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Whitaker

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[54] **MUSICAL TUNING INSTRUMENT UTILIZING DIGITAL TECHNIQUES**

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[51] **Int. Cl.** **G10g 7/02**

[58] **Field of Search** ..... 84/454, 1.01, 444; 324/79 R, 79 D, 81

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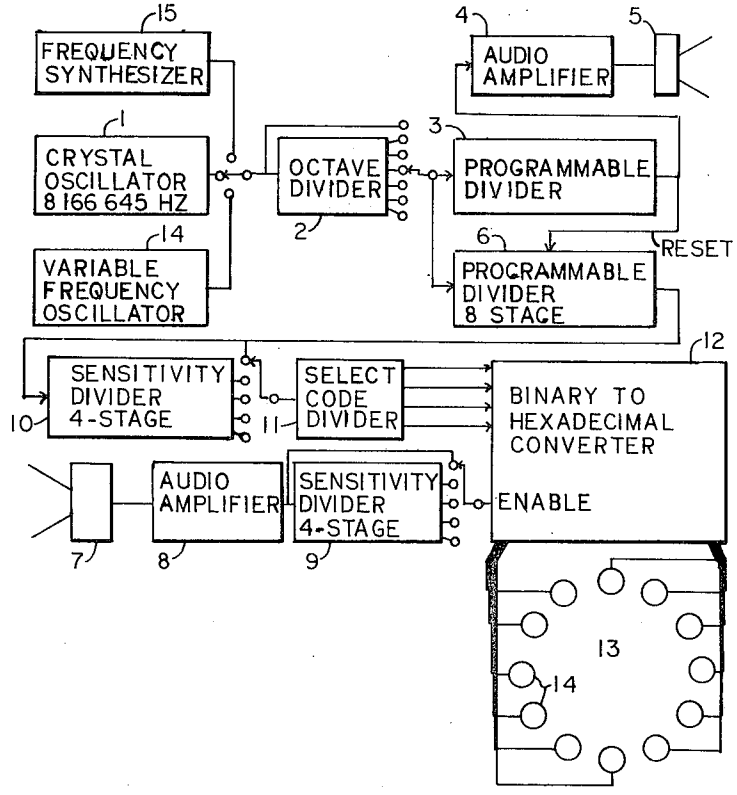
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[57] **ABSTRACT**

A musical tuning instrument for use by high school bands is disclosed. Instrument produces reference tones of the musical scale. Instrument also indicates whether a sounded tone is higher or lower than a particular musical note. Indication is visual. An eight MgHz reference oscillator feeds a programmable counter to produce close approximations to the musical scale. Sounded tones are compared in frequency with the reference frequencies and the comparison indicated by a pattern on a light emitting diode display.

3 Claims, 2 Drawing Figures



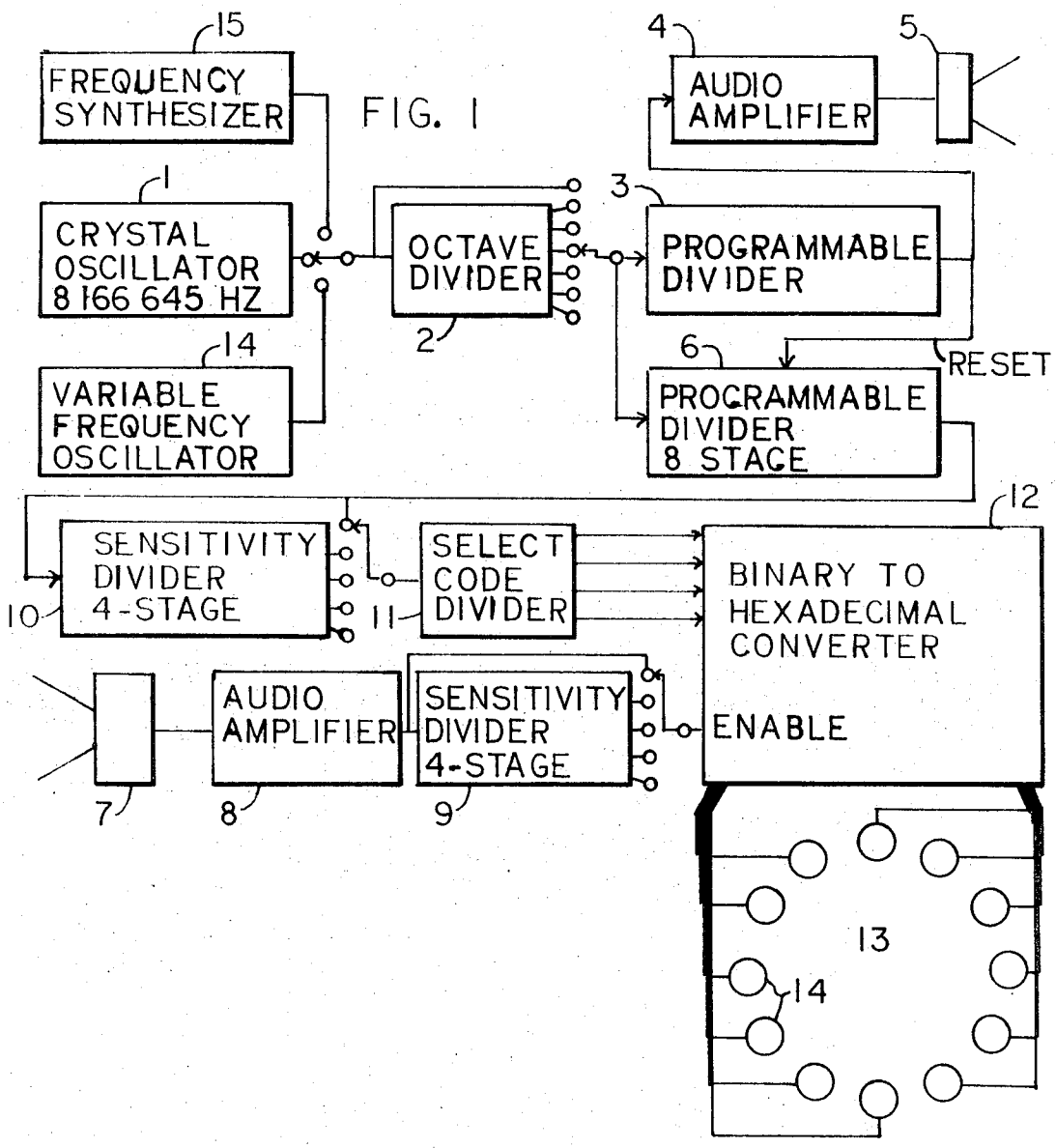
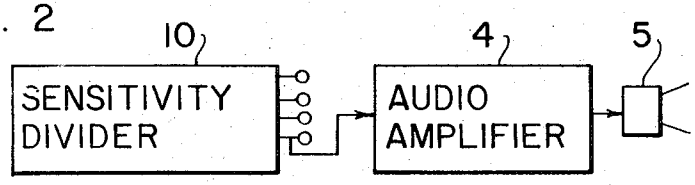

15
FREQUENCY SYNTHESIZER
FIG. 1
4
AUDIO AMPLIFIER
5
1
CRYSTAL OSCILLATOR 8 166 645 HZ
OCTAVE DIVIDER
2
3
PROGRAMMABLE DIVIDER
14
VARIABLE FREQUENCY OSCILLATOR
6
RESET
PROGRAMMABLE DIVIDER 8 STAGE
12
SENSITIVITY DIVIDER 4-STAGE
10
11
SELECT CODE DIVIDER
BINARY TO HEXADECIMAL CONVERTER
ENABLE
7
AUDIO AMPLIFIER
8
SENSITIVITY DIVIDER 4-STAGE
9
13
14

FIG. 2


10
SENSITIVITY DIVIDER
4
AUDIO AMPLIFIER
5

MUSICAL TUNING INSTRUMENT UTILIZING DIGITAL TECHNIQUES

BACKGROUND OF THE INVENTION

Skilled musicians generally tune their instruments by listening to reference tones and adjusting their pieces to the same frequency. Beats are heard as the tone generated by the instrument approaches the reference tone in frequency. The musician tunes for zero beat. Persons of lesser skill, such as members of high school bands, find it beneficial to use additional tuning aids. Such aids generally are visual in nature. Typical is the stroboscopic display in which whirling discs form a visual pattern in response to a tone generated by the student. The pattern moves clockwise or counterclockwise depending upon whether the student is tuned high or low. The student adjusts his piece until the pattern assumes a stationary position. The stroboscopic unit suffers several shortcomings:

1. It does not give an audible tone to induce the student to tune by ear in a professional manner.
2. It is generally too heavy to be carried in suitcase fashion. It is not easily moved.
3. It is expensive—presently costing some $750.00.
4. It has moving parts and vacuum tubes, both of which contribute to service requirements

SUMMARY OF THE INVENTION

A crystal reference oscillator provides a reference signal which is divided down by a programmable divider to produce close approximations of the several frequencies of the musical scale. An audio output section generates tones for use by the student. The student may also play his piece into a microphone which feeds to the instrument. The frequency of the tone generated by the student is compared by the instrument with a musical scale frequency obtained from the programmable divider. As a result of the comparison a pattern of light and dark Leds (light emitting diodes appears in a display. The pattern moves clockwise or counterclockwise depending upon whether the student is tuned high or low. Two additional division circuits permit adjustment of the sensitivity of the display. In the most coarse position the tone generated by the student must shift approximately **16** cycles from the reference signal before the display pattern rotates one revolution. In the fine position a shift of one cycle causes a rotation of one revolution.

Advantages over conventional instruments are:

1. A tone is generated to assist the student in learning to tune by ear.
2. No moving parts are involved. Solid state circuitry is used throughout. These two items contribute greatly to reliability of product.
3. Mass and size of the unit is reduced over conventional tuning aids by an order of magnitude.
4. Cost is reduced by a similar order of magnitude.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram indicating interrelationship of the several sections of a musical tuning instrument built according to the present invention.

FIG. **2** is a block diagram indicating an alternate embodiment of the present invention. Specifically, FIG. **2** shows an alternate connection of selected components of FIG. **1.**

DETAILS OF THE INVENTION

Referring to FIG. **1,** oscillator **1** is preferably a crystal unit providing a very stable output frequency of 8,166,645 Hz. A Motorola type K1091A has been used and is suitable.

While the instrument is capable of providing tuning assistance for each note of the musical scale, understanding of the operation of the system may best be gained through consideration of a single note. Since middle A having a frequency of 440 Hz is most commonly used for tuning it will be used in the following explanation.

Octave divider **2** provides seven outputs corresponding to the seven octaves of the musical scale. The output selector switch is set to the middle octave in which A 440 is found. Two TTL 7493 made by Texas Instruments Corporation integrated circuits are suitable for this divider.

Programmable divider **3** consisting of 12 binary stages is programmed in 12 ways to provide close approximations of the 12 notes of the octave. In the present case it is programmed to provide at its output a signal whose frequency closely approximates the A 440. Several programming techniques are common in the art. They will not be discussed. The divider may consist of three TTL type 8281A made by National Semiconductor Corporation integrated circuits. For details of design of such a divider see Approximating the Frequencies of the Musical Scale with Digital Counter Circuits by Roelif Staplefeldt on Page 478 of Vol. 46 of the Journal of the Acoustical Society of America.

Audio amplifier **4** feeding to speaker **5** causes the selected note to be sounded. In the present case A 440 is sounded. The amplifier may consist of two cascaded transistors type 2N1711 made by Texas Instruments Corporation coupled as emitter followers.

Microphone **7** picks up the note from the musical instrument being tuned. The resultant signal is amplified by amplifier **8** and fed to sensitivity divider **9.** This signal will be approximately 440 Hz. Amplifier **8** may be an RCA type 3010A integrated circuit. Divider **9** may be a TTL 7493.

Amplifier **8** is overdriven so that the output is essentially a square wave capable of acting as a suitable digital input to sensitivity divider **9.** Alternatively a Schmitt trigger may be interposed between the two items. However, this was found unnecessary.

The output of octave divider **2** is fed to a second programmable divider **6** consisting of eight stages. The programming of this divider is coordinated with the programming of divider **3** so that the frequency of the output of divider **6** is approximately 16 times the frequency of the output of divider **3.** The output of divider **6** feeds to sensitivity divider **10.** Divider **6** is reset by divider **3.** Consequently the output pulse train from divider **6** is repeated once for each output pulse from divider **3.** Divider **6** may be formed of two cascaded TTL type 8281A integrated circuits.

The output selector switches of dividers **9** and **10** are ganged.

Binary to hexadecimal converter **12** is an integrated circuit (TTL type 74154) commonly available. It has 16 outputs. Any one of the 16 outputs is selected in accordance with a four bit select code delivered on four input lines. However, for any of the output lines to be activated an "Enable" signal must also be received.

The select code for converter **12** is provided by the select code divider **11.** This may be a TTL 7493. The Enable signals obtained directly from the switch associated with divider **9.**

A display **13** consisting of 16 Leds **14** formed in a circle is fed from the outputs of converter **12.** The arrangement is such that only one Led is addressed at any one time. This "Address" moves sequentially around the circle. For the present case of A 440, the movement is at a rate closely approximating 440 revolutions per second.

If audio amplifier **8** is overdriven, the Enable signal will be high approximately 50 percent of the time. If the note sounded into the microphone is exactly 440 Hz, a stationary pattern of half the Leds lit and the other half unlit will appear in display **13.** If the note sounded into microphone **7** is low, the pattern appearing on display **13** will rotate in a first direction. If the note sounded is high, the pattern will rotate in the opposite direction. Rate of rotation will depend upon how far "off" the sounded note is from the reference signal. If it is off by 1 hertz, the pattern will rotate once per second. If it is off by 10 Hz, the rotation will approach the flicker rate and the eye will hardly be able to tell in which direction the pattern is rotating.

To reduce the flicker problem, sensitivity dividers **9** and **10** have been incorporated. They provide for division by factors of **2,4,8,** and **16.** if the selector switch is set to the **16** position, then an error of 16 Hz for the sounded note will cause a rotation in the display of one revolution per second. For A 440 the 16 Hz is more than half a semitone. Consequently the sensitivity divider having four binary stages appears adequate. Integrated circuits used in the divider may be TTL 7493.

ALTERNATE EMBODIMENTS

In some cases a band leader may desire to tune high by a few cents or perhaps low by a few cents. In these cases oscillator **1** may be replaced or supplemented by variable frequency oscillator **14.** Varying the frequency of this oscillator from the prescribed 8,166,645 Hz causes the entire range of reference frequencies to move up or down by a proportionate amount. A suitable variable frequency oscillator using an FET **3N128** is described by Hanchett in the Oct. 1960 issue of QST.

Alternatively a frequency synthesizer **15** may be used, of which several types are presently reaching that state of development where they can be economically applied.

Binary to hexadecimal converter **12** operated in conjunction with select code divider **11** may be replaced by a shift register fed directly from divider **10.** This system is more economical. It has been tried and works well.

A Schmitt trigger (TTL 7413 made by Texas Instruments Corporation) may be inserted between amplifier **8** and divider **9.** This removes the requirement for overdrive on amplifier **8.**

A Schmitt trigger may be inserted ahead of divider **2** in those cases where the oscillator does not give a digitally compatible signal.

Alternate embodiments involve different combinations of the sections of FIG. **1.** To cover only one octave, divider **2** may be omitted and the frequency of oscillator **1** shifted to provide outputs in the desired range. If only reference tones are desired, all circuitry associated with the display may be omitted. If only the display is desired, the audio output circuitry may be omitted.

It is apparent that increasing the frequency of oscillator **1** by a factor of 16 will permit divider **6** to be eliminated. However, another divide-by-16 divider must be inserted between divider **3** and amplifier **4.** The 8 MgHz oscillator is near the upper limit of conventional TTL technology, which fact precludes use of this technique at present. As Schottky TTL becomes available or ECL comes into common use, this approach will probably prove preferable.

It is also apparent that the display may be in a straight line rather than in a circle. Also, the sweep rate need not be closely related to the reference frequency as is provided presently by dividers **6** and **10.** The only requirement is that the sweep be triggered by the output of divider **3.** An entirely separate system may be used in place of dividers **6, 10,** and **11.** One such system would consist of a simple multivibrator feeding a shift register, the shift register being reset by the output of divider **3.**

It is also apparent that the sweep of the display need not be at a rate equal to the frequency of the note under consideration. A sweep rate of 440 Hz causes one lobe of lit Leds and one lobe of unlit Leds. A sweep rate of 220 Hz causes two lit lobes and two unlit lobes. A sweep rate of 147 Hz causes three lit and three unlit lobes. And so on. However, the clearest indication accrues from the one-to-one correspondence in frequencies. The sweep rate may not be higher than the frequency of the tone under consideration.

In another alternate embodiment the input to the output audio amplifier **4** is taken from the output of sensitivity divider **10** rather than from programmable divider **3.** This is indicated by the dotted line in FIG. **1.** The output of divider **10** is essentially a square wave of the same frequency as the output of divider **3.** Output of divider **3** is far from a square wave for frequencies near the top of the octave. Since a square wave provides optimum drive for the amplifier, taking the signal from divider **10** improves performance.

I claim:

1. A musical tuning instrument comprising:

a reference signal source generating a reference signal of reference frequency;

an octave divider comprising cascaded binary divider stages for receiving said reference signal and producing at the output of each successive stage a signal whose frequency is half the frequency of the input of said stage and means for selecting the output of a particular stage;

a primary programmable divider consisting of cascaded binary divider stages for receiving said selected output from said octave divider and adapted for being programmed in twelve modes each successive mode producing as a final output of said primary programmable divider a signal whose frequency is that of a successive musical note of the particular octave corresponding to said selected output of said octave divider;

a secondary programmable divider accepting as input the output of said octave divider and similar to said primary programmable divider but consisting of four fewer stages and adapted to produce at its output a signal whose frequency is approximately 16 times the frequency of said final output of said primary programmable divider, said secondary pro-

grammable divider being adapted for being reset by said final output of said primary programmable divider;

an audio input section consisting of an acoustical pickup feeding to an audio amplifier and producing a digitally compatible output in response to an audio input;

an audio input sensitivity divider consisting of cascaded binary stages the output of each stage being a signal whose frequency is half the frequency of the input to said stage and accepting as input the output of said audio input section;

a reference sensitivity divider consisting of the same number of cascaded binary stages as said audio input sensitivity divider, the output of each stage being a signal whose frequency is half the frequency of the input to said stage and accepting as its input the output of said secondary programmable divider;

means for selecting the output of one of the stages of said audio input sensitivity divider and simultaneously selecting the output of the corresponding stage of said reference sensitivity divider;

a display consisting of sixteen light emitting diodes; and

a drive circuitry having a first input and a second input and adapted to cause each diode in succession to be activated in response to successive highs of said second input if and only if said first input is high simultaneously, said first input being the selected output of said audio input sensitivity divider, and said second input being the selected output of said refrence sensitivity divider.

2. A musical tuning instrument as in claim **1** and having an audio output section comprising an audio amplifier and a speaker for receiving the output of said primary programmable divider and generating a corresponding tone.

3. A musical tuning instrument as in claim **1** and having an audio output section (comprising an audio amplifier and a speaker for receiving an appropriate output of said reference sensitivity divider and generating a corresponding tone) adapted for receiving the output of an appropriate stage of said reference sensitivity divider and generating an audio tone of like frequency.

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