" denotes a minor interval, "A" denotes an "Augmented" interval, and "d" denotes a "diminished" interval. It must be noted that some of these intervals are very hard to hear in the bass region of the piano. These checks, however, are still valid. To make use of these checks, hold down one of the octave notes and the test note without playing them. (You may have to use the sostenuto pedal in some cases). Play the strike note with a staccato blow. Repeat this procedure with the other octave note and the test note. When the two beat rates are the same, the type of octave, which has been tested for, will have been tuned. The strike note in all cases is the note listed in the electronic setting instructions for that particular type of octave.

Octave Type	Aural Tests	Classifications	Electronic Setting Instructions	Area Generally Used
2:1	**M10 - M17 P5 - P12**	**A C**	**on the upper note**	**Treble**
4:2	**M3 – M10 P4 – P5**	**A,B C,D**	**octave above the upper note**	**Midrange**
6:3	**m3 – M6 P12 – P5**	**B B**	**twelfth above the upper note**	**Midrange, Bass**
8:4	**m6 – M3 P11 – P4**	**B D**	**two octaves above the upper note**	**Low Bass Medium Pianos**
10:5	**M6 – m3 A4 – d5**	**D B**	**seventeenth above the upper note**	**Lower bass Large pianos**
12:6	**m10 – m3 P19 – P12**	**B B**	**nineteenth above the upper note**	**Lower bass Large pianos**
4:1	**M3 – M17 P4 – P12**	**A C**	**on the upper note**	**Midrange, Treble**
8:2	**m6 – M10 P11 – P5**	**B D**	**octave above the upper note**	**Bass**

SANDERSON ACCU-TUNER® III SPECIFICATIONS

NOTE RANGE:
9 Octaves. C1 through B 9 (A4 = 440.00 Hz).

CENTS RANGE:
±198.0 cents with ±0.005 cents accuracy throughout the scale.

CALIBRATION ACCURACY:
Built-in 440.00 Hz crystal frequency standard for self-calibration, accurate to ±0.001 cents.

DISPLAYS:
Liquid crystal displays (LCD) for NOTE, OCTAVE and CENTS, 4 1/2 Digits with step-up, step-down, and non-equal Temperament Indicators. Rotating light-emitting-diode (LED) display for continuous analog FLAT or SHARP tuning indicator. Separate LED wide-range sharp/flat indicator.

STRETCH CALCULATOR:
Built-in stretch calculator with automatic selection of NOTE, OCTAVE and CENTS settings.

MEMORY MODE:
Standard with the ability to memorize 198 complete 88-note tunings.

MEASURE MODE:
Computer measures unknown pitch of a note automatically and displays cents deviation.

MICROPHONE:
Built-in high-fidelity electret microphone. No external microphone required.

TEMPERATURE DRIFT:
Less than ±0.01 cents in temperatures from 40°F to 100°F.

BATTERY:
Rechargeable nickel-metal hydride (NiMH) battery with sixty to eighty hours of operation per charge. Will recharge in 6 to 7 hours and has a long life expectancy. Accu-Tuner may be battery operated or plugged into an AC line. Automatic shut down to conserve battery power after 30 minutes.

SIZE & WEIGHT: 6" wide, 4 1/2" high and 3" deep. Weight 1.0 lbs.

INPUT/OUTPUT JACKS

AUDIO IN: Input for high-level audio signals from electronic pianos and organs.

MAG IN: Input for low-level audio signals, from magnetic pickups and similar devices.

FLTR OUT: Filtered audio output at pitch selected by NOTE, OCTAVE and CENTS settings.

OSC OUT: Oscillator output for broadcasting an oboe-like tone at pitch selected by NOTE, OCTAVE and CENTS settings. (Use Speaker/Amplifier listed below.)

NOTE SWITCH: Input for the foot pedal or thumb switch used to advance or decrement NOTE setting by single semitones.

BAT CHGR: Input for battery charger plug.

ACCESSORIES

ALUMINUM CASES:
Inside Dimensions:

Size	Width	Depth	Height
Large	17.5”	12.25”	6.0”
Medium	15.25”	9.25”	6.5”
Small	12.5”	9.75”	4.75”
Accu-Tuner III	11.5”	7.25”	3.5”

MAGNETIC PICKUP:
A microphone that magnetically attaches to the plate of the piano and picks up the signal directly from the strings without interference from room noise.

SPEAKER/AMPLIFIER:
The speaker/amplifier allows the user to listen to the tone instead of using the display in the Accu-Tuner and is especially useful for chipping pianos.

PIANO LIBRARIAN:
An Inventronics program for storing and cataloging piano tunings for Windows based computers.

PATENTS:
U.S. Pat. Nos. 3,968,719; 3,982,184; 4,014,242; 5,285,711; other patents pending; plus foreign patents.

Notes