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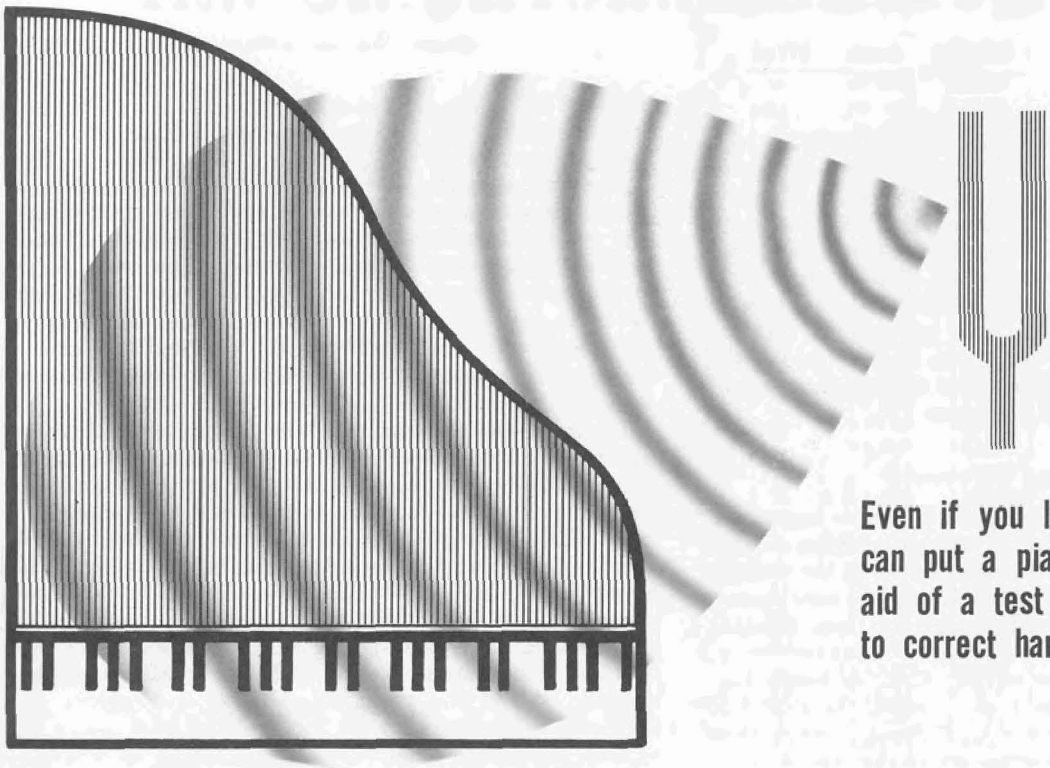

Even if you lack a trained ear, you can put a piano "on key" with the aid of a test instrument that tunes to correct harmonic and beat note.

PIANO TUNING—THE ELECTRONIC WAY

by

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PIANO TUNING — THE ELECTRONIC WAY

GOOD piano tuners, it seems, are becoming increasingly scarce—so scarce, in fact, that it's not unusual to find a tuner "booked solid" for several weeks in advance, especially just before a holiday. This state of affairs, coupled with the renewed popularity of the piano, may interest many piano owners in the art of piano tuning. If there is electronics in your background and especially if there are certain types of electronic instruments that are available for your use, piano tuning can be simplified to the point where you need not be afraid to do something about the clinkers coming from that old piano.

Basic Tuning Procedure

Tuning a piano, as almost everyone knows, is basically a matter of adjusting the tension of the piano wires so that the notes occur at the frequencies assigned to the equally tempered scale. The tuner, after calibrating one note against a tuning fork or other standard, strikes that note together with a note 2/3, 3/2, or 3/4 of the reference note's frequency, in such combinations that the second, third, or fourth harmonic of the second note should nearly equal the second or third harmonic of the reference note. ("Nearly," rather than "exactly," because of the compromises of the equally tempered scale.) The tuner adjusts the second note for the proper beat frequency and then uses that note as a reference for another, and so on in a "knight's tour" of a central octave. This octave is then used as the reference for all other notes on the keyboard.

The actual adjustment of wire tension involves use of a special wrench, which fits over the square ends of the pins to which the wires are attached. The long handle on such a wrench provides the necessary leverage and sensitivity of adjustment.

Throughout most of the keyboard, there are three strings per note. The usual procedure involves tuning the center string of each note and then setting the adjacent strings to unison. (The idea is to avoid creating stress unbalances that might damage the piano.) While tuning the first string of a two- or three-string note, tuners use rubber wedges to "damp out" the companion string or strings. Sometimes a long strip of felt is tucked along an octave or so, ribbon-candy style, to damp the "outside" strings of three-string notes.

Wrench, wedges, a strip of felt, and a tuning fork or two are the basic tools of the trade, plus one of the excellent handbooks covering the mechanical aspects of tuning and the proper care of a piano (*e.g.*, "Piano Tuning and Allied Arts" by William B. White). The piano is a delicate, expensive instrument, and you should not try to tune a piano for the first time without reading such a handbook. The results of such an attempt could be catastrophic.

Recognizing the Beats

Assuming that one is familiar with the basic procedure and with the mechanical aspects of tuning, the most difficult part for the inexperienced tuner is usually recognition of the beat frequencies in the presence of the much louder fundamentals. To one who has been tuning pianos for years, the beats are as clear as church bells. This ability to recognize the proper beats, even at the high and low ends of the keyboard, is probably the piano tuner's most valuable asset.

Lacking a trained ear, one can call on some electronic help to filter out the fundamentals and pass only the desired harmonics. The filter must be tunable, of course, and must cover the audio range. Such a filter is the *General Radio* Type 1232-A Tuned Amplifier and Null Detector (see "A Tuned Amplifier and Null Detector with One-Microvolt Sensitivity" by A. E. Sanderson in the *General Radio Experimenter*, Vol. 35, No. 7, July, 1961), with a tunable frequency range from 20 cps to 20 kc., low noise level, small size (8" x 6" x 7½"), and battery operation. The only other equipment needed, beyond the usual piano-tuning implements, is a microphone connected to the input of the filter and a pair of high-impedance headphones connected to its output.

For each note pair struck, it is necessary to set the frequency control on the filter to pass the desired harmonics. Table 1 lists these frequency settings for the entire central-octave tuning sequence. Note that for all pairs except the first, the tuned note is adjusted for a beat frequency on the flat side of zero beat. The octaves on either side of the central octave can easily be tuned to the central octave. A_2 (110 cps), for instance, can be tuned so that its fourth harmonic is at

Table 1. Filter frequencies for the standard tuning sequence. The values are for the central octave, after tuning C_4 with respect to a tuning fork or other standard. A plus sign in the middle column indicates the note should be tuned above zero beat; minus sign indicates tuning to be below zero beat.

NAMES OF TONES Ref.—Tuned	NO. OF BEATS PER SECOND	FREQ. AT WHICH BEATS ARE HEARD (cps)
C_4—F_3	+0.6	523
C_4—G_3	−0.9	784
G_3—D_4	−0.7	587
D_4—A_3	−1.0	880
A_3—E_4	−0.8	660
E_4—B_3	−1.1	988
B_3—$F\#_3$	−0.8	740
$F\#_3$—$C\#_4$	−0.6	554
$C\#_4$—$G\#_3$	−1.0	831
$G\#_3$—$D\#_4$	−0.7	622
$D\#_4$—$A\#_3$	−1.0	932
$A\#_3$—F_4	−0.8	698

Tuned amplifier and null detector.

zero-beat with the second harmonic of A_3, with the filter set at 440 cps. Such straight-octave tuning can be used for all but the extremely high and low ends of the keyboard, where one must call on "expanded-third" or other techniques described in the handbooks. By noting the harmonic relation of any prescribed note pair, one can easily determine the frequency at which beats should be heard, and set the filter frequency accordingly.

Using a Counter*

If one has access to a frequency counter, each note can be tuned directly to its proper fundamental as indicated by the counter, without recourse to harmonic techniques. A tuned filter is once again needed, between the microphone and the counter. Accuracy of direct-frequency measurement is limited to ±1 cps, a fairly significant percentage at the low end of the keyboard. With a "universal counter," one can switch to period or multiple-period measurement and thus gain more than enough precision. The period of A_0 (27.50 cps) for instance, is 0.036364 second. A counter with a 100-kc. time base indicates this as 3636 for a single-period measurement, 36364 for a 10-period measurement.

Since period measurements are made in terms of time rather than frequency, a conversion table must be used. Table 2 gives period indications for the entire keyboard. The five digits given are as they appear on a "universal counter" with a 100-kc. time base, set for single- or multiple-period as noted. The five digits given will be found to offer far more precision than the "settability" or frequency stability of the average piano justifies.

The counter can probably best be used as a check on tuning adjustments made by the usual harmonic procedures. The tuned filter is really all that is needed to do a first-class job, and it is doubted that much time is saved or accuracy gained by a top-to-bottom tuning by period measurement.

* An addendum on tuning with a counter appears on the following page.

Tuning pianos with the aid of a tuned filter offers several obvious advantages: accuracy of tuning, convenience, low cost (assuming one has access to the instrument in the first place). Also, after listening to the beats through the tuned filter, one soon develops the "piano-tuner's ear" and can, if he chooses, do the job in the old-fashioned way.

Table 2. Frequencies (in cps) and periods for the equally tempered scale. The five digits in the "Period" column are the readings on a "universal" counter with a 100-kc. time base, set for single- or multiple-period measurement. These figures may be read as "period in microseconds" for the 10-period measurements. For 100-period measurements, period figures are ten times the values in microseconds. For the 1000-period measurements, figures are 100 times the values in microseconds.

	NOTE	FREQ.	PERIOD		NOTE	FREQ.	PERIOD
10 period	A_0	27.500	36364	100 period	F_4	349.23	28634
	$A\#_0$	29.135	34323		$F\#_4$	369.99	27028
	B_0	30.868	32396		G_4	392.00	25510
	C_1	32.703	30578		$G\#_4$	415.30	24079
	$C\#_1$	34.648	28862		A_4	440.00	22727
	D_1	36.708	27242		$A\#_4$	466.16	21452
	$D\#_1$	38.891	25713		B_4	493.88	20248
	E_1	41.203	24270		C_5	523.25	19111
	F_1	43.654	22907		$C\#_5$	554.37	18038
	$F\#_1$	46.249	21622		D_5	587.33	17026
	G_1	48.999	20409		$D\#_5$	622.25	16071
	$G\#_1$	51.913	19267		E_5	659.26	15167
	A_1	55.000	18182		F_5	698.46	14317
	$A\#_1$	58.270	17161		$F\#_5$	739.99	13514
	B_1	61.735	16198		G_5	783.99	12755
	C_2	65.406	15289		$G\#_5$	830.61	12039
	$C\#_2$	69.296	14431		A_5	880.00	11364
	D_2	73.416	13623		$A\#_5$	932.33	10726
	$D\#_2$	77.782	12856		B_5	987.77	10124
	E_2	82.407	12135	1000 period	C_6	1046.5	95557
	F_2	87.307	11454		$C\#_6$	1108.7	90196
	$F\#_2$	92.499	10811		D_6	1174.7	85128
	G_2	97.999	10204		$D\#_6$	1244.5	80354
100 period	$G\#_2$	103.83	96313		E_6	1318.5	75844
	A_2	110.00	90909		F_6	1396.9	71587
	$A\#_2$	116.54	85807		$F\#_6$	1480.0	67568
	B_2	123.47	80991		G_6	1568.0	63776
	C_3	130.81	76447		$G\#_6$	1661.2	60197
	$C\#_3$	138.59	72155		A_6	1760.0	56818
	D_3	146.83	68106		$A\#_6$	1864.7	53628
	$D\#_3$	155.56	64284		B_6	1975.5	50620
	E_3	164.81	60676		C_7	2093.0	47778
	F_3	174.61	57271		$C\#_7$	2217.5	45096
	$F\#_3$	185.00	54054		D_7	2349.3	42566
	G_3	196.00	51020		$D\#_7$	2489.0	40177
	$G\#_3$	207.65	48157		E_7	2637.0	37922
	A_3	220.00	45454		F_7	2793.8	35794
	$A\#_3$	233.08	42904		$F\#_7$	2960.0	33784
	B_3	246.94	40496		G_7	3136.0	31888
	C_4	261.63	38222		$G\#_7$	3322.4	30099
	$C\#_4$	277.18	36077		A_7	3520.0	28409
	D_4	293.66	34053		$A\#_7$	3729.3	2o815
	$D\#_4$	311.13	32141		B_7	3951.1	25309
	E_4	329.63	30337		C_8	4186.0	23889

A universal counter can be used for direct indication of period of piano notes.

With regard to the *"Using the Counter"* section of my article, several readers have correctly pointed out that a top-to-bottom tuning by direct (fundamental) frequency measurement will fail to take into account the inharmonicity of the piano. Largely because of the mechanics of the piano wires and suspensions, the relationships between fundamentals differ slightly from those between corresponding harmonics. Therefore a piano tuned by means of a frequency counter (measuring fundamentals) will not agree with one tuned by an experienced piano tuner who uses the usual harmonic techniques. The difference will be especially noticeable at the extremes of the keyboard. For an excellent discussion of inharmonicity, see *"Subjective Evaluation of Musical Scale Temperament in Pianos,"* by D. W. Martin and W. D. Ward, in the *Journal of the Acoustical Society of America*, May 1961.

The problem of inharmonicity does not affect the tunable-filter technique that is the chief subject of my article. This method is based on the traditional harmonic tuning sequence, which assumes inharmonicity.

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