DAN BARTON'S TUNING PROCEDURE REVISITED

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"How to Tune an Organ" by Dan Barton in the July/August 1985 THEATRE ORGAN, originally published in *Posthorn* in April 1962, shows that organ builders/tuners of yesteryear must have been persons of great patience indeed. Electronics (organic and non-organic) has come a long way since the Wurlitzer heyday.

Today there are available the equivalent of precision electronic "tuning forks" for each of the notes in a rank of pipes or the strings in a piano. Each pipe or string can readily be tuned in unison with the sound from the electronic device and tuning is thus a snap.

To understand why Mr. Barton said "The imperfect scale was adopted in the 14th century and is now in universal use throughout the world," a few things should be noted:

1. In a chromatic scale of "equal temperament" every semitone increases in pitch by exactly the same percentage (just under 6%) from its lower neighbor.
2. In Mr. Barton's fascinating tuning procedure, each pipe to be tuned is compared either *up* seven semitones (perfect fifth) or *down* five semitones (perfect fourth).
3. In equal temperament all octaves are pure and eight-note scales (do-re-mi — do) have the same impurity in all keys.
4. J. S. Bach (1685-1750) did much arranging of music for other composers, and he found it necessary to de-tune keyboard instruments slightly so that they would not need to be re-tuned every time the key signature changed. He used equal temperament.

Because, in a scale of equal temperament, there are 12 semitones in an octave, the percentage (or factor or ratio) between the pitch of adjacent pipes or strings, is what mathematicians call "the twelfth root of two," somewhat akin to the more familiar "square root of two" (1.41421 +) which multiplied by itself gives exactly two. The twelfth root of two is a number (1.059463 +) for which 12 successive multiplications of any number (or pitch) will exactly double that number (or pitch). For example, if we start with the number one (1) we will get the results shown at the left of Table 1.

TABLE 1

	Equal Temperament Ratio	Nearest Harmonic Ratio	Interval	Percent "Error"
1	1.00000	1/1 = 1.00000	Unison	None
2	1.05946	16/15 = 1.06667	Minor Second or semitone	.67% flat
3	1.12246	9/8 = 1.12500	Major Second or whole tone	.23% flat
4	1.18921	6/5 = 1.20000	Minor Third	.90% flat
5	1.25992	5/4 = 1.25000	Major Third	.79% sharp
6	1.33484	4/3 = 1.33333	Perfect Fourth	.11% sharp
7	1.41421	*	Tritone	
8	1.49831	3/2 = 1.50000	Perfect Fifth	.11% flat
9	1.58740	8/5 = 1.60000	Minor Sixth	.79% flat
10	1.68179	5/3 = 1.66667	Major Sixth	.91% sharp
11	1.78180	16/9 = 1.77778	Minor Seventh	.23% sharp
12	1.88775	15/8 = 1.87500	Major Seventh	.68% sharp
13	2.00000	2/1 = 2.00000	Octave	None

*Tritone is also called augmented fourth or diminished fifth. Ratios are 7/5, 64/45 or 45/32, and the sound is dissonant. Its equal temperament ratio is the square root of two.

Table 1 also shows the simple ratios, which, if voiced exactly, would make the music sound good for one key but not so good for other keys without re-tuning. The equal temperament ratios are the same for all keys, which is the ingenious feature of the scale of equal temperament.

It can be seen that the perfect fourth and perfect fifth have the smallest "error," which is why Mr. Barton chose these for his tuning procedure. Note that when the perfect fifth is used, the pipe being tuned is higher in pitch than the previously-tuned reference pipe and hence must be flatted about 1/9th of 1 percent (0.11%) of its pitch. If the perfect fourth were used to tune a higher-pitched pipe, then the pipe would need to be sharped by that same amount. But, in Mr. Barton's procedure the perfect fourth is always used to tune a pipe down the scale, so those pipes also must be flatted.

Using Mr. Barton's scale as described in his noteworthy article observing the convention that A above middle C is 440 Hertz (called cps for cycles per second in older literature) we get Table 2. In tuning E to A, E becomes 330 Hertz. The amount to be flatted is 0.11% which is 0.363 Hertz, leaving E at 329.637 Hertz, in practical agreement with the value shown in Table 2.

TABLE 2

		Hertz
1	C	261.626
2	C# = D♭	277.183
3	D	293.665
4	D# = E♭	311.127
5	E	329.628
6	F	349.228
7	F# = G♭	369.994
8	G	391.995
9	G# = A♭	415.305
10	A	440.000
11	A# = B♭	466.164
12	B	493.883
13	C	523.251

Other octaves are obtained by multiplying or dividing these values by 2, 4, 8, 16, etc. A table of values spanning ten octaves from 16 Hertz to 16,000 Hertz is shown on page 48 of the book by Olson (1).

References

1. *Music, Physics and Engineering*, by Harry F. Olson, Dover Publications, 2nd ed., 1967.
2. *The Physics of Music*, by Alexander Wood, University Paperbacks (London), Dover Publications (USA), 6th ed., 1962.
3. "A $19 Music Interface (And Some Music Theory for Computer Nuts)," by Bill Struve, *Byte Magazine*, December, 1977, page 48. □