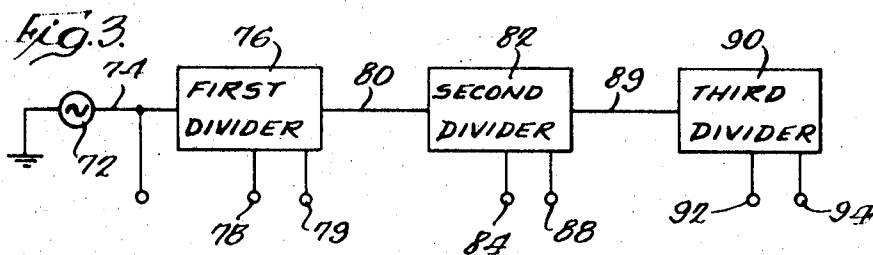
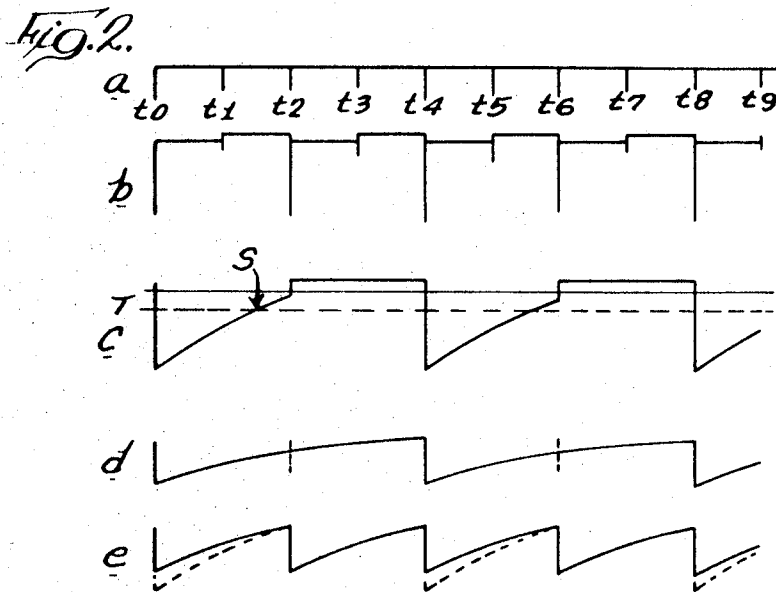
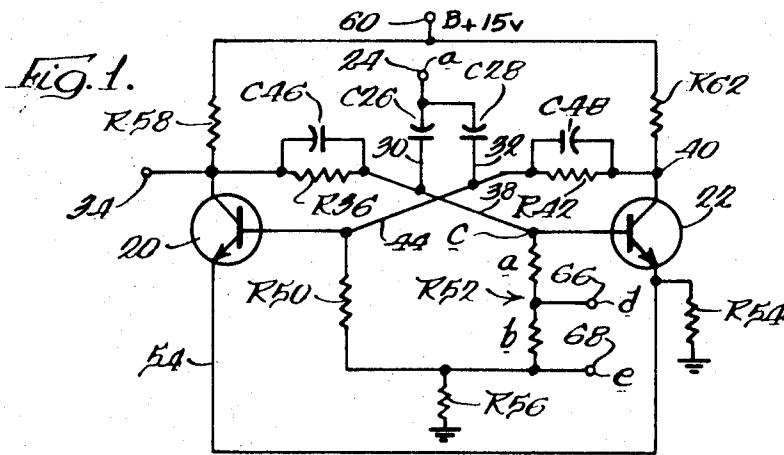


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MUSICAL INSTRUMENT FREQUENCY DIVIDER WHICH
DIVIDES BY TWO AND BY FOUR
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MUSICAL INSTRUMENT FREQUENCY DIVIDER WHICH DIVIDES BY TWO AND BY FOUR

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9 Claims

ABSTRACT OF THE DISCLOSURE

A musical instrument frequency divider of bistable flip-flop type which operates at one-fourth input pulse speed and provides divide-by-four and divide-by-two output signals. Signals from the inputs to the two sides of the flip-flop are added on a scaled basis to obtain good bright wave form at both output terminals. An ancillary feature is the provision of an additional divide-by-four output terminal having a substantially rectangular wave form signal.

The present invention relates primarily to electrical musical instruments, organs for instance, and is concerned with the generation of musical tone signals.

The bistable divider circuit of this invention is an improvement over the prior invention of applicant, entitled "All Harmonic Wave Frequency Divider," Ser. No. 455,820, filed May 14, 1965, now Patent No. 3,387,527, issued June 11, 1968. Typical prior art devices are free running when used for dividing by four or when used as sawtooth tone sources.

The bistable divider of this invention is adapted to provide two signals an octave apart by dividing by four, each of which is a sawtooth signal, and combining two base signals into a divide-by-two sawtooth signal. This provides a complete range of musical tones with a minimum number of components.

A disadvantage of the conventional flip-flop type divider is that it provides a rectangular wave output and this has a hollow clarinet sound. Since a rectangular wave contains only the fundamental and odd harmonics, it is not very useful as a fundamental musical tone signal source. It is musically monotonous and is difficult to use when it is combined with higher octave signals for the purpose of filling in the missing even harmonics.

Problems are encountered with contamination of the source with unwanted subharmonics and contact sequencing effects when the effort is made to get the various types of sounds necessary to give the organ a reasonable complement of resources. The sawtooth wave which contains a full complement of both odd and even harmonics overcomes the foregoing shortcoming and is much easier to modify to give the other required tones. Therefore, it is much to be preferred as a basic tone source.

In general, a full harmonic nonsymmetrical wave is seen as a sawtooth wave shape on an oscilloscope. It is almost vertical at one side and tapers off at a relatively constant rate at the other. It should be understood, however, that this is an idealization and that as a practical matter some deviation from this ideal is possible before much, if any, difference in sound or in general usefulness of the tone source will be noted.

In view of the above, it is an object of the invention to provide a novel flip-flop or bistable type frequency divider which has an all harmonic output with a full complement of both even and odd harmonics and which is adapted to provide two sawtooth signals an octave apart by providing a means for dividing by four and for combining two base signals into a divide-by-two signal.

An additional object is to provide a novel low cost frequency divider having an all harmonic output.

A further object is to provide a novel flip-flop divider circuit having little or no DC component associated with the output tone signal.

A further object is to provide a novel low cost frequency divider cascade having a minimum number of frequency divider elements.

A further object is to provide a novel bistable divider circuit which is stable, having no need to change component values and adaptable to plural tones to produce a sawtooth output.

A further object is to provide a novel low cost flip-flop divider cascade which has a half and quarter frequency sawtooth output signal for each divider element.

Other objects and advantages will become apparent from the following description of a preferred embodiment of the invention, which is illustrated in the accompanying drawings in which:

FIG. 1 is a schematic diagram of a circuit embodying the invention;

FIGS. 2a, b, c, d, and e show wave forms for the circuit of FIG. 1; and

FIG. 3 is a block diagram illustrating a typical embodiment of frequency dividers such as the basic circuit of FIG. 1 in an electric organ tone signal supply system.

Referring to FIG. 1, which illustrates a basic embodiment of the invention, it will be seen that the circuit is of a flip-flop or bistable configuration. It consists, as shown, of a pair of transistors 20 and 22. An input trigger signal is supplied to a terminal 24 which is connected through capacitors C26 and C28 and leads 30 and 32, respectively, to the bases of transistors 20 and 22, respectively. The collector of transistor 20 is connected by lead 34, resistor R36, and lead 38 to the base of transistor 22. Similarly, the collector of transistor 22 is connected by lead 40, resistor R42, and lead 44 to the base of transistor 20.

Capacitors C46 and C48 are connected across resistors R36 and R42, respectively. The base of transistor 20 is also connected to the base of transistor 22 by series resistors R50 and R52. A resistor R56 is connected between the junction of resistors R50, R52 and ground. The emitters of transistors 20 and 22 are connected together by lead 54 which is grounded through resistor R54.

The collector of transistor 20 is connected through resistor R58 to a direct current source represented by the terminal 60, and the collector of transistor 22 is similarly connected through resistor R62 to terminal 60.

The output signal to drive the next frequency divider in the cascade is taken from a terminal 34 connected to the collector of transistor 20. The frequency at terminals 34 and 66 is one-quarter of the input frequency at terminal 24. The output for terminal 66 is a tap on resistor R52. Resistor R52 is divided into two portions R52a and R52b where R52a is approximately two-thirds of the value of resistance R52 when R56 is 10K ohms for a smooth sawtooth output signal. A second output is taken at terminal 68 which is connected to the bases of transistors 20 and 22 through resistors R50 and R52, respectively. This output is a sawtooth whose frequency is one-half of the input frequency at terminal 24 and is a combination of the two base signals.

A typical organization of the circuit of FIG. 1 into a multi-octave musical instrument is shown in FIG. 3. Such an instrument has a group of oscillators 72 of any suitable and well-known type which generate the highest frequencies. Ordinarily there will be twelve of these to generate the twelve notes for the top octave, but in the interest of simplification, only one is shown.

The output musical signal from the oscillator 72 ap-

pears at terminal 74 and this signal is also supplied to the first frequency divider at 76, which may be the equivalent circuit of FIG. 1, the signal from the oscillator being supplied to the input terminal 24 thereof. The frequency divider 76 supplies an output musical signal one octave lower than the signal from the oscillator 72 at the terminal 78, which is equivalent to the terminal 68 of FIG. 1. Also, it supplies a signal at the terminal 79 one-quarter or two octaves below the signal from oscillator 72. The signal at terminal 80 which is equivalent to terminal 34 of FIG. 1 is connected to a second frequency divider stage 82, input to this stage being the equivalent of terminal 24 of FIG. 1, and so on.

For the purpose of illustration, two more frequency dividers are indicated at 82 and 90, respectively, with musical signal outputs one octave lower than the previous output being indicated at 84, 88, 92 and 94. The output from divider 82, at terminal 89, which corresponds to the quarter wave signal at terminal 34 of FIG. 1, is connected to divider 90 which corresponds to terminal 24 of FIG. 1.

Component values for elements used in the construction of a working model of this invention shown in FIG. 1 for output frequencies of 87-350 c.p.s. are as follows:

R36	-----ohms---	82K
R42	-----do-----	82K
R50	-----do-----	10K
R52	-----do-----	10K
R52a	-----do-----	5K
R52b	-----do-----	5K
R54	-----do-----	470
R56	-----do-----	10K
R58	-----do-----	15K
R62	-----do-----	15K
C46	-----mfd---	0.2
C48	-----mfd---	0.2
C26	-----pf---	470
C28	-----pf---	470
Transistors	-----	2N2926

The operation will now be described with reference to FIG. 2, in which FIG. 2a is a wave form diagram of the input at terminal 24 from driving circuit 72. FIG. 2b shows a base wave form of a conventional bistable circuit for reference purposes. FIG. 2c shows a base signal of a divide-by-four flip-flop with large capacitors in the cross coupling networks between collector and base of the transistors. FIG. 2d shows the quarter frequency sawtooth signal output, and FIG. 2e discloses the half frequency sawtooth signal output.

In order to divide by four, the divider of FIG. 1 must be made to ignore alternate trigger pulses. This can be accomplished by selecting a value of both cross coupling, collector to base, capacitors such that at the operating frequency the base recovery time constant is longer than the time between trigger pulses. This can be seen in FIG. 2c where the trigger level T shown by dotted horizontal line is not reached by the time a trigger pulse is applied at t1 and t3 (t3 being concerned with the other side of the flip-flop action).

Care must be taken to insure that within practical tolerances and when fixed values are used at several adjacent tone frequencies the RC time constant must not be so long that the two trigger pulses are passed by, thereby producing a divide-by-six output signal. The amplitude of the trigger pulses also has a direct effect in the process and must be optimized to insure reliable triggering while being alternately ignored. By using a resistor network to mix both base signals properly, a full sawtooth will be obtained at one-fourth the trigger frequency, t0-t4, in FIG. 2d. This wave contains a full complement of both odd and even harmonics. If the complete network has matched resistances as seen by each base and the normally grounded branches are connected to a common

resistance to ground, the divide-by-two signal will appear at this junction, t0-t2, in FIG. 2e.

Any unbalance of the two resistances or any dissimilar action at either base will produce, in addition, some of the divide-by-four signal. As shown in FIG. 2e, the dashed curve at t0 and t4 represents unwanted subharmonics. This has been found to be controllable by careful design and by the use of precision resistors such as a thick film printed network. Transistors are quite predictable in this application. They are driven to saturation and to cut off and operate well as long as the base emitter Zener point is avoided. In the case of 2N2926 transistors, this point is around 8 to 12 volts. The supply voltage to the divider must be chosen to avoid this condition. Output circuit loading of the quarter wave signal must not be excessive if unbalancing is to be avoided; but because this is a larger signal than the divided-by-two signal, a large decoupling resistor may be used so that it poses no severe problems in practical organ design.

The subharmonic level can be as high as 5% before it can be detected in the divide-by-two signal when the highest frequency of operation of this signal in a practical design is about 400 cycles. As the frequency of operation becomes lower, a higher percentage of subharmonics in the signal is allowable. This is probably due to the ear's lack of sensitivity and discrimination at low frequencies.

Various modifications may be made in the invention without departing from the spirit and scope thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and are set forth in the appended claims.

Having described my invention, what I claim as new and useful and desire to secure by Letters Patent is:

1. A musical instrument all harmonic wave frequency divider comprising a pair of transistor amplifiers, an RC cross connecting network interconnecting the output of each transistor amplifier with the input of the other to provide a balanced bistable flip-flop, circuit means for supplying trigger pulses to said flip-flop at a certain frequency, said cross connecting network having time constants sufficient to cause a change in the conducting state of the flip-flop on alternate trigger pulses and to cause the flip-flop to ignore the intervening pulses, a divide-by-four output terminal, a first impedance element connected between said divide-by-four output terminal and the input of one of said amplifiers, a divide-by-two output terminal, a second impedance element connected from said divide-by-two output terminal to said divide-by-four output terminal, a third impedance element connected from said divide-by-two output terminal to the input of the other amplifier, said first and said second impedance elements together having a value substantially equal to that of said third impedance element so that said divide-by-two output terminal receives the input signals to the two amplifiers substantially balanced, and said divide-by-four output terminal receives an unbalanced signal which is much stronger from one of said amplifier inputs than from the other of said amplifier inputs.

2. The frequency divider called for in claim 1 in which said first impedance element and said second impedance element are adjusted so that the wave slope at said divide-by-four terminal from one of said amplifier inputs is substantially a continuation of the wave slope from the other of said amplifier inputs.

3. A musical instrument all harmonic wave frequency divider comprising a pair of amplifiers having inputs, outputs and a common return circuit, an RC cross connecting network interconnecting the output of each amplifier with the input of the other to provide a balanced bistable flip-flop, circuit means for supplying trigger pulses to said flip-flop at a certain frequency, said cross connecting network having time constants sufficient to cause a change in the conducting state of the flip-flop on alternate trigger pulses and to cause the flip-flop to ignore the intervening pulses, an impedance network interconnecting

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the amplifier inputs, a divide-by-two output terminal connected to a tap at substantially the midpoint of the last said network, a divide-by-four output terminal connected to a tap between the divide by two output tap and one of said amplifier inputs, an impedance connected from said divide-by-two terminal to said common return circuit, said divide-by-two tap being adjusted to provide balanced signals from said amplifier inputs at said divide-by-two terminal, and the adjustment of said divide-by-four tap and the value of the last said impedance being such that the output wave slope from one of said amplifier inputs at said divide-by-four terminal is substantially a continuation of the output wave slope from the other of said amplifier inputs at said divide-by-four terminal and the signals at said divide-by-two and said divide-by-four terminals have a desired relative balance.

4. The musical instrument frequency divider as called for in claim 3 in which the amplifiers comprise a pair of transistors each having a base, an emitter and a collector with the inputs connected to the bases, the outputs connected to the collectors and the return circuit interconnecting the emitters.

5. The musical instrument frequency divider as called for in claim 3 in which the divide-by-four tap is connected to the impedance network at a point of the order of half way between one of the amplifier inputs and the divide-by-two terminal.

6. The musical instrument frequency divider as called

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for in claim 4 in which the divide-by-four tap is connected to the impedance network at a point of the order of half way between one of the amplifier inputs and the divide-by-two terminal.

7. The musical instrument frequency divider as called for in claim 4 in which a second divide-by-four output terminal is provided, the last said terminal being connected to the collector of the transistor the base of which is most remote from the first said divide-by-four terminal.

8. The musical instrument frequency divider as called for in claim 3 in which all the impedance elements recited are resistors.

9. The musical instrument frequency divider as called for in claim 4 in which all the impedance elements recited are resistors.

References Cited

"Synchronized Oscillator for Frequency Division," in IBM Technical Disclosure Bulletin, vol. 8, No. 9, February 1966, pp. 1253 and 1254.

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84—1.01; 307—225, 291; 328—17, 39, 206