

Oct. 20, 1959

C. W. ANDERSEN

2,909,727

TUNING DEVICE

Filed Sept. 15, 1953

5 Sheets-Sheet 1

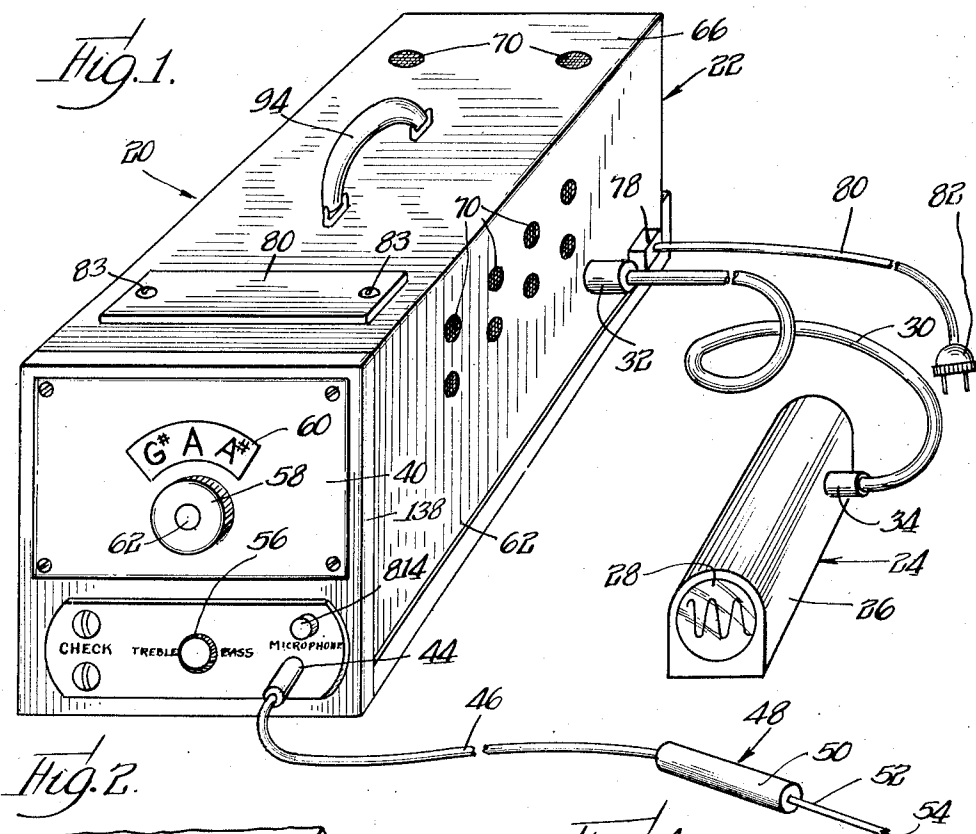


Fig. 2.

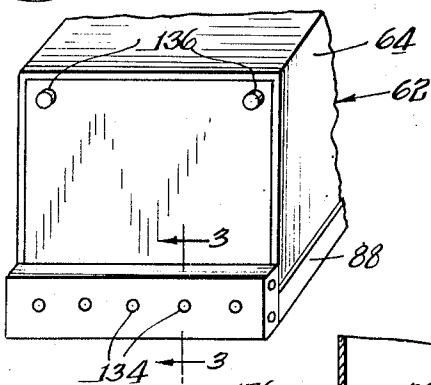


Fig. 3.

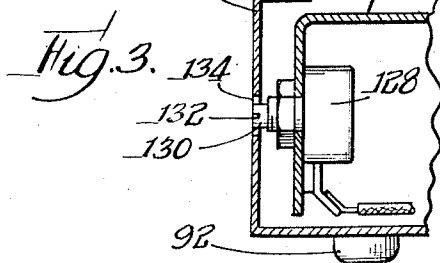
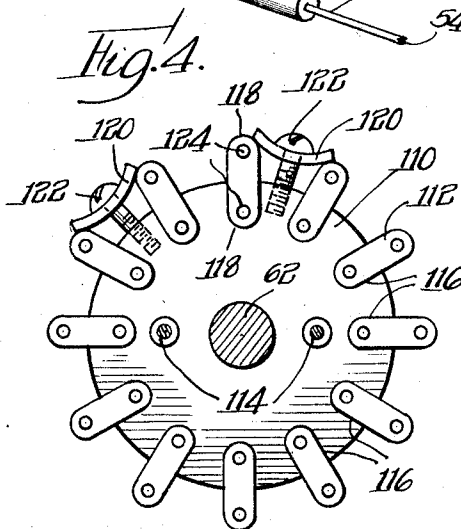


Fig. 4.



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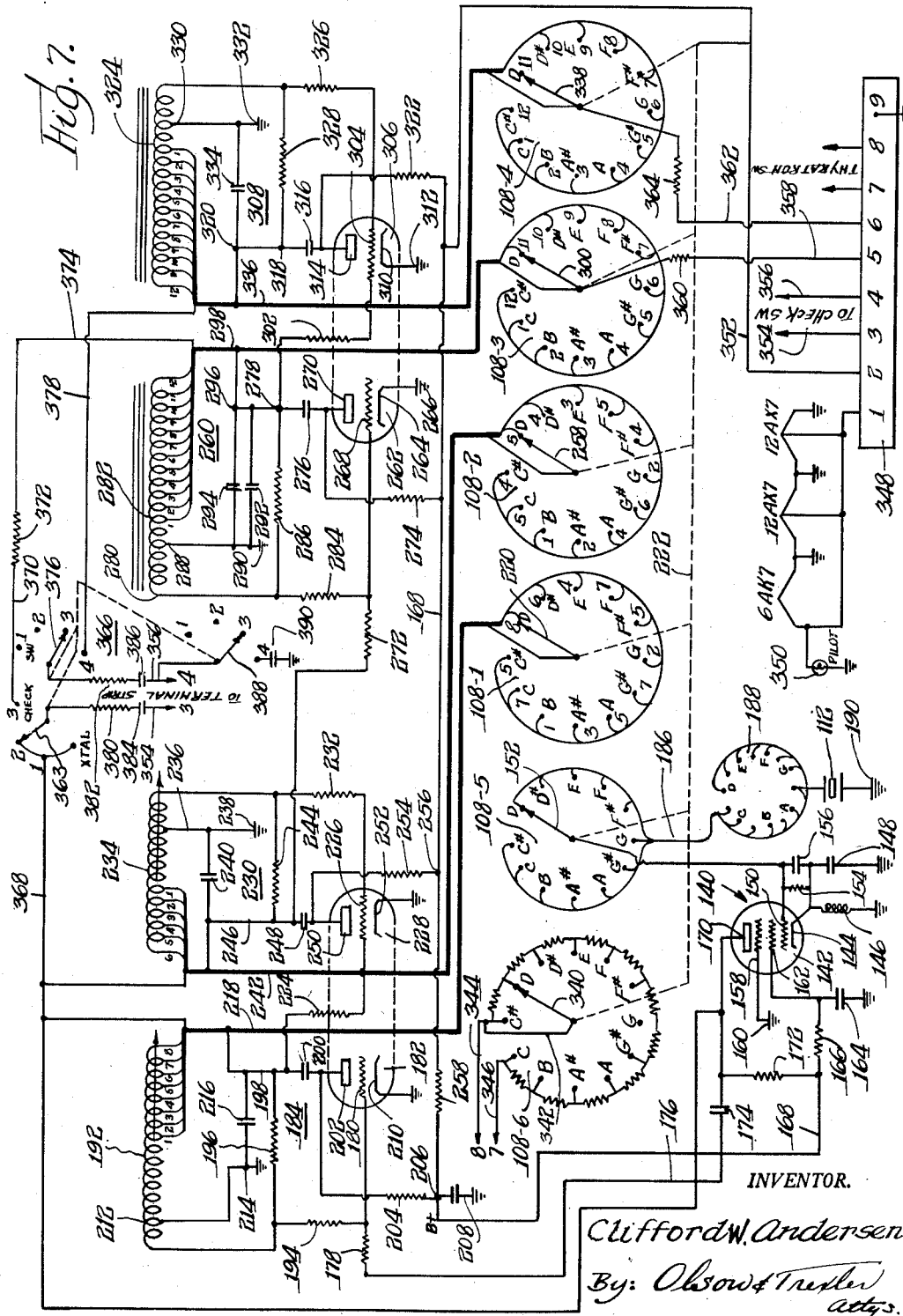
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TUNING DEVICE

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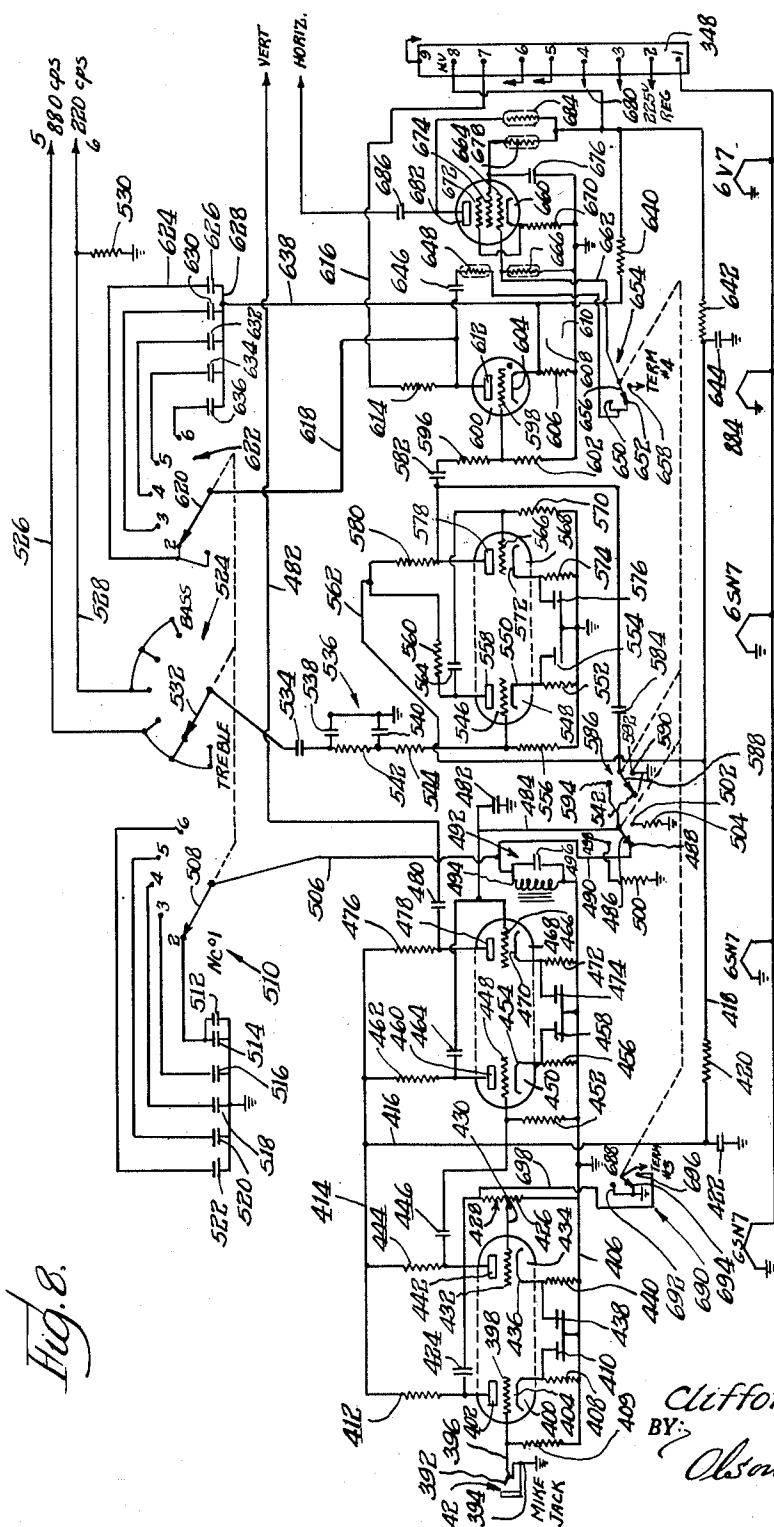
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5 Sheets-Sheet 4



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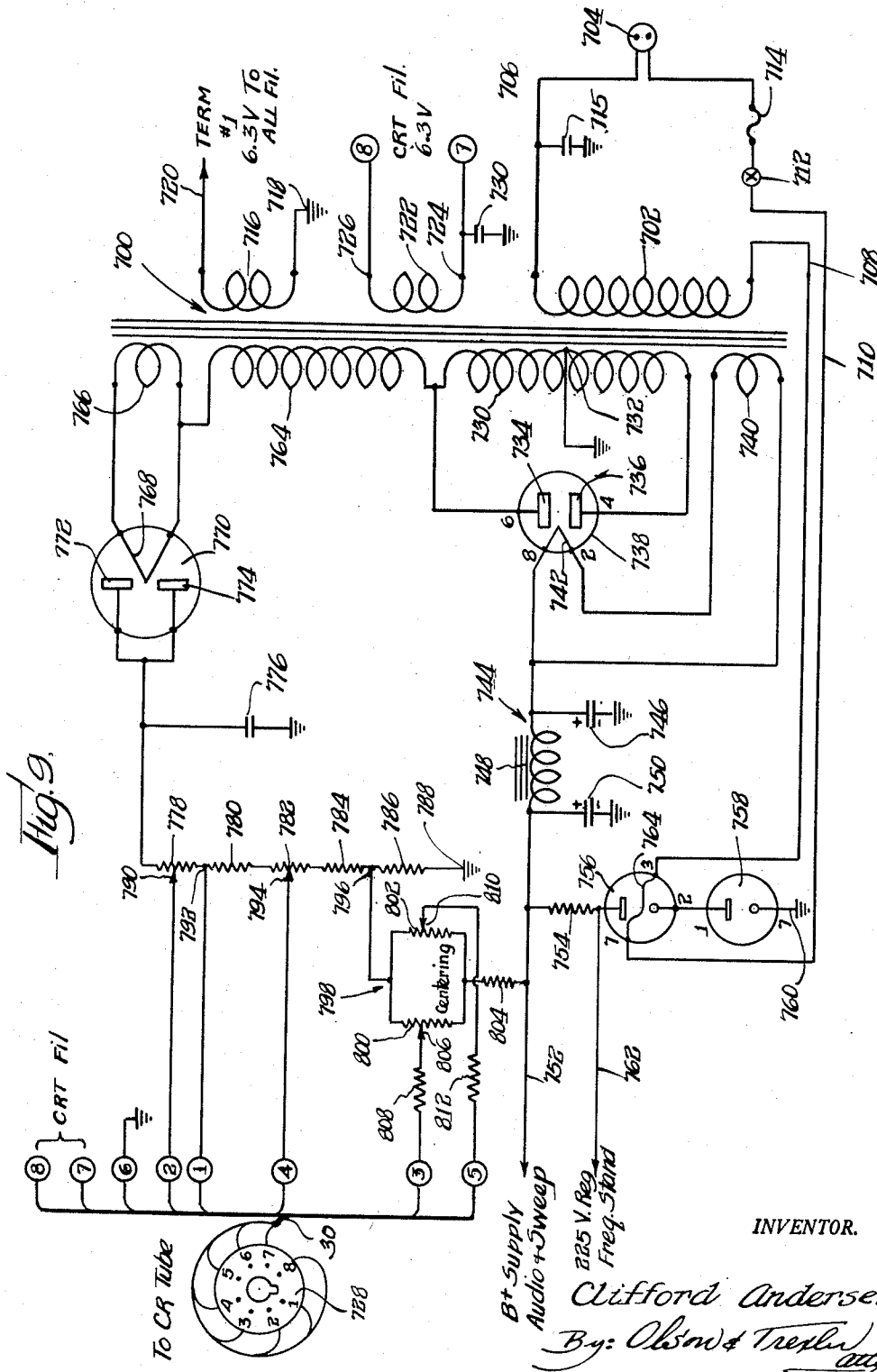
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TUNING DEVICE

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5 Sheets-Sheet 5



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2,909,727

TUNING DEVICE

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Application September 15, 1953, Serial No. 380,278

12 Claims. (Cl. 324—79)

This invention is concerned with an electronic tuner for a piano and other musical instruments.

According to conventional practices, pianos are tuned by an artisan who listens concurrently to the pitch of a tuning fork vibrating at a frequency corresponding to a key note and to the pitch of the corresponding piano string. Tuning of pianos by this conventional practice requires a highly trained ear. It also requires a rather quiet location free from distracting sounds, and particularly free from other musical sounds. Consequently, only one piano can be used in a room, a highly undesirable circumstance when pianos are manufactured in large quantities. Furthermore, the second string, or second and third strings of each set or unison of strings playing the same note in a piano, must be mechanically muted or damped, as by the use of rubber wedges so that the piano tuner hears the vibrations of only one string at a time.

The broad object of this invention is to provide means for tuning a piano operable by a person of moderate skill and training and not necessarily having any musical ability.

A further object of this invention is to provide a piano tuning apparatus wherein the frequency at which a piano string is vibrating is compared visually with a frequency standard.

More specifically, it is an object of this invention to provide an apparatus for tuning pianos wherein all of the overtones of a piano string are discarded and the fundamental is compared with a frequency standard.

Another specific object of this invention is to provide an electronic apparatus for tuning pianos.

A further object of this invention is to provide a piano tuning apparatus responsive only to the specific string being tested, thereby generally obviating the need of rubber wedges and allowing any number of pianos to be tuned in the same room at the same time.

Yet another object of this invention is to provide a piano tuning apparatus which is light in weight and which is so constructed so as to be readily portable.

A further object of this invention is to provide a portable piano tuning apparatus which is simply and conveniently set up in on-the-job locations.

Yet another object of this invention is to provide an automatic piano tuning apparatus having a continuous range of operation for successively tuning all of the strings of the piano.

Yet another object of this invention is to provide, in an electronic piano tuner, a novel mounting for crystals for controlling the test frequency of the tuner.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

Fig. 1 is a perspective view of an electronic piano tuner constructed in accordance with the principles of my invention;

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Fig. 2 is a fragmentary perspective view of the rear end of the tuner;

Fig. 3 is a vertical sectional view on an enlarged scale taken along the line 3—3 of Fig. 2;

Fig. 4 is a side view illustrating the crystal mounting;

Fig. 5 is a perspective view similar to Fig. 1 with the case or housing removed;

Fig. 6 is an exploded perspective view of the case or housing;

Fig. 7 is a schematic wiring diagram of the frequency standard;

Fig. 8 is a schematic wiring diagram of the audio and sweep circuit; and

Fig. 9 is a schematic wiring diagram of the power supply.

Referring first to Figs. 1, 5 and 6 for an understanding of the general physical arrangement of my invention, there will be seen an electronic tuner 20 comprising a main unit 22 and an oscilloscope unit 24. The oscilloscope unit 24 comprises a small case 26 which conveniently may be made of sheet metal and which carries internally thereof a small cathode ray tube 28 which for illustrative purposes may be a two inch tube. The oscilloscope unit 24 is detachably connected to the main unit 22 by means of a cable 30 having a plug and socket connection 32 with the main unit and preferably having a plug and a socket connection 34 with the oscilloscope unit.

The main unit 20 comprises a chassis 36 having suitable electronic frequency standard, amplifying, and power supply means 38 which will hereinafter be set forth in greater detail in conjunction with the schematic wiring diagrams. The chassis 36 includes an upstanding front panel 40 having a jack 42. The jack 42 receives a plug 44 connected by a cable 46 to an electronic probe 48. The probe 48 preferably is of the type disclosed in my Patent No. 2,538,184, dated January 16, 1951 and entitled "Electronic Piano Tuning." Briefly, the probe comprises a handle 50 housing a pick-up element, preferably a piezo electric crystal, connected to a shaft 52 having a bifurcated tip 54 adapted to fit over an individual string being tuned.

The front panel 40 further includes a knob 56 for controlling the frequency range as will be brought out hereinafter with regard to the electronic circuits. The upper part of the front panel 40 is provided with a tuning knob 58 for tuning the tuner 20 to the desired note. An arcuate window 60 is provided just above the knob 58 for displaying the note to which the tuner is tuned. More specifically, a dial displaying the various notes of the scale is fixed on the shaft 62 of the knob 58 for rotation therewith. The note designations, such as G#, A, and A# shown in Figs. 1 and 5 are displayed three at a time in the window 60. The central note, such as A in Figs. 1 and 5, is the one to which the tuner is tuned, and a small light bulb behind the center of the window 60 illuminates the central displayed note, such as A in Figs. 1 and 5. The concurrent display of three note indicia, rather than indicium for a single note, offers considerable advantages. The most obvious advantage is that the next note to be tuned readily can be seen and the operator will know which way to turn the knob 58 without having to remember and without having to resort to a trial and error process. Another less apparent advantage is recognized when it is considered that it often is desirable to tune all of the notes of a piano a half tone sharp, or a half tone flat. For instance, in some older pianos the pegs fit loosely enough in their holes that they could not successfully hold strings under the tension to produce their proper pitches, or the strings or frame might be damaged by such tension. Such pianos are cus-

tomarily tuned a half tone flat. Thus, with the indicia for three notes showing in the window 60, the tone to which a string actually is being tuned can be seen at the same time as the note on the piano to which the note actually corresponds.

The main unit 22 further includes a sheet metal case or housing 62 best seen in Fig. 6 and comprising a channel-shaped top portion 64 having a top 66 and side walls 68. The top portion 64 is provided with a plurality of ventilating apertures 70 along the side walls 68, and with suitable apertures 72 for accommodating jacks 74 and 76 (Fig. 5) on the chassis 36 for respectively receiving the plug 32 of the oscilloscope unit 24 and a plug 78 on a power cord 80 having a line plug 82. The top 66 of the top portion of the case or housing is provided near the front end with a transverse opening 79 closed by a rectangular plate 81 held in place by means such as screws 83 (Fig. 1). The opening 79 provides access for adjustment of tuning slugs 84 (Fig. 5). The housing or case 62 also includes a flat bottom 86 having upwardly extending flanges 88 along its longitudinal edges. The bottom 86 is held to the top portion 64 by screws fitting through suitable apertures in the flanges 88 and threaded into suitable apertures in the sides 68 near the lower edges thereof. The bottom 86 is provided with a relatively large ventilating opening covered over by a screen 90. Rubber bumpers or feet 92 are provided for the under side of the bottom to prevent marring of surfaces on which the tuner 20 may be placed. A handle 94 for carrying the tuner is provided on top of the housing or case as illustrated in Fig. 1.

The forward part of the chassis 36 is provided with a support 96 comprising a vertical wall 98 which is provided with a horizontal flange 100 for attachment to the top of the chassis 36 by means such as screws 102. The support 96 also includes a top wall 104 provided with a relatively large aperture 106 for access to parts within the support 96.

The parts of importance with regard to the support 96 are the tuning slugs 84 carried thereby and previously mentioned, and also the shaft 62, previously mentioned, and parts carried thereby. The front of the shaft 62 adjacent the knob 58 is journaled in the front plate 40 of the main unit 22, while the rear end of the shaft is journaled in the rear vertical wall 98.

A plurality of wafers 108, preferably six in number, forming tap switches for controlling the frequency as will be brought out more fully hereinafter, are mounted on the shaft 62. Also mounted on the shaft 62 is a substantially cylindrical block 110 carrying a plurality of crystals 112.

Reference should be had to Fig. 4 for a more thorough understanding of the cylindrical block 110 and the mounting of the crystals 112. The block 110 is positively coupled to the wafers 108 by a pair of rods 114 passing through the blocks and the wafers. The block is formed about its periphery with a plurality of axially extending, arcuately spaced grooves 116. In each of these grooves there is removably carried one of the crystals 112, the crystals being relatively flat and having rounded off longitudinal edges 118. Curved straps 120 bridge successive pairs of crystals 112, and screws 122 pass through the straps and are threaded into suitable openings in the cylindrical block 110 to clamp the crystals securely in position without placing undue strain upon them. The crystals are provided with suitable connectors 124 on corresponding ends thereof, the connections made to these connectors not being shown physically, but only in the schematic wiring diagrams as will be brought out hereinafter.

The rear end of the top portion 64 of the housing or case 62 is provided at the bottom thereof with a rearwardly projecting section 126 within which the rear end of the chassis 36 extends. A plurality of adjustable

potentiometers 128 is mounted on the rear of the chassis 36, and the functions of these adjustable potentiometers will be set forth more fully hereinafter with regard to the electronic circuits of the tuner. The shafts 130 of the adjustment potentiometers 128 are provided with cross slots 132 for screw driver adjustment, and suitable apertures 134 are formed in the rearwardly projecting part 126 of the housing to provide access to the shafts.

The main unit 22 of the tuner may be used in either horizontal position as shown in Fig. 1, or in vertical position. The upper corners of the rear of the upper portion 64 of the housing 62 are provided with a pair of rubber feet 136 projecting into the same plane as the rear of the projection 126 so that the main unit 22 of the tuner may sit level in a vertical position.

In order to insure clearance of the adjustment potentiometer shafts when the case or housing is removed from the chassis, the front plate 40 is formed with a rearwardly extending circumferential flange 138 which overlies the front edges of the case or housing 62 as may be seen in Fig. 1. This makes for an extremely firm connection at the front of the main unit of the tuner, and requires that the case or housing be shifted rearwardly for removal from the chassis.

Referring now to Fig. 7 for an understanding of the frequency standard against which the piano notes are compared in tuning a piano, there will be seen in the lower left-hand corner of the figure a crystal controlled oscillator 140 including an oscillator tube 142, which for illustrative purposes may be a type 6AK6. The cathode 144 of the tube is grounded through a parallel connected inductance coil 146 and a capacitor 148. According to a specific example of a tuner constructed in accordance with the principles of my invention, the inductance 146 is 60 millihenries, while the capacitor 148 is a 500 microfarad capacitor.

The control grid 150 of the oscillator tube 142 is connected to the movable switch arm 152 associated with the fifth wafer 108 and identified in Fig. 7 as 108-5. The control grid 150 further is connected through a parallel connected resistor 154 and capacitor 156 to the cathode 144. In the illustrative example, the resistor is 470,000 ohms while the capacitor is 100 microfarads.

The suppressor grid 158 is grounded as at 160, while the screen grid 162 is grounded through a capacitor 164, valued at .01 microfarad in the illustrative embodiment, and is connected through a resistor 166 to a B+ line 168. In the illustrative embodiment the resistor 166 is a 470,000 ohm resistor.

The plate 170 of the oscillator 142 is connected through a resistor 172 to the B+ line 168, this resistor in the illustrative embodiment being equal to 56,000 ohms. The plate 170 further is coupled through a capacitor 174, a wire 176, and a resistor 178 to the control grid 180 of an oscillator tube 182 forming a part of a controlled oscillator 184. In the illustrative embodiment the capacitor 174 is a .001 microfarad capacitor, the resistor 178 is valued at 470,000 ohms, and the tube 182 is one half of a 12AX7 twin triode.

Referring back to the crystal controlled oscillator 140, the switch arm 152 on the wafer 108-5 is cooperable with a dozen arcuately spaced switch contacts corresponding to the notes of an octave of the diatonic scale as labeled on the drawings. These contacts are connected individually by the wires of a cable 186 to a plurality of corresponding contacts generally indicated at 188 and respectively connected to the various crystals 112, one contact of each crystal being grounded as at 190. The crystal controlled oscillator, or master oscillator, 140 thus oscillates at a frequency depending upon which crystal 112 is connected in the circuit by the switch arm 152. This, in turn, is dependent upon the angular position of the knob 58 which is indicated by the indicia showing in the window 60. The circuit values of the crystal controlled or master oscillator 140, including the crystal, are chosen so that the master oscillator oscillates at a frequency on

the order of, and generally slightly above, 100 kilocycles. The master oscillator frequency is subsequently divided by a series of controlled oscillators including the controlled oscillator 184 and others yet to be discussed to obtain the desired audio frequencies. The substantial division, running on the order of a division by about a hundred, of the master oscillator frequency results in extremely stable audio frequency. A drift of about a hundred cycles in the master oscillator frequency is necessary for a drift of a single cycle in audio frequency, and crystal controlled oscillators are much more stable than this once they have warmed up. As a practical matter, only a short warm-up period is necessary before the crystal controlled or master oscillator has settled down to an operational state resulting in an audio frequency stabilized within a fraction of a cycle per second. Accordingly, only a very short warm-up is necessary with my tuner.

In addition to the oscillator tube 182, the controlled oscillator 184 comprises a tapped oscillator coil 192 having one end thereof connected through a resistor 194 to the grid 180. In the illustrative embodiment the resistor 194 is equal to 56,000 ohms. The junction between the coil 192 and the resistor 194 is connected through a resistor 196 to a wire 198 leading through a capacitor 200 to the plate 202 of the tube 182. Again referring to the illustrative embodiment, the resistor 196 is a 470,000 ohm resistor, while the capacitor is a .001 microfarad capacitor. The plate 202 is connected through a resistor 204 to the B+ bus as at 206, this point being grounded through a decoupling capacitor 208 which for illustrative purposes may be taken as being equal to 8 microfarads, the resistor 204 being equal to 56,000 ohms. The cathode 210 of the tube 182 is grounded directly as readily may be seen.

The first tap 212 on the coil 192 is grounded as at 214 and also is connected through a capacitor 216 to the wire 198. In the illustrative embodiment the capacitor 216 has a value of .0002 microfarad.

The remaining taps, hereinafter known as the oscillation taps, numbered 1-8, are respectively connected through the individual wires of a cable 218 to the contacts of the first wafer 108, identified in Fig. 7 as 108-1. The taps on the wafer 108-1 correspond to the octave notes in the same order as on the wafer 108-5, the notes being indicated on the drawing in their proper positions. The taps on the wafer 108-1 are numbered in accordance with the oscillation taps 1-8 of the coil 192 to which they are connected. The taps on the wafer 108-1 are not arranged in the same order as on the oscillating coil 192, and some of the taps on the oscillating coil are connected to more than one of the switch taps on the wafer 108-1, all as will be clearly evident from an inspection of Fig. 7. The movable switch contact 220 cooperable with the switch taps of the wafer 108-1 is connected by one of the wires of the cable 218 to the wire 198 of the oscillator 184.

The oscillator 184 is designed to operate at approximately $\frac{1}{8}$ the frequency of the master oscillator 140. The various switch arms on the several wafers 108 are ganged together as indicated by the dashed lines 222. Accordingly, when a different one of the crystals 112 is connected in the master oscillator to change the frequency of the master oscillator, a different one of the taps 1-8 of the coil 192 is connected to the wire 198 to cause the oscillator 184 to change its frequency concurrently with the frequency change of the master oscillator, the controlled oscillator 184 tending at all times to oscillate at $\frac{1}{8}$ the frequency of the master oscillator. Since the master oscillator operates at a frequency which is substantially an integral multiple of the controlled oscillator frequency, the controlled oscillator 184 locks in with the master oscillator 140 and oscillates at exactly $\frac{1}{8}$ the frequency of the master oscillator.

The wire 198 of the oscillator 184 is connected through

a resistor 224 to the control grid 226 of an oscillator tube 228 of a second controlled oscillator 230. In the illustrative example, the tube 228 comprises the second half of the aforementioned 12AX7 triode, while the resistor 224 is a one megohm resistor. The control grid 226 is also connected through a resistor 232 to one end of an oscillating coil 234 which is tapped by a wire 236 grounded at 238. The wire 238 is connected through a capacitor 240 to a cable 242 leading to the second wafer identified in Fig. 7 as 108-2. The wire connecting the coil 234 to the resistor 232 is connected through a resistor 244 to a wire 246 connected to the side of the capacitor 240 opposite to the wire 236. The wire 246 is connected through a capacitor 248 to the plate 250 of the tube 228, the cathode 252 again being grounded. The plate 250 is connected through a resistor 254 to the B+ bus line at 256, a resistor 258 being interposed between the points 206 and 256 on the bus line. In the illustrative embodiment previously referred to the resistor 232 is 56,000 ohms, the resistor 244 is 470,000 ohms, the resistor 254 is 56,000 ohms, the capacitor 248 is .003 microfarad, and the capacitor 240 is .0015 microfarad.

There are six remaining taps on the oscillator coil 234 labeled 1-6 respectively, and connected through the cable 242 to the fixed switch contacts or taps of the wafer 108-2. The wafer 108-2 is provided with switch taps corresponding to the various notes of an octave as in the wafers heretofore discussed, the switch contacts being labeled with the note indicia as heretofore. The contacts also are labeled with the numbers 1-6 corresponding to the taps of the coil 234 to which they are connected. It will be noted that the taps on the wafer 108-2 do not occur in order and that more than one tap may be connected to certain of the taps of the coil. The movable switch contact arm 258 is ganged with the movable switch arms of the other wafers and is connected by one of the wires of the cable 242 to the wire 246 of the oscillator 230 for connecting different sections of the coil 234 in the oscillating circuit in the oscillator 230. The oscillator 230 tends to oscillate at $\frac{1}{8}$ the frequency of the oscillator 184, the frequencies of the oscillators being changed concurrently by the wafer switches, and the integral multiple relationship of these two oscillators causes the oscillator 230 to lock in at exactly $\frac{1}{8}$ of the frequency of the oscillator 184.

A third controlled or divider oscillator 260 is provided for further dividing the crystal frequency. This divider divides the frequency of the preceding controlled oscillator 230 by a factor of 4, 5, 6, 7 or 8 depending upon the tap of the oscillator coil used. The variable divider rate is used so that crystals causing the master oscillator to oscillate in the region slightly above 100 kilocycles while attaining the desired audio frequencies can be used. Crystals for this frequency range are extremely reliable in operation, are of a desirable physical size, and are readily available commercially at a reasonable price.

The divider oscillator 260 includes a tube 262 having a cathode 264 grounded at 266, a control grid 268, and a plate 270. The control grid is connected through a resistor 272 to a point just above the capacitor 248 to couple the output of the oscillator 230 to the input of the oscillator 260. The plate 270 is connected through a resistor 274 to the B+ supply line 168 and is also connected through a capacitor 276 to a junction point 278. One end 280 of a tapped oscillator coil 282 is connected through a resistor 284 to the grid 268, and also is connected through a resistor 286 to the junction point 278.

A first tap 288 on the oscillator coil 282 is grounded as at 290, and a pair of capacitors 292 and 294 are connected between the tap 288 and the junction point 296 directly connected to the junction point 278.

Twelve taps labeled 1-12 on the coil 282 are connected to wires leading through a cable 298 to the tap switch contacts of the third wafer 108-3. These taps again correspond to the various notes as in the other wafer

switches and labeled on the drawing. The tap switch contacts on the wafer are connected in order in a counterclockwise direction to the tap switches on the coil as indicated by the numerals 1-12 on both the coil and the wafer. The arm 300 associated with the wafer 108-3 is connected through the cable 298 to the junction point 296.

In the piano tuner built in accordance with this invention as hereinbefore set forth, the tube 262 is one half of a 12AX7 twin triode. The resistor 272 is equal to one megohm, the resistor 274 is equal to 56,000 ohms, the capacitor 276 is equal to .01 microfarad, the resistor 284 is equal to 56,000 ohms, resistor 286 is equal to 470,000 ohms, and the capacitors 292 and 294 are respectively equal to 500 micromicrofarads and .0001 microfarad. The two capacitors 292 and 294 are connected in parallel in order to provide a capacity value not available commercially in a single capacitor.

The junction point 278 is connected through a resistor 302 to the grid 304 of a tube 306 of another divider oscillator 308, the circuit constants of this oscillator being such as to cause it to tend to oscillate at $\frac{1}{4}$ the frequency of the oscillator 260, the coupling of the oscillator 308 causing the oscillator to lock in at exactly $\frac{1}{4}$ the frequency of the former. The tube 306 includes a cathode 310 grounded at 312, and a plate 314 connected through a capacitor 316 to junction points 318 and 320 which are connected together. The plate 314 further is connected through a resistor 322 to the B+ supply line 168. An oscillator coil 324 is connected at one end through a resistor 326 to the grid 304, and also through a resistor 328 to the junction point 318. A tap 330 on the coil 324 is grounded as at 332, and the junction point 320 is also connected to the ground point 332 through a capacitor 334.

Twelve additional taps on the coil 324 are indicated on the drawing by the numerals 1-12 inclusive. These tap points are connected individually through the wires of a cable 336 to the individual tap switches of similar numeral on the fourth wafer indicated at 108-4. These tap switches on the wafer 108-4 again correspond to the notes of the scale as may be seen on the drawing.

The arm 338 comprising the movable switch member on the wafer 108-4 is connected through the cable 336 to the junction point 320. For illustrative purposes, the specific values of the divider oscillator 308 are given as they occur in the tuner constructed in accordance with the teachings of this invention. The resistor 302 is a one megohm resistor, the resistor 22 is a 56,000 ohm resistor, the resistor 326 also is a 56,000 ohm resistor, the resistor 328 is a 470,000 ohm resistor, the capacitor 316 is a .02 microfarad capacitor, and the capacitor 334 is a .001 microfarad capacitor.

The sixth wafer, indicated at the left end and identified by the numeral 108-6 in Fig. 7 is connected to the thyatron tube in the sweep circuit shortly to be described. The wafer 108-6 includes switch taps corresponding to the notes of an octave as labeled on the drawing.

The C# and D taps are connected by a 220,000 ohm resistor while the D and D# similarly are connected by a 220,000 ohm resistor. The D# and E taps are connected by a 150,000 ohm resistor. The E tap is connected to the F tap through a 120,000 ohm resistor, while the F tap and F# tap are likewise connected through a 120,000 ohm resistor. The F# tap is connected to the G tap through a 100,000 ohm resistor, and a 100,000 ohm resistor similarly connects the G tap to the G# tap. A 120,000 ohm resistor interconnects the G# and A taps, while 100,000 ohm resistors respectively interconnect the A and A# taps and the A# and B taps. A final resistor of 56,000 ohms interconnects the B and the C taps. There is no such connection between the C and C# taps.

The movable arm 340 associated with the wafer 108-6 is connected by a wire 342 to the C# tap or terminal. A

wire 344 connects the C# tap to terminal No. 8 of a terminal strip, while a wire 346 connects the C tap to terminal No. 7 on the terminal strip.

The terminal strip is shown at the lower right-hand corner of Fig. 7 and is identified by the number 348. The strip is provided with a terminal 1 near its left end which is provided with a 6.3 volt potential for energizing the filaments of the oscillator tubes and for lighting the pilot light indicated at 350. The second terminal on the strip 348 is connected by a wire 352 to the B+ bus line 168.

The third and fourth terminals are connected by wires 354 and 356 to a check switch shortly to be described. Terminal No. 5 is connected through a wire 358 and a resistor 360 to the arm 300 of the wafer 108-3. In the illustrative embodiment of this invention, the resistor 360 is a one megohm resistor. Terminal No. 6 is similarly connected by a wire 362 and a resistor 364 to the arm 338 of the wafer 108-4. In the illustrative embodiment of the invention, the resistor 364 is a one megohm resistor.

The seventh and eighth terminals are connected to the wires 346 and 344 respectively of the thyatron switch as previously indicated. Terminal No. 9 is grounded.

Means is provided for checking the oscillators and comprises a check switch indicated generally by the numeral 366 at the top central portion of Fig. 7. The check switch includes a first switch arm 363 cooperable with four switch contacts, the first three of which are connected to the crystal oscillator and to the first two divider oscillators through the cable 368 as indicated. The fourth contact is connected to the third divider oscillator through a wire 370, a resistor 372, and a wire 374 leading to the junction point 296 in the oscillator 260. In the illustrative embodiment of this invention, the resistor 372 is a one megohm resistor.

A second switch arm 376 is ganged with the first switch arm for cooperative engagement with four terminals labeled 1, 2, 3, and 4. The fourth of these terminals is connected through a wire 378 to the terminal point 320 of the fourth divider oscillator 308.

The two switch arms 368 and 376 are respectively connected through resistors 380 and 382 in series with capacitors 384 and 386, the latter being connected to the wires 354 and 356 previously indicated. The wire 356 is also connected to a movable switch arm 388 cooperable with four switch contacts labeled one through four, the first of these contacts being grounded through a capacitor 390. For illustrative purposes, the resistors 380 and 382 are 270,000 ohms, the capacitors 384 and 386 are .0003 microfarad, and the capacitor 390 is .002 microfarad.

Reference now should be had to Fig. 8 for an explanation of the audio and sweep circuit. The audio circuit includes the microphone jack 42 having contacts 392 for receiving the plug 44 of the probe as heretofore noted. The jack has a grounded terminal 394 and a spring terminal 396 directly connected to the grid 398 of an amplifier tube 400. When the plug is not in place, the spring contact 396 engages the grounded contact 394 so that there will be no input to the amplifier circuit. The tube 400 further includes a plate 402 and a cathode 404, the latter being connected to a ground line 406 through a parallel resistor 408 and capacitor 410. A grid resistor 409 is connected from the grid 398 to the ground line 406. The plate 402 is connected through a resistor 412 and through wires 414 and 416 to a B+ supply line 418, the wire 418 being provided with a decoupling circuit comprising a resistor 420 and a grounded capacitor 422 at its junction with the wire 416.

The plate 402 is coupled by means of a capacitor 424 to a potentiometer 426, the other end of which is grounded by means of the ground wire 406. The potentiometer 426 comprises a volume control 428 having a sliding tap 430 directly connected to the grid 432 of a vacuum tube 434. The cathode 436 of this tube is grounded through a parallel combination of a capacitor 438 and a resistor

440. The plate 442 is connected through a load resistor 444 to the wire 414, and is also connected by means of a capacitor 446 to the next succeeding amplifier stage.

In the previously mentioned tuner built in accordance with this invention, and these values are given by way of illustration only, the tubes 400 and 434 comprise the halves of a 6SN7 twin triode. The plate resistors 412 and 444 are 100,000 ohms each. The cathode resistors 408 and 440 are 1,200 ohms each, while the cathode capacitors 410 and 438 (it will be noted that these capacitors are of the type having a common ground) are 10 microfarads each. The grid resistor 409 is one megohm, while the potentiometer resistor 426 is 500,000 ohms. The coupling capacitors 424 and 446 are each equal to .05 microfarad.

The capacitor 446 couples the output of the tube 434 to the control grid 448 of an electron tube 450, the grid 448 being connected to the ground line 406 by a resistor 452. The cathode 454 of the tube 452 is grounded through a parallel resistor 456 and capacitor 458. The plate 460 is connected through a load resistor 462 to the wire 414, and is coupled through a capacitor 464 to the grid 466 of an electron tube 468. The cathode 470 of the tube 468 is grounded through a parallel resistor 472 and capacitor 474. A load resistor 476 connects the plate 478 of the tube 468 to the wire 414, while the plate 478 is connected through the capacitor 480 to a wire 482 leading to the vertical deflection plates of the oscilloscope unit 24.

The grid 466 is grounded through a capacitor 482 and also is connected to a wire 484 leading to a switch arm 486. In the normal position of the switch arm as illustrated, it contacts a fixed contact 488 which is connected through a wire 490 to a band pass filter 492 comprising a choke 494 and a capacitor 496 which are connected to the ground line 406. The switch arm 486 also is engageable with a contact 498 which is grounded through a resistor 500, and with a contact 502 which is grounded through a resistor 504.

The wire 490 further is connected to a wire 506 leading to a switch arm 508 of a tap switch 510 for connecting selected capacitors in parallel with the band pass filter 492 for varying the pass band. The switch arm 508 is cooperable with any of six contacts labeled 1-6 respectively. The first contact is not connected and this allows the band pass filter to peak at about 4,000 cycles to pass a band in this region. The second contact is grounded through a pair of capacitors 512 and 514 which are so chosen as to make the filter peak at about 2,000 cycles per second. The third contact is grounded through a capacitor 516 chosen to make the filter peak at about 1,000 cycles per second, while the fourth contact is grounded through a capacitor 518 chosen to make the filter peak at about 600 cycles per second. The fifth contact is grounded through a capacitor 520 chosen so as to make the filter peak at about 500 cycles per second and the sixth contact is grounded through a capacitor 522 chosen to make the filter peak at about 400 cycles per second.

Again referring to the tuner constructed in accordance with this invention, the grid resistor 452 is 470,000 ohms. Each of the cathode resistors 456 and 472 is 1,200 ohms, and each of the cathode capacitors 458 and 474 is 10 microfarads. The plate load resistors 462 and 476 are each 100,000 ohms and the coupling capacitors 464 and 480 are each .05 microfarad. The tubes 450 and 468 are halves of a 6SN7 twin triode. The capacitor 482 is .0005 microfarad, the resistor 500 is 22,000 ohms, and the resistor 504 is 10,000 ohms. The capacitors 512 and 514 connected to the tap switch 510 are respectively .002 and .006 microfarad. The capacitor 516 is .03 microfarad, the capacitor 518 is .1 microfarad, the capacitor 520 is .2 microfarad, and the capacitor 522 is .5 microfarad.

A tap switch 524 is provided with six taps, the first

three of which are treble taps and are connected in parallel to the fifth tap on the terminal strip 348 by means of a wire 526. The oscillation frequency supplied through the fifth tap or terminal on the terminal strip 348 to the three treble taps on the tap switch 524 is 880 cycles per second for the note A, and is on this general order for other notes. The last three taps on the surface 24 are bass taps and are connected in parallel by a wire 528 to the sixth terminal on the terminal strip 348, oscillations of 220 cycles per second being supplied to this terminal for the note A, and oscillations on the same order of magnitude being supplied for other notes in the same octave. The wire or line 528 is shunted to ground by a resistor 530.

The tap switch 524 is provided with a movable arm 532 engageable with any of the six taps for controlling the firing rate of a thyratron, and hence the sweep of the oscilloscope unit 24. The arm 532 is ganged with the arm 538 for movement therewith by the knob 56, and is connected through a capacitor 534 to a filter circuit 536 including capacitors 538 and 540 and a pair of resistors 542 and 544. The resistor 544 is connected with the grid 546 of an electronic tube 548 having a cathode 550 grounded through a parallel connected resistor 552 and capacitor 554. A grid resistor 556 is connected between the grid 546 and ground. The plate 558 of the tube 548 is connected through a load resistor 560 to a wire 562 leading to the B+ supply line 418.

The plate 558 also is connected by means of a capacitor 564 to the grid 566 of an electron tube 568. The grid is grounded through a grid resistor 570. The cathode 572 of the tube 568 is connected to ground through a parallel connected resistor 574 and capacitor 576. The plate 578 of the tube 568 is connected through a load resistor 580 to the wire 562. The plate is also connected to a coupling capacitor 582, and through a capacitor 584 to a three position tap switch 586 having a movable arm 588 which normally is connected to the first of a pair of grounded taps 590 and 592, the arm 588 being ganged with the arm 486 immediately to the left thereof. A wire on the arm 486 leads to the third contact or tap 594 of the tap switch 586.

Again referring to the tuner constructed in accordance with my invention for specific circuit values, the resistor 430 is 220,000 ohms, the capacitor 534 is .05 microfarad, the capacitors 538 and 540 are .006 and .001 microfarad respectively, and the two resistors 542 and 544 each are 470,000 ohms. The grid resistor 556 is 470,000 ohms. Each of the two cathode resistors 552 and 574 is 1,200 ohms, and each of the cathode capacitors 554 and 576 is 10 microfarads. The plate load resistors are 100,000 ohms each and the feed-back capacitor 584 is .003 microfarad. Each of the coupling capacitors 564 and 582 is .05 microfarad. The two electron tubes 548 and 568 are halves of a 6SN7 twin triode.

The plate 578 is connected through the capacitor 582 and through a resistor 596 to the grid 598 of a thyratron tube 600. The grid 598 is grounded through a resistor 602. The cathode 604 of the tube 600 is connected through a parallel combination of a fixed resistor 606 and a variable resistor 608 in series with a fixed resistor 610. The plate 612 is connected through a load resistor 614 and a wire 616 to terminal No. 7 of the terminal strip 348.

The plate 612 further is connected by a wire 618 to the movable arm 620 of a tap switch 622. The arm is ganged with the switch arms 508 and 532 and is co-operable with any of six fixed contacts. The first two contacts are connected in parallel by a wire 624 to a capacitor 626 which is connected to a bus line 628. The third tap is connected through a capacitor 630 to the bus line 628, while the fourth, fifth and sixth taps are connected, respectively, through capacitors 632, 634, and 636 to the bus line 628. The bus line 628 is connected through a wire 638 and a resistor 640 to the B+ bus

line 418, being connected thereto by a decoupling resistor 642 and capacitor 644. The cathode 604 also is connected to the wire 638. The resistors on the sixth wafer 108-6 as shown in Fig. 7, and the various capacitors 626-636 determined approximately the firing rate of the thyatron 600, the exact rate being determined by the amplified frequency fed to the thyatron by the amplifier stages including the tubes 548 and 568. The output of the thyatron tube 600 is coupled by a capacitor 646 and a resistor 648 to two of the taps 650 and 652 of a tap switch 654, the arm 656 of which is ganged for movement with the arm 588 of the tap switch 586, the arm 656 in its normal position engaging the tap 652. The remaining terminal or tap 658 of the tap switch 654 is connected to terminal No. 4 of the terminal strip 348.

Illustrative values of the various circuit elements again are set forth in accordance with the tuner constructed according to the principles of this invention. The thyatron tube 600 is a type 884 tube. The resistor 596 is 270,000 ohms, the resistor 602 is 3,300 ohms, the resistor 608 has a maximum value of 2,000 ohms, the resistor 610 is 5,000 ohms, the plate load resistor 614 is one megohm, the coupling resistor 648 is 470,000 ohms, and the resistor 640 is 100,000 ohms. The coupling capacitor 646 is .05 microfarad, while in the thyatron timing circuit the capacitor 626 is .004 microfarad, the capacitor 630 is .01 microfarad, the capacitor 632 is .03 microfarad, the capacitor 634 is .05 microfarad, and the capacitor 636 is .1 microfarad. The output of the thyatron is coupled to an amplifier tube 660 through the tap switch 654 and a wire 662 leading to the control grid 664 of the tube 660. A grid resistor 666 is connected between the grid 664 and ground, while the cathode 668 is grounded through a cathode resistor 670. The suppressor grid 672 is directly connected to the cathode according to the usual practice. The screen grid 674 is shunted to ground by a capacitor 676 and is connected through a resistor 678 to the B+ supply line 418, this line being connected through a wire 680 to the high voltage terminal, namely terminal No. 8, on the terminal strip 348. The plate 682 is connected through a plate load resistor 684 to the high voltage wire 680, and is coupled through a capacitor 686 to the horizontal deflection plates of the oscilloscope unit 24.

Again referring to the tuner constructed in accordance with the principles of this invention, the resistor 666 is 270,000 ohms, the cathode resistor 670 is 5600 ohms, the screen grid and plate resistors 678 and 684 each are 82,000 ohms, while the screen shunting capacitor 676 is .1 microfarad and the output coupling capacitor 686 is .05 microfarad.

The first terminal of the terminal strip 348 is provided with a 6.3 volt A.C. filament potential. This is connected to the filaments of the various tubes shown in Fig. 8 as readily may be seen in this figure.

The third terminal is connected to the arm 688 of a tap switch 690, this arm being ganged with the arms 588 and 656 of the tap switches 586 and 654 as indicated by the dashed line. This arm is cooperable with any of three contacts, the first two of which, numbered 692 and 694, are grounded. The third contact 696 is connected by a wire 698 to the top of the volume control resistor 426. The three ganged tap switches are used for testing purposes as will be brought out hereinafter.

The ninth terminal on the strip 348 is grounded as previously indicated, while the second terminal is provided with 225 volts D.C. regulated potential from the power supply described immediately hereinafter.

The power supply is shown in Fig. 9 and includes a transformer 700, the primary 702 of which is connected to a connector 704 for receiving the connector 78 of the line cord 80. The primary 702 is connected directly to the connector 704 by a wire 706, and also through wires 708 and 710, a switch 712 on the volume control, and a fuse 714. A capacitor 715 is connected between the wire

706 and ground. The wires 708 and 710 are interconnected by a jumper on a voltage regulator tube as will be brought out hereinafter so that the power cannot be turned on unless the voltage regulator tube is in place.

The transformer 700 is provided with two filament windings. The first filament winding 716 is grounded at one end as at 718 and is connected at the other end by a wire 720 to terminal No. 1 on the terminal strip 348 for supplying 6.3 volts A.C. filament voltage to all of the tubes in the frequency standard and in the audio and sweep circuit. The second filament winding 722 is provided for supplying 6.3 volts A.C. filament voltage to the cathode ray tube 28 in the oscilloscope unit 24. The output terminals 724 and 726 of the cathode ray tube filament winding 722 are connected to wires 7 and 8 as shown at the winding, and also at the upper left-hand corners of Fig. 9, of the cable 30 leading to the cathode ray tube of the oscilloscope unit 24, the cathode ray tube socket being indicated at 728. A capacitor 730 is connected between the terminal 724 and ground.

The transformer 700 further is provided with a secondary coil 730 which is center tapped and grounded at 732. The two ends of the coil 730 are connected to the two plates 734 and 736 of a rectifier tube 738 in a full wave rectifier. A five volt filament coil 740 of the transformer is connected to the filament 742 of the tube 738, and one side of the filament is connected to a smoothing filter 744. The filter includes a grounded capacitor 746, a choke coil 748, and a grounded capacitor 750. A wire 752 leads directly from the filter 744 to the eighth terminal on the terminal strip for supplying B+ to the audio and sweep circuits. A resistor 754 leads from the wire 752 to a voltage regulator tube 756 which is arranged in series with a voltage regulator tube 758, the latter being grounded at 760. A wire 762 leads from the plate of the voltage regulator tube 756 to terminal No. 2 on the terminal strip 348 for supplying regulated voltage to the frequency standard. As previously indicated, two of the terminals of the voltage regulator tube 756 are jumpered as at 764 to connect the wires 708 and 710 in the primary circuit of the transformer 700.

A high voltage secondary coil 764 is connected in series with half of the coil 730 above the ground tap 732. The end of the coil 764 which is not connected to the coil 730 is connected to one end of a five volt filament coil 766, the latter being connected to the filament 768 of a rectifier tube 770. The rectifier tube 770 has two plates 772 and 774 which are connected in parallel. The parallel connected plates are filtered by a capacitor 776 connected to ground, and by a series of resistors 778, 780, 782, 784 and 786, the resistors being connected in series and grounded at 788, thereby providing a complete half wave rectifying circuit between the ground points 788 and 732, half the coil 730, the coil 764 and the rectifier tube 770.

The resistor 778 is provided with a sliding tap 790 connected to wire No. 2 of the cable 30 and leading to pin No. 2 on the cathode ray tube socket 728. A connection is provided at 792 between the resistors 778 and 780 to the first wire of the cable 30 leading to pin No. 1 of the CR tube socket. The resistor 782 is provided with a sliding tap 794 which is connected to wire No. 4 of the CR tube socket.

A tap 796 is provided between the resistors 784 and 786 and is connected to a centering network 798 for adjusting the centering of the cathode ray tube. The filter network includes a pair of resistors 800 and 802 connected in parallel between the tap 796 and a resistor 804, the resistor 804 in turn being connected to the B+ supply line 752. A sliding tap 806 is provided on the resistor 800 and is connected through a resistor 808 to wire No. 3 of the cable 30. A sliding tap 810 on the resistor 802 is connected through a resistor 812 to wire No. 5 of the cable 30.

For illustrative purposes only, reference again will be

made to the tuner constructed in accordance with the principles of this invention. The transformer 700 may be of the type known commercially as Stancor T-306049 or it may be of the type known commercially as Thordarson T-52678. The capacitor 715 in the input circuit is .1 microfarad. The capacitor 730 on the CR tube filament winding is a .006 microfarad capacitor. The full wave rectifier tube 738 is a type 5V4, while the tube 770 used as a half wave rectifier is a type 80. In the filter 744 the capacitor 746 is an eight microfarad capacitor, the capacitor 750 is a 20 microfarad capacitor, while the choke coil 748 is rated at 325 volts D.C. and 40 ma. The voltage regulator tube 756 is a type OA3, VR75, and the voltage regulator tube 758 is a type OA2, VR150. The resistor 754 is 5,000 ohms. In the series of voltage divider resistors the resistor 778 is 250,000 ohms, the resistor 780 is 390,000 ohms, the resistor 782 is 500,000 ohms, the resistor 784 is 820,000 ohms, and the resistor 786 is 510,000 ohms. In the centering network the resistors 800 and 802 each are one megohm resistors, the resistor 804 is a 510,000 resistor, the tap resistor 812 is 510,000 ohms and the tap resistor 808 is 4.7 megohms.

Operation

To use the tuner heretofore described, the main unit 22 is placed in a horizontal or vertical position in any convenient location and is connected to a suitable electrical outlet by means of the cord 80 and plug 82. The oscilloscope unit 24 is connected to the main unit 22 by means of the cable 30 and is placed in any convenient position where it can be seen by the operator. For instance, the oscilloscope unit can be placed on the top of the piano back, or on the fall board, or on a chair. Generally speaking, the best place is on the back right next to the string being tuned. The electronic pick-up 48 is connected to the main unit by inserting the plug 44 into the "microphone" jack on the front panel.

The tuner as heretofore described is particularly adapted for tuning pianos, but it can be used for tuning other instruments, and pick-ups other than the pick-up 48 may be used. For instance, a high impedance crystal microphone may be plugged into the microphone jack, and a piano or other instrument may be tuned according to conventional practices, except that the visual indication on the cathode ray tube 28 is relied upon to indicate proper tuning, as opposed to the customary reliance upon the ear of the person doing the tuning. When testing electronic instruments, such as electronic organs, the sound can be picked up directly from the speakers with a microphone. Preferably, however, a special cable is utilized to pick up the sound electronically. The cable utilizes an octal adapter plug wired for insertion in the socket of an output tube and provided with an isolating condenser and a volume control box. By this means, there need be no audible sound, no distortion can be introduced by speakers or microphones, and no spurious sounds can be introduced into the tuner.

The crystal controlled oscillator determines the horizontal sweep of the oscilloscope unit 24. As will be obvious from the earlier description, whichever one of the crystals 112 is connected in circuit by the wafer switch 108-5 controls the frequency of the master oscillator 140. The approximate frequency of the divider oscillator 184 is determined by whichever one of the taps 1-8 of the coil 192 is connected by the wafer switch 108-1. The oscillator 184 locks in with the master oscillator 140 to determine its exact frequency. Similarly, the approximate frequencies of the divider oscillators 230, 260, and 308 are determined by the taps on their coils as connected by the corresponding wafer switches, and by locking in with the immediately preceding oscillator. An extremely stable audio frequency selectively corresponding to the notes of a piano or other musical instrument thus is produced by the last divider oscillator 308.

The discharge frequency of the thyatron tube 600

is determined approximately by the position of the wafer switch 108-6, and also by the position of the switch 622. The audio frequency from either the last divider oscillator 308, or from the next to the last divider oscillator 260, depending upon the position of the tap switch 524, is amplified by the two amplifier stages including the tubes 548 and 568 and exactly controls the firing of the thyatron 600. This produces an extraordinarily stable saw-tooth sweep voltage that is amplified by the amplifying stage including the tube 660. The amplified saw-tooth sweep voltage then is applied to the horizontal deflecting plates of the cathode ray tube. The circuit components of the thyatron circuit are chosen so that there is an appreciable time taken in discharging the capacitors 626, and 630-636 in order to produce a visible return trace on the cathode ray tube as an aid in tuning as will be brought out shortly.

The vertical deflection of the cathode ray tube is controlled by the input from the electronic pick-up as amplified by the stages including the tubes 400, 434, 450, and 468. The filter or parallel resonant circuit 492 peaks the amplified signal in the general region of the fundamental and eliminates or greatly reduces the harmonics so that a sine wave is applied to the vertical deflection plates.

In order to use the tuner after the various parts have been connected and the plug 82 has been inserted in a suitable receptacle, a knob 814, Fig. 1 on the front panel immediately above the microphone jack is turned to close the line switch 712 (Fig. 9) and also to operate the volume control 428 (Fig. 8) of the audio amplifier. The knob 58 is turned to bring the note to be tuned into the center of the window 60 and to set the various wafer switches.

In tuning a piano, it generally is preferable to start by tuning the bass and to work up toward the treble end through the successive notes. The electronic pick-up is adapted to clip directly on to the middle and treble strings, but it will not clip on to the built up strings of the bass. Accordingly, in tuning the bass the electronic pick-up should be placed between the strings about middle C with the clip end of the pick-up firmly engaging the sounding board. The pick-up may be moved around slightly to obtain the best image on the cathode ray tube screen. In tuning the bass notes, wedges should be used to mute one of the pair of strings producing the note being tuned so as to keep from obtaining a double image. The volume control should not be advanced any farther than necessary to obtain a good picture. The knob 56 of the treble-bass switch should be turned to No. 5 or Bass to suit the operator. If, for example, the A string is being tuned, the knob 58 of the selector dial should be turned until A appears at the lighted area in the center of the window. A rubber wedge should be used to mute one of the A strings until the other string is in tune, and the wedge then should be inserted beneath the other string for tuning of the string that was first muted.

As aforementioned, the image on the cathode ray screen is a sine wave. The number of loops in the sine wave depends on the frequency of the note being tuned and on the position of the treble-bass switch. The number of loops can be changed by turning the knob 56. When the test frequency (horizontal sweep rate) and the note being tuned are equal in frequency, the image on the screen will appear to be standing still. When the instrument being tuned is flat, the image will appear to be running to the left, and when the instrument being tuned is sharp, the image will appear to be running to the right. Once the note is brought approximately into tune, the image will move very slowly and the horizontal return trace is resorted to for final tuning. When the return trace is stationary and not moving up and down, then the image is standing still and the note is in tune.

To tune the middle section and the treble, the electronic pick-up should be removed from the sounding

board and clipped to the string being tuned. The clip on the end of the electronic pick-up should touch only one string at a time, or a double or multiple image will appear on the cathode ray indicator. It is preferable to clip the electronic pick-up between the pressure bar and the plate bearing so that the pick-up will not tend to damp the vibration of the string. If the plate bearing and the pressure bar are too close together, the electronic pick-up can be clipped below the pressure bar, but as close to the pressure bar as is mechanically possible.

By clipping the pick-up on to each string individually and moving the selector dial to indicate the screen being tuned, the entire middle and treble sections can be tuned without the use of felts or wedges.

When tuning the middle and treble sections, the treble-bass switch can be set to any number between Treble and No. 5 that will suit the operator. The recommended procedure is to start on No. 5 and to use it up to the break to the middle section and the upper section. Use No. 4 to the first C above the break and No. 3 for the next octave. The operator can use any combination he likes as there will be no difference in the final tuning, the only difference being in the number of loops in the sine wave on the cathode ray screen.

Switches and trimmers are incorporated in the tuner for easy adjustment in the field and for checking by means of the cathode ray tube or oscilloscope unit. To check the dividers, turn the switch on the front panel marked "Check" to the left to adjust the tap switches 690, 586, and 654 (Fig. 8) associated with the audio and sweep circuits. On the right-hand side of the main unit, there are provided two small holes (not shown) close to the panel and a larger hole (not shown) about 3½ inches toward the rear. The four throw rotary switch 366 with a screw driver adjustment is right inside the larger hole for operating the switch having the switch arms 368, 376, and 388 (Fig. 7). When the screw driver slot is vertical, the switch is on position No. 4, and when the slot is horizontal, the switch is on position No. 1. Trimmers are located immediately behind the two smaller holes. The numbers on the switch and trimmers can be seen by removing the housing from the main unit. The switch 366 checks the divider stages by putting the crystal oscillator on the vertical deflection plates and the successive divider stages, according to the switch position, on the horizontal deflection plates to get Lissajous figures on the cathode ray screen.

Testing should be started with the switch on the side in position No. 1. The image appearing on the oscilloscope unit will be normal 1:5 Lissajous figure. Should the image appear out of synchronism, the trimmer for that stage can be found on the left hand side near the panel behind the lower of two small holes (not shown). The knob 58 should be turned to move the selector dial one revolution from C back to C and each note should be checked. Proper vertical height can be attained by adjustment of the microphone control 814 on the front panel. The switch on the right-hand side then should be turned to position No. 2. The image again is a 1:5 Lissajous figure and of considerably greater magnitude than the first image. The procedure is repeated and each note checked, the trimmer being found on the left-hand side above the first trimmer. Should a Lissajous figure appear to have a 1-5 ratio, but be fuzzy and have double lines, trimmer No. 1 can be turned slightly clockwise to clear up the image. The reason for this is that in taking enough voltage from the first divider stage to give a readable Lissajous figure, sufficient capacity is sometimes added to upset the tuning. This will not occur in any other stage.

The switch on the right-hand side should be turned to position No. 3 and No. 4 and the operations repeated. The third and fourth trimmers are found in the previously noted two small holes close to the panel on the

right side, No. 3 being on the bottom and No. 4 on top. The Lissajous figure on position No. 3 varies from 1:4 to 1:8. On position No. 4 the Lissajous figure is 1:4 on all notes. When these checks are made, the audio standard will be right in frequency and all of the dividers will be operating properly. The check switch on the front panel in the lower left-hand corners then should be turned one step to the right to its normal operating position.

The four screw driver adjustment potentiometers 128 available from the rear of the main unit are for adjusting the oscilloscope unit. Looking from the rear of the unit, the one on the right moves the image vertically and the one next to it moves the image horizontally through movement of the slidable taps 806 and 810 (Fig. 9). The one on the left adjusts the intensity, and the one near to it adjusts the focus, these adjustments being made by the sliding taps 790 and 794.

Utilizing the tuner disclosed herein, a person of only moderate training and skill readily can tune a musical instrument. No musical ability nor ear training is necessary. The visual tuning eliminates the necessity for these skills, and the filter circuit reduces the complex musical wave to a simple sine wave which is readily studied by the person doing the tuning. Movement of the sine wave is readily observed for approximate tuning, and the horizontal return trace provides for extremely accurate final tuning. The visual tuning makes it unnecessary to provide a special tuning room for pianos and electronic instruments. Since in instruments of these types, sound is not relied upon at any stage of the tuning, a plurality of such instruments can be tuned in the same room.

The entire tuner including the main unit, the oscilloscope unit, the pick-up, the various connecting wires and cables, and a carrying case (not shown) weighs only twenty-two pounds, and hence is readily portable. The two-part construction allows the unit to be set up readily at any site. The main unit can be placed at a convenient, but out of the way, location in either a vertical or horizontal position, while the oscilloscope unit can be placed immediately adjacent the instrumentality, such as a piano string, being tuned so that the indication of the tuning can be seen on the cathode ray screen at the same time as the instrumentality is being adjusted.

The physical arrangement of the crystals and of the wafer tap switches leads to a small and compact structure which decreases the size and weight of the tuner, thereby rendering the same more readily portable.

The continuous range of operation of the tuner allows all of the notes of a musical instrument to be tuned without the necessity of making complicated adjustments to the tuner. All that is necessary is to turn the tuning knob 58, and occasionally the knob 56 of the treble-bass switch.

The structure of the invention herein described is capable of modification without departing from the inventive principles involved. It therefore is to be understood that the embodiment herein shown and described is for illustrative purposes only, and that my invention includes all that which falls fairly within the spirit and scope of the appended claims.

I claim:

1. Apparatus for tuning musical instruments comprising a crystal controlled oscillator having a plurality of selectively operable crystals for controlling oscillations of said oscillator at selected frequencies substantially above the audio range, a succession of oscillators, each of said succession of oscillators having a tapped tuning coil, means for selectively bringing the crystals of said crystal controlled oscillator and selected taps of the coils of said succession of oscillators simultaneously into operation to operate said succession of oscillators at submultiple frequencies of the frequencies of said crystal controlled oscillator for producing stable audio reference frequen-

cies, said crystal controlled oscillator and said succession of oscillators being connected in series whereby each oscillator positively determines the frequency of the oscillator following it, means for picking up the oscillations of a note of a musical instrument being tuned, and means for comparing the oscillations picked up with said stable audio frequencies.

2. Apparatus for tuning musical instruments comprising a crystal controlled oscillator adapted to oscillate at a frequency substantially above the audio range, a plurality of divider oscillators adapted to oscillate at different submultiple frequencies of the crystal controlled oscillator and successively controlled by said crystal controlled oscillator and by one another, means for picking up the oscillations of a note of a musical instrument being tuned, means for filtering oscillations picked up to pass substantially only a sine wave, an oscilloscope, means for applying said sine wave to said oscilloscope, and means for connecting the divider oscillators to said oscilloscope for controlling the sweep rate of said oscilloscope, said connecting means including means for connecting different ones of said divider oscillators to produce different numbers of loops of said sine wave on the oscilloscope.

3. Apparatus for tuning musical instruments as set forth in claim 2 and further including means for producing a sweep for said oscillator with an appreciable return time so that a return trace is visible for aid in indicating when the instrument is properly tuned.

4. Apparatus for tuning musical instruments comprising a crystal controlled oscillator, a plurality of crystals, tap switch means for connecting said crystals selectively to said crystal controlled oscillator for controlling oscillations thereof at frequencies substantially above the audio range, a succession of divider oscillators successively controlled by said crystal controlled oscillator and by one another, to produce standard audio reference frequencies, each of said succession of divider oscillators having a tapped coil, tap switch means for selectively connecting the taps of said coils to tune said divider oscillators to submultiple frequencies of said crystal controlled oscillators, means for mounting said crystal connecting tap switch, said tap connecting tap switches, and said crystals as a unit for simultaneous movement, means for picking up the oscillations of a note of a musical instrument being tuned, and means for comparing the oscillations picked up with the standard audio frequency produced by said divider oscillators.

5. Apparatus for tuning musical instruments as set forth in claim 4 wherein the means for mounting the crystals comprises a cylinder having a plurality of axially extending recesses arcuately spaced about the periphery thereof, hold down members between successive pairs of recesses, and detachable fastener means for urging said hold down members toward said recesses to hold crystals in said recesses.

6. Apparatus for tuning musical instruments comprising a crystal controlled oscillator, a plurality of crystals, tap switch means for connecting said crystals selectively to said crystal-controlled oscillator for controlling oscillations thereof at frequencies substantially above the audio range, a succession of divider oscillators successively controlled by said crystal-controlled oscillator and by one another to produce standard audio reference frequencies, some of said divider oscillators producing a fixed division, and at least one of said divider oscillators providing a variable division, an oscilloscope having horizontal and vertical deflection means, means connecting said succession of divider oscillators to the horizon-

tal deflection means, a pickup for picking up the oscillations of a note of a musical instrument being tuned, and means for connecting said pickup to said vertical deflection means whereby the frequency of the musical instrument being tuned can be compared with the frequency established by said crystal-controlled oscillator and said succession of divider oscillators.

7. Apparatus as set forth in claim 6 and further including a plurality of tap switches, one for each divider oscillator, said tap switch means and said tap switches each having a movable arm, and said movable arms being ganged for movement as a unit.

8. Apparatus as set forth in claim 6 wherein the means connecting divider oscillators to the horizontal deflection means comprises a thyatron and an amplifier for the output of said thyatron.

9. Apparatus as set forth in claim 8, and further including a plurality of tap switches, one for each of said divider oscillators and for an oscillation circuit associated with said thyatron, said tap switch means and said tap switches each having a switch arm, and all of the said switch arms being ganged for movement as a unit.

10. Apparatus for tuning musical instruments comprising a controlling oscillator having a plurality of selectively operable frequency determining elements for controlling oscillations of said oscillator at selected frequencies above the audio range, a succession of divider oscillators, each of said divider oscillators having variable tuning means, means for simultaneously switching the frequency determining elements of said controlling oscillator and varying the tuning means of said divider oscillators simultaneously to operate said divider oscillators at submultiple frequencies of said controlling oscillator for producing stable audio reference frequencies, said controlling oscillator and said divider oscillators being connected in series whereby each oscillator positively determines the frequency of the succeeding divider oscillator, means for picking up the oscillations of a note of a musical instrument being tuned, and means for comparing the oscillations picked up with said stable audio frequencies.

11. Apparatus for tuning musical instruments as set forth in claim 10 wherein the variable tuning means of each of the divider oscillators comprises a tapped tuning coil.

12. Apparatus for tuning musical instruments as set forth in claim 11 and further including tap switch means for connecting said frequency determining elements to said controlling oscillator and tap switch means for selectively connecting the taps of said coils to tune said divider oscillators, and means for mounting all of said tap switch means as a unit for simultaneous movement.

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