April 9, 1946. E. L. KENT 2,398,097

PHASE MODULATION METHOD AND APPARATUS

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Fig. 1

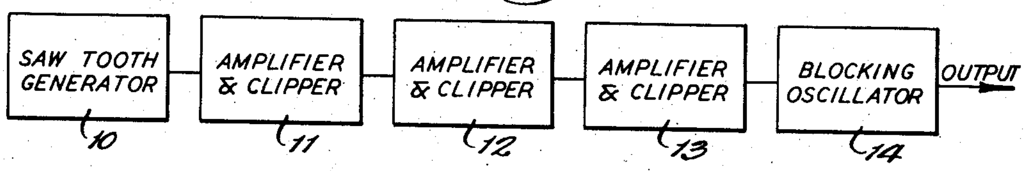

Fig. 2

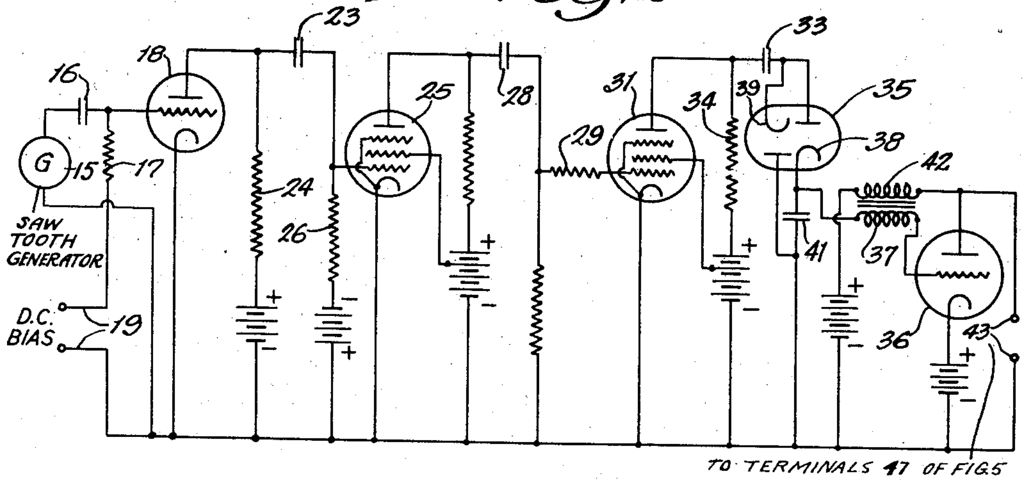

Fig. 3

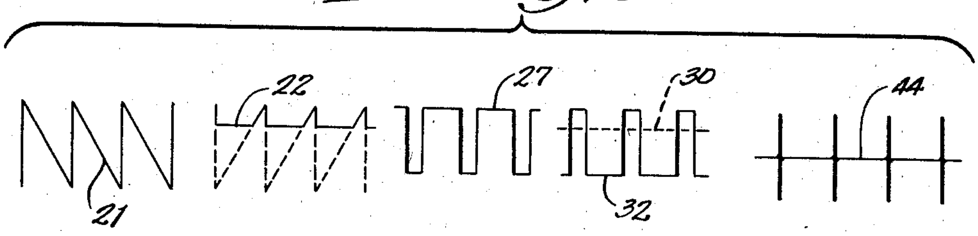

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Fig. 4

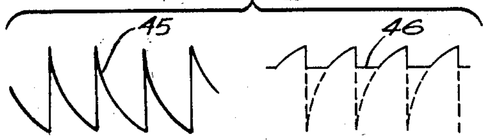


Fig. 5

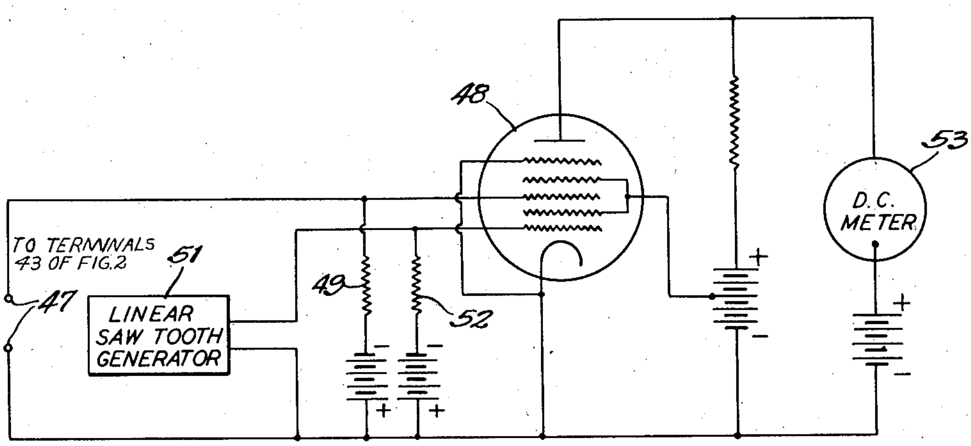
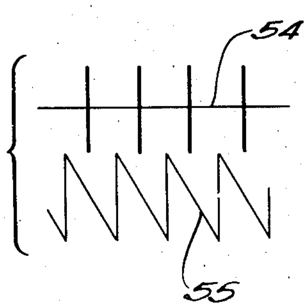


Fig. 6



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PHASE MODULATION METHOD AND APPARATUS

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Application July 17, 1943, Serial No. 495,106

5 Claims. (Cl. 250—36)

This invention relates to phase modulation method and apparatus and more particularly to a method and apparatus for shifting the phase of a series of pulses.

One of the objects of the invention is to provide a phase modulation method and apparatus in which the phase of a series of pulses may be shifted through a wide range.

Another object of the invention is to provide a phase modulation apparatus in which there are no moving parts.

Still another object of the invention is to provide phase modulation which may vary according to a straight line or to an exponential curve to provide logarithmic control.

A further object of the invention is to provide a method and apparatus for producing logarithmic amplification.

The above and other objects and advantages of the invention will be more readily apparent when read in connection with the accompanying drawings, in which—

Figure 1 is a block diagram illustrating the several steps in the invention;

Figure 2 is a wiring diagram of one apparatus for carrying out the invention;

Figure 3 is a diagram illustrating the wave shapes produced at various steps in the method;

Figure 4 is a partial diagram similar to Figure 3;

Figure 5 is a wiring diagram of a logarithmic amplifier circuit; and

Figure 6 is a diagram showing the input waves supplied to the amplifier circuit of Figure 5.

In carrying out the invention a saw-tooth wave is generated in any desired type of generating apparatus indicated at 10 in the block diagram of Figure 1. The saw-tooth wave may be a linear wave or may, if desired, be an exponential wave to give a logarithmic output variation. The wave from the generator 10 is supplied to an amplifier and clipper stage 11 in which the wave is amplified and inverted. A biasing voltage which is the controlling voltage for the phase shift is supplied to the stage 11 to determine the point at which the saw-tooth wave is clipped so that the output of this stage is a relatively flat wave having spaced saw-tooth peaks. The clipped wave is supplied to an amplifier and clipper stage 12, where it is again inverted and amplified and clipped to provide a substantially square wave. This wave is passed through a third amplifier and clipper stage 13 which functions principally to invert the wave but which may also further amplify and clip it to provide a more nearly square wave. The output of the stage 13 is supplied to a pulse producing circuit such as a multivibrator or gaseous discharge tube circuit but which is shown as a blocking oscillator 14 which is tripped by rising voltage in the square wave to form a series of pulses. The apparatus is so designed that the rising voltage which trips the blocking oscillator is supplied by a portion of the square wave corresponding to the base of the clipped wave at its sloping side so that variation of the biasing voltage on the first amplifier and clipper stage will shift the phase of the pulses in the output of the blocking oscillator.

One circuit comprising the several elements above described is shown in Figure 2, including a saw-tooth generator 15 coupled through a condenser 16 and resistor 17 to the grid of an amplifier tube 18. A D. C. bias is supplied at 19 and forms the controlling voltage which varies the clipping level of the tube 18 and thereby shifts the phase of the blocking oscillator as will appear hereinafter.

Figure 3 illustrates the wave forms generated by the generator 15 and as clipped by the tube 18. In this figure the saw-tooth wave generated by the generator is indicated at 21 as being a standard straight sided saw-tooth wave. This wave is inverted and clipped by the tube 18 whose output is in the form indicated at 22 in Figure 3. It will be noted that the wave 22 has a rising voltage at the base of its sloping side.

The tube 18 is coupled through a condenser 23 and resistor 24 to the control grid of a pentode tube 25 which serves as the second amplifier and clipper stage 12. The control grid is biased through a resistor 26 from any desired source, shown as a battery, so that it will operate to convert the slipped saw-tooth wave into a substantially square wave. The output of tube 25 is indicated at 27 in Figure 3 in the form of a substantially square wave which is inverted with respect to the wave 22.

The tube 25 is coupled through a condenser 28 and a grid resistor 29 to the control grid of a pentode tube 31 which operates as the third amplifier and clipper stage. This tube inverts the output wave 27 of tube 25 and further amplifies and clips it to provide a wave as shown at 32 in Figure 3. It will be noted that this wave provides a rising voltage at points corresponding to the base of the sloping side of the saw-tooth wave 22.

The tube 31 is coupled through condenser 33 and resistor 34 to a blocking oscillator circuit shown as including a double diode tube 35 and a tube 36. One cathode 38 of the tube 35 is connected through a transformer winding 37 to the grid of the tube 36 and the corresponding plate is connected to the plate circuit of tube 31. The other cathode 39 of the tube 35 is connected to the plate circuit of tube 31 and its corresponding plate is connected through a condenser 41 to the cathode 38.

The plate circuit of the tube 36 is connected to a positive potential source through a transformer winding 42 and to output terminals 43.

In operation as the plate voltage of the tube 31 increases, it builds up an increased charge across the resistor 34 and causes an increase in potential across the condensers 33 and 41 which are in series with each other and with the cathode section 38 of tube 35. The potential across condenser 41 increases and is impressed on the grid of tube 36 until it reaches the tripping level of the tube, indicated at 30 in Figure 3. At this time the tube 36 fires, causing a pulse to be impressed on the output terminals 43 and which feeds back through the transformer winding 42 so that a complete pulse will be produced. The cathode 39 and its plate neutralize any negative charge on the grid of the tube 36 so that it will be in condition to trip for production of the next pulse. The pulse wave produced by the tube 36 is indicated at 44 in Figure 3 which illustrates this wave to be a series of spaced sharp pulses.

With this apparatus when the biasing voltage applied at 19 is changed, the saw-tooth wave will be clipped at a different point to shift the phase position of the base of the clipped wave at its sloping side. This will cause a corresponding shift of the corresponding points in the waves 27 and 32 and will shift the pulses in the wave 44 to vary the phase thereof. Since each saw-tooth of the wave 21 corresponds to a complete cycle it will be seen that the pulses in the output wave can be shifted through substantially 360°.

Instead of using a linear saw-tooth wave as shown at 21, it is possible with the apparatus as above described, to cause the phase to shift according to some function of the biasing voltage other than a straight line function. For example, if a saw-tooth wave is generated as shown at 45 in Figure 4 having an exponential curve, the phase shift will bear a logarithmic relation to variations in the biasing voltage. When a wave such as 45 is passed through the first amplifier and clipper stage the output wave will appear as at 46 in Figure 4 from which it will be seen that a variation in the biasing level results in a logarithmic change in the phase position of the base of the sloping side of the wave. Thus, if a saw-tooth generator of known construction capable of generating a wave such as 45 is used in the circuit of Figure 2 at 15, a logarithmic shift of phase will result.

One circuit in which a logarithmic phase shift is desirable is indicated in Figure 5 which shows a logarithmic amplifier circuit. The pulses in the output of the phase shifting circuit as shown in Figure 2 are supplied at the terminals 47 in Figure 5 as by connecting terminals 43 of Figure 2 with the terminals 47. These pulses are impressed on one of the control grids of a multigrid tube 48. A bias is preferably supplied from a suitable source through a resistor 49. A linear saw-tooth wave is supplied to a second control grid of the tube 48 by a generator 51 and the second grid is biased from a suitable source through a resistor 52. The output of the tube 48 may be connected to any desired apparatus but is shown connected to a D. C. meter 53 for purposes of illustration.

The two waves supplied to the control grids of tube 48 are illustrated in Figure 6 as including a pulse wave 54 supplied through the terminals 47 and a linear saw-tooth wave 55 supplied by the generator 51. The tube 48 when properly biased combines the two waves so that its plate voltage is proportional to the amplitude of the wave 55 at the time the pulses of the wave 54 are impressed. Thus the meter 53 will indicate a value which varies with the position or phase of the pulses of wave 54 and in the construction described this voltage will bear a logarithmic relation to the biasing voltage applied at the terminals 19.

It will be understood that the apparatus may be used for many purposes other than amplification control, and that other changes might be made therein as will occur to those skilled in the art. Reference will, therefore, be had to the appended claims to determine the scope of the invention.

What is claimed is:

1. The method of logarithmic phase modulation which comprises generating an exponential saw-tooth wave, amplifying and clipping the wave to produce a clipped wave, utilizing the clipped wave to provide a series of pulses whose phase corresponds to the level at which the wave was clipped, generating a straight saw-tooth wave in phase with the exponential wave, and combining the last named wave and the pulses to obtain a voltage equal to the amplitude of the last named wave at the level thereon where the pulses occur.

2. Phase modulating apparatus comprising a saw-tooth wave generator, an amplifier tube having its grid connected to the generator, means for applying a bias to the grid so that the tube will clip the wave, an amplifier coupled to the plate circuit of the tube to convert the clipped wave to a substantially square wave, a blocking oscillator connected to the amplifier to be tripped by the square wave, a second saw-tooth wave generator operating in phase with the first named generator, and a tube having a pair of control grids one of which is connected to the output of the blocking oscillator and and the other to the second saw-tooth generator.

3. Phase modulating apparatus comprising a saw tooth generator for generating saw tooth waves of constant frequency having a steep upward slope and a gentle downward slope, an amplifier, means for coupling the output of said generator to said amplifier, means to variably bias said amplifier to such a value that the amplifier will clip the applied saw tooth wave to produce a further wave having sharp upward peaks separated by flat base sections, an amplifier coupled to the output of said first amplifier for converting said further wave into a substantially square wave of the same width as the base of the sharp upward peaks, and a pulse producing circuit coupled to the last named amplifier to be tripped by one side of the square wave, whereby pulses, phase modulated in accordance with the variations of said bias are produced.

4. The method of phase modulation which comprises generating a saw tooth wave of constant frequency and having a steep upward slope and a gentle downward slope, amplifying and variably clipping the saw tooth wave to produce a further wave having sharp upward peaks separated by flat base sections, amplifying said further wave to produce a substantially square wave of the same width as the base of the sharp upward peaks

and producing pulses corresponding in time with the vertical sides of said square wave, whereby pulses, phase modulated in accordance with the variations in said clipping are produced.

5. The method of phase modulation which comprises generating a saw tooth wave of constant frequency and having a steep upward slope and a gentle downward slope, amplifying and variably clipping the saw tooth wave to produce a further wave having sharp upward peaks separated by flat base sections, amplifying said further wave to produce a substantially square wave of the same width as the base of the sharp upward peaks, and utilizing one of the vertical sides of said square wave to produce pulses, phase modulated in accordance with the variations in said clipping.

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