

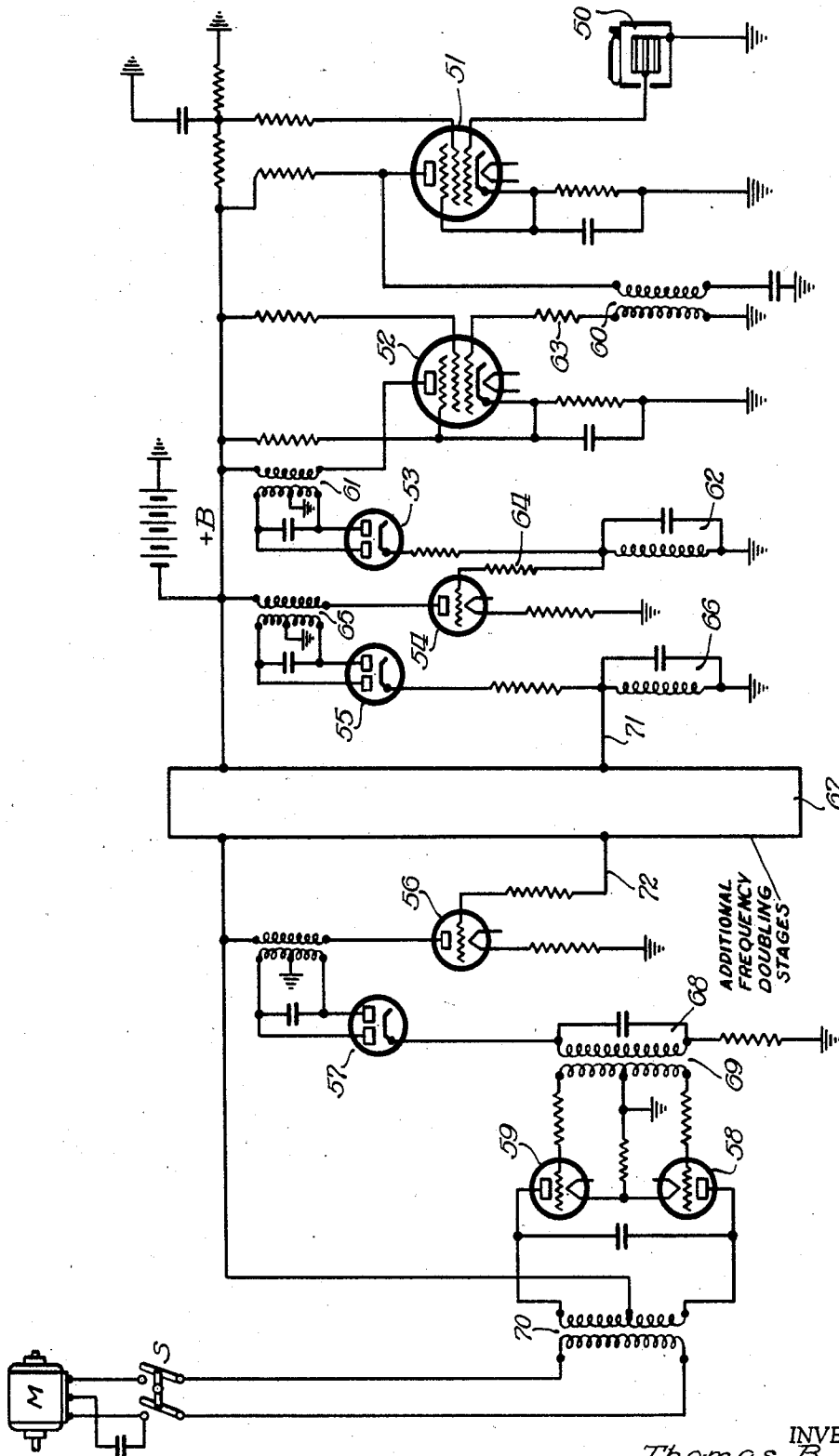
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FREQUENCY MULTIPLIER

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FREQUENCY MULTIPLIER

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The present invention relates in general to frequency multipliers, and the object of the invention is to produce a new and improved apparatus of this character.

The invention is especially adapted for use in watch timing apparatus. In certain types of watch timing devices it is necessary to employ the beats of a watch to drive a small synchronous motor. The watch may be the watch which is being timed or tested, or it may be a master watch having a known constant rate. In any event, the beat frequency of the watch, usually five beats per second, is too low to permit the currents generated by the watch beats to be converted directly into alternating current for driving a motor, and some means must be interposed for raising the frequency to a value within the range of frequencies which is suitable for use. The frequency multiplier disclosed herein is well adapted for this purpose.

In some respects this invention may be considered to be an improvement on the invention disclosed in Patent No. 2,235,317, granted March 18, 1941, which shows apparatus by means of which a master watch may be used to operate a synchronous motor at constant speed. This apparatus, however, has a rather limited frequency range and while it is entirely satisfactory for multiplying the frequency of a master watch it cannot be used with the general run of watches which have to be timed, in view of the fact that such unregulated watches vary widely in rate. The frequency multiplier according to the present invention has the advantage of a much wider frequency range whereby it is adapted to supply the need for a device by means of which a motor can be driven from the watches which are being timed and thereby enables a watch timing apparatus using such a motor drive to be manufactured for the first time.

The frequency multiplier disclosed herein has other advantages, and may be used for other purposes in addition to the one pointed out above.

This application is for subject matter disclosed in an application for patent for Timing apparatus, Ser. No. 400,342, filed June 28, 1941, but not claimed therein.

The invention and various features thereof are described more in detail hereinafter in connection with the accompanying drawing, which shows diagrammatically the apparatus and circuits involved.

Referring to the drawing, the reference character 50 indicates a microphone which is used for picking up the beats of a watch being tested. A

suitable microphone for this purpose is shown in Patent No. 2,175,021, granted October 3, 1939.

The space discharge device indicated at 51 may be a type 6F6G pentode and is connected as shown in the drawing. This tube functions to amplify the output of the microphone 50.

The device 52 may be another type 6F6G pentode and has its control grid coupled to the plate circuit of tube 51 by means of a transformer 60. The tube 52 functions mainly as a "noise eliminator" or voltage regulator, as will be explained presently.

The device 53 may be a type 6H6 full wave rectifier tube, and is connected in a circuit which includes the filter or tuned circuit 62 and the secondary windings of the transformer 61. The transformer 61 couples the plate circuit of tube 52 to the rectifier circuit.

The reference character 54 indicates an amplifier tube, which may be a type 6F8C triode. The control grid of tube 54 is coupled to the circuit of the rectifier tube 53 through a resistor 64. The plate circuit of tube 54 is coupled by means of transformer 65 to another rectifier circuit which includes the rectifier tube 55, similar to tube 53, and the tuned circuit 66. The tube 55 and associated circuits functions as a frequency doubler, as will be explained.

Additional frequency doubling stages are provided, the number depending on the desired output frequency. In the present case it is assumed that the output frequency is 80 cycles per second, which requires four frequency doubling stages. One stage has been described, two additional stages are represented by the rectangle 67, and a final stage is shown to the left of the rectangle. This final stage includes the rectifier tube 57 and the amplifier tube 56. The several frequency doubling stages are alike except for the tuned circuits such as 66 and 68, which are tuned to different frequencies. Circuit 66 is tuned to 10 cycles per second, and the circuits at the intervening stages are tuned to 20 and 40 cycles per second, respectively. The tuned circuit 62 may be tuned to 5 cycles per second.

The inductive element of the tuned circuit 68 is the primary winding of a transformer 69, by means of which the final frequency doubling stage is coupled to a push-pull power amplifier comprising the tubes 58 and 59. The secondary winding of the output transformer 70 may be connected to the motor M by means of switch S. The motor M may be part of a watch timing apparatus, as disclosed in the application hereinabove referred to.

The operation of the circuits and apparatus shown in the drawing will now be explained. For this purpose it may be assumed that a watch to be tested is clamped to the microphone 50. In response to the beating of the watch, trains of impulses are generated by the microphone 50 and are impressed on the grid of the amplifier tube 51, where they are amplified in known manner. The plate circuit of tube 51 is coupled to the grid of tube 52 by means of the transformer 60, and trains of alternating voltages are accordingly impressed on the control grid of tube 52.

The nature of the watch beat impulses produced by the microphone 50 may be explained a little more in detail. These impulses are generated by the mechanical shocks transmitted to the microphone by the beating watch, which appear to set up trains of vibrations affecting the microphone. At any rate, each separate beat of the watch produces a train of a dozen or more impulses, and the microphone output therefore is a succession of spaced impulse trains having a frequency which is the same as the watch beat frequency. If a five-beat watch is being tested, the impulse train frequency is five trains per second.

The microphone 50 is also affected by room noises and accidental shocks, which produce stray impulses of various frequencies and magnitudes. The function of the tube 52 is to eliminate or minimize the effect of these stray impulses so that they cannot interfere with the proper operation of the equipment. For the purpose of eliminating the effects of minor noises, which produce impulses of lesser amplitude than those produced by the beating of the watch, the control grid of tube 52 is biased negatively to a point below cut-off, so that the tube normally passes no current. The negative bias is obtained by means of two resistances, connected between ground and the plus B lead, and a connection to the cathode from the junction of these resistances. This circuit arrangement maintains the cathode at a positive potential with respect to ground and since the control grid is normally at ground potential, its potential is negative with respect to that of the cathode. The adjustment of the parts is such that the trains of alternating voltages produced by the beating of a watch and impressed on the control grid of tube 52 cause the tube to pass current on the positive half-waves, whereas stray voltages of somewhat less amplitude are unable to overcome the negative bias on the control grid and produce no effect. The occasional stray impulse which may be produced by an accidental shock may be of large amplitude but is reduced to the same amplitude as the watch beat impulses by means of a rather high resistance 63 in the grid circuit. When the grid swings positive in response to watch beat impulses or stray impulses, cathode grid current starts to flow, but the current flow is limited to a very low value by the high resistance 63 and hence the grid cannot become more than very slightly positive with respect to the cathode and the plate current is limited correspondingly.

Continuing with the explanation, it will be understood, in view of the foregoing, that impulse trains having a frequency of five trains per second are set up in the plate circuit of tube 52. The impulses of each train induce alternating voltages in the secondary winding of transformer 61, which cause intermittent unidirectional current impulses to flow in the rectifier circuit. These impulses are many times higher in frequency than

the watch beat frequency of five beats per second. The tuned circuit 62 is tuned to 5 cycles per second, and cannot oscillate at the higher impulse frequency, with the result that the condenser charges up while a train of impulses is flowing in the rectifier circuit and discharges during the interval between this train and the next. Thus each impulse train is converted into an alternating voltage cycle of fair wave shape, producing a five-cycle alternating voltage which is applied to the grid of tube 54.

The resulting 5-cycle impulses which are produced in the plate circuit of tube 54 induce 5-cycle alternating voltages in the secondary winding of the transformer 65. Due to the action of the rectifier 55, however, each half-cycle of voltage produces a uni-directional current impulse in the rectifier circuit, and in this circuit, therefore, an intermittent current is set up having a frequency of 10 impulses per second. The filter circuit 66 is tuned to 10 cycles per second and converts each impulse into an alternating voltage cycle which is applied over conductor 71 to the grid of the triode in the next frequency doubling stage.

Summing up the operations so far, it will be seen that the 5-cycle impulse trains generated by the beating of the watch have been converted to 5-cycle alternating current and that the 5-cycle alternating current has been converted to 10-cycle alternating current. Voltages due to noises which affect the microphone 50 have been eliminated at the tube 52, and at this same tube stray voltages due to accidental shocks have been reduced in amplitude to the same amplitude as that of the impulses due to beating of the watch. Such stray voltages, if any, affect the wave form of the alternating current to a degree, but their influence is progressively reduced by the action of the tuned circuits 62, 66, and similar tuned circuits in the other frequency doubling stages. The final output, therefore, has a satisfactory wave form in spite of any ordinary hazards to which the microphone may be subjected in practice.

At the next two frequency doubling stages, represented by the rectangle 67, the 10-cycle alternating voltages impressed on conductor 71 are converted to 40-cycle alternating voltages which are impressed on conductor 72, each stage operating to double the frequency of its input voltage. The frequency is doubled again at the last stage comprising tubes 56 and 57, with the result that 80-cycle alternating voltages are applied to the grids of the power amplifier tubes 58 and 59 by means of the transformer 69. The amplifier output frequency is therefore 80 cycles per second.

The output frequency is exactly 80 cycles per second only if the rate of the watch being tested is correct and it is beating at exactly five beats per second. If the watch is slow, the output frequency is less than 80 cycles per second, while if the watch is fast the output frequency will be higher than 80 cycles per second. In other words, the output frequency varies with the rate of the watch being tested and is exactly 16 times the beat frequency. The variations in beat frequency which are met with in practice are relatively small, when considered in terms of variations in output frequency in cycles per second, and the tuning of the tuned circuits such as 66 is broad enough so that the arrangement operates satisfactorily with watches in various conditions of faulty regulation. The use of the tuned circuits, however, has a tendency to produce variations in the output voltage, depending on the rate of

the watch being tested, the voltage tending to be the higher the more nearly the rate of the watch being tested approximates the correct rate of exactly five beats per second. To counteract this tendency, each tube such as 54 is provided with a high resistance (on the order of 5 megohms) in its grid circuit in order to limit the extent to which the potential on the grid may rise in a positive direction and thereby limit the amplitude of the plate current variations. These tubes therefore function as voltage regulators and insure a substantially constant output voltage.

When the switch S is closed the amplifier output is delivered to the motor M and the motor is driven at a speed which depends on the rate of the watch being tested. As previously mentioned, the motor M may be part of a watch timing apparatus, and the timing of the watch may accordingly proceed as explained in application Serial No. 400,342 hereinbefore referred to, but since the instant application is not concerned with these operations they will not be described herein.

The invention having been described, that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

We claim:

1. Apparatus for producing alternating current from the beats of a watch, said apparatus being operable with watches having different rates, comprising means for generating currents responsive to the watch beats, means for converting said currents into alternating currents having the same frequency as the watch beat frequency, a plurality of frequency doubling stages, each including a full wave rectifier and a tuned circuit, means for coupling said stages, and means for amplifying the output of the last stage.

2. Apparatus for producing alternating current from the beats of a watch, said apparatus being operable with watches having different rates, comprising means for generating currents responsive to the watch beats, means including a tuned circuit for converting said currents into alternating currents having the same frequency as the watch beat frequency, a frequency doubler circuit including a full wave rectifier and a second tuned circuit connected in series, means including a transformer and a voltage limiting device for coupling said first tuned circuit to said doubler circuit, a plurality of additional doubler circuits each coupled to the preceding doubler circuit by means of a transformer and a voltage limiting device, and means for amplifying the output of the last doubler circuit.

3. Apparatus as claimed in claim 1, including means for eliminating unwanted currents produced at the current generating means by extraneous causes, and comprising a space discharge device for coupling said generating means to the converting means, means for biasing the grid of said device below cut-off, and a high resistance in series with said grid.

4. In a frequency multiplier, means for producing spaced trains of alternating voltages, means including a rectifier for converting said trains to trains of direct current impulses, means

including a tuned circuit tuned to the frequency of said trains for converting said impulse trains to alternating voltages of the impulse train frequency, means including a full wave rectifier for converting successive half-cycles of said alternating voltages to direct current impulses, and means including a tuned circuit tuned to twice the frequency of said alternating voltages for converting said last mentioned direct current impulses to alternating voltages.

5. In a frequency multiplier, two frequency doubling stages each including a full wave rectifier and a tuned circuit in series therewith, and means for coupling said stages comprising a three-element space discharge device, a high resistance connecting the tuned circuit at the first stage with the grid of said device, and a transformer connecting the plate circuit of said device with the rectifier at the second stage.

6. In a frequency multiplier for multiplying input currents varying in frequency over a certain limited range, a plurality of frequency doubling stages, each including a full wave rectifier and a tuned circuit in series therewith, said tuned circuits being tuned to successively higher frequencies which are multiples of the average input frequency and the tuning being broad enough to pass frequencies resulting from variations of the input frequency over said range, and means at each said stage for substantially preventing an increase in output voltage at times when the frequencies at said stages coincide with the resonant frequencies of the said tuned circuits.

7. Apparatus for running a motor at a variable speed under control of watches having beat frequencies which may differ considerably from a standard frequency, comprising means responsive to watch beats for generating alternating current, a plurality of tandem connected frequency doublers responsive to said alternating current and having outputs of successively higher frequencies which are multiples of the frequency of said alternating current, filters in said doublers tuned to their respective output frequencies, said filters being tuned broadly enough to pass output frequencies resulting from watches having non-standard beat frequencies, means associated with said doublers to limit the output voltage in the event the watch beat frequency substantially coincides with the standard frequency, and means for amplifying the output of the last doubler.

8. In a frequency multiplier, a frequency doubling stage for doubling the frequency of alternating current energy which is subject to variations in voltage, said stage comprising a voltage regulating tube responsive to said energy, means associated with said tube for causing the output thereof to remain substantially constant notwithstanding said voltage variations, a full wave rectifier tube, a transformer coupling the plate circuit of said regulating tube to said rectifier tube, and a tuned circuit connected in series with said rectifier tube and tuned to a frequency which is double the frequency of said alternating current energy.

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