May 27, 1958 F. L. ADAMS 2,836,360

PULSE COUNTER

Filed Dec. 20, 1954 2 Sheets-Sheet 1

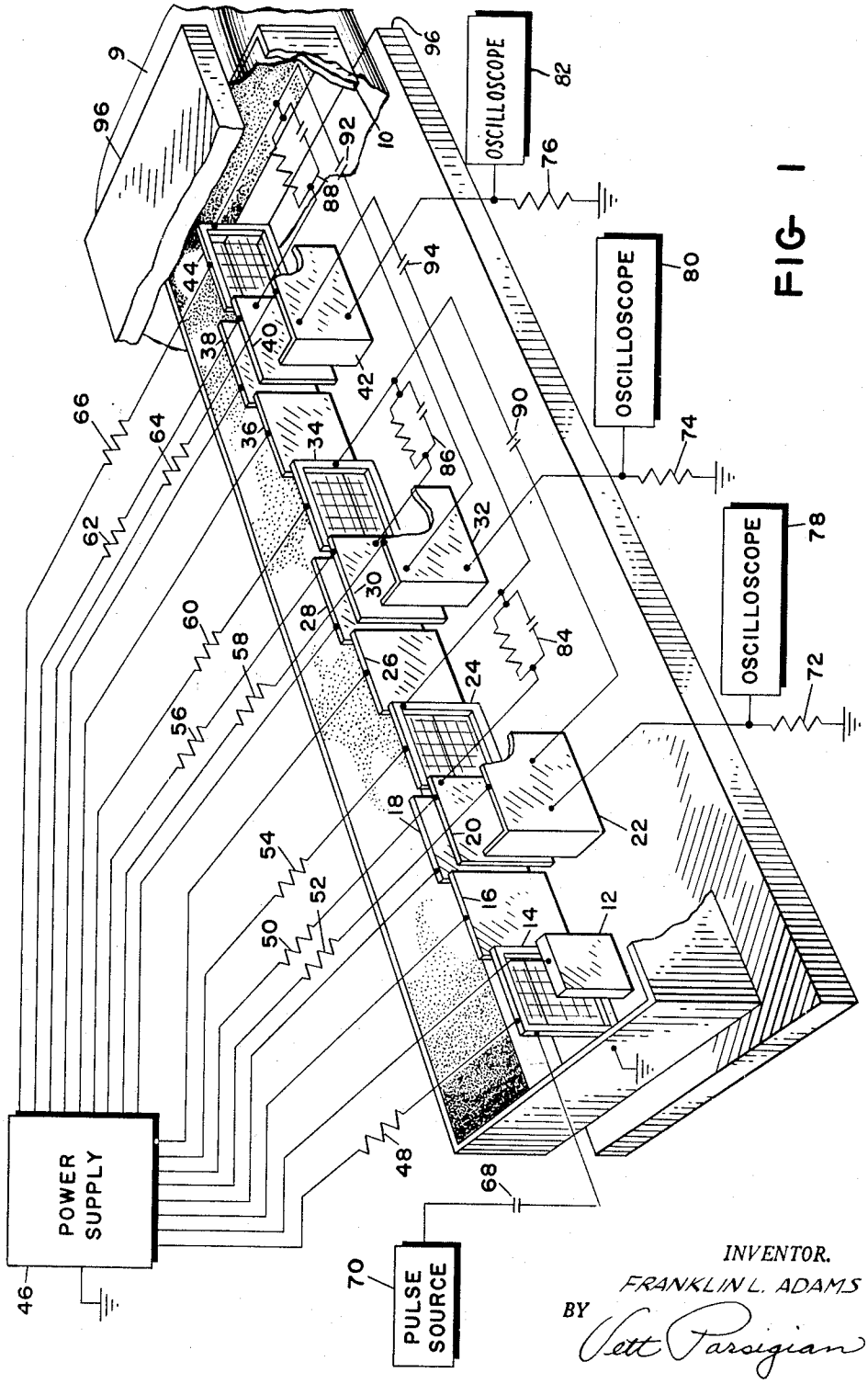


FIG 1

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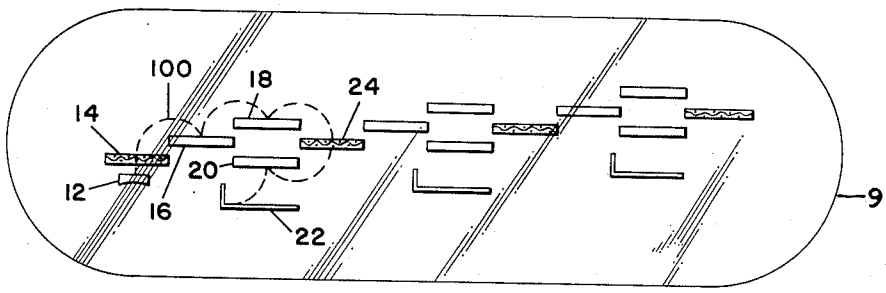


FIG 2

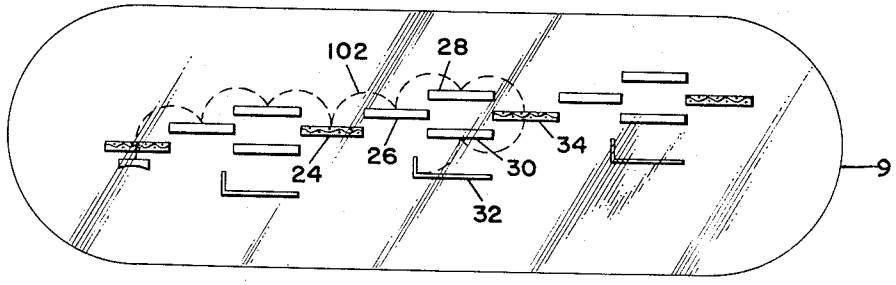


FIG 3

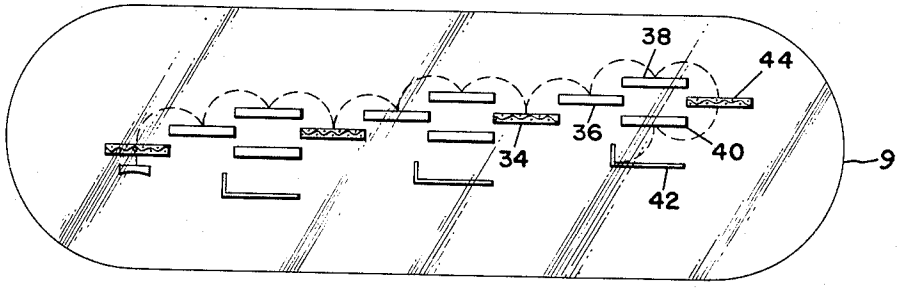


FIG 4

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United States Patent Office 2,836,360 Patented May 27, 1958

2,836,360

PULSE COUNTER

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Application December 20, 1954, Serial No. 476,262

5 Claims. (Cl. 235—92)

This invention relates to counters and more particularly to a high speed electronic pulse counter.

In recent years electronic counters have gained importance because of their increased use in electronic equipment such as computers. Although counters are known for counting electrical pulses at a relatively high rate, extremely high speed counters as may be required for certain applications have been heretofore unavailable. For example, counters presently available can not be reliably used to count electrical signals on the order of 10 megacycles or more.

This invention provides apparatus for operating in a simple and reliable manner to count electrical pulses at a relatively high rate. The invention includes a magnetic electron multiplier. Upon the introduction of each pulse, a plurality of grids in the multiplier are successively biased to pass in succession electrons flowing in the multiplier. In this way, depending upon the grid in the plurality which is passing electrons, the count of the electrical pulses can be determined.

An object of this invention is to provide a counter.

Another object of this invention is to provide apparatus for counting electrical signals.

A further object of this invention is to utilize a magnetic electron multiplier for counting electrical signals.

Still another object is to provide apparatus of the above character which is reliable in its operation and is capable of counting electrical pulses at extremely high speeds.

A still further object is to provide apparatus of the above character in which a plurality of gates are opened in succession upon the introduction of successive pulses to the apparatus.

Other objects and advantages will become apparent from a detailed description of the invention and from the appended drawings and claims.

In the drawings:

Figure 1 is a somewhat schematic view partly in block form and partly in perspective illustrating one embodiment of the invention.

Figures 2, 3 and 4 are top plan views of the electron multiplier shown in Figure 1 illustrating the paths of electron flow under different conditions in the electron multiplier.

In one embodiment of the invention, a vacuum tube **9** encloses a container **10** which may be substantially rectangular in shape is connected to ground. Disposed within the container at its left end is means for emitting electrons, such as a cathode **12**. The cathode **12** is positioned to emit electrons towards a screen type grid **14** when the cathode is heated.

Disposed to the right of the grid **14** is a plate **16**, a plate **18** and a plate **20** disposed in opposed relationship to the plate **18**. An anode **22** is disposed to face the plate **20** and is placed in front of the plate **20**. The grid **14**, the plate **16**, and the plate **18** are positioned in laterally contiguous relationship to one another such that the left extremity of the plate **16** is positioned close to the right extremity of the grid **14** and the left extremity of the plate **18** is positioned close to the right extremity of the plate **16**. Each of the plates **16** and **18** are disposed slightly to the rear of the grid **14** and the plate **16**, respectively, in progressively staggered relationship. The plate **20** may be positioned in substantially the same lateral position as the grid **14** and the anode **22** may be positioned in front of the plate **20** to receive electrons emitted by the plate.

To the right of the plate **18** and slightly in front of the plate **18** is a screen type grid **24**. Disposed at the right of the grid **24** are plates **26**, **28** and **30**, an anode **32** and a grid **34**. The plates, the anode and the grid are disposed in substantially the same relationship to the grid **24** as the plates **16**, **18** and **20**, the anode **22** and the grid **24** are disposed relative to the grid **14**. Similarly, plates **36**, **38** and **40**, an anode **42** and a grid **44** are disposed to the right of the grid **34** and bear the same relationship to the grid **34** as the plates **16**, **18** and **20**, the anode **22** and the grid **24** bear to the grid **14**.

Direct voltages are applied to the cathode **12**, the plates **16**, **18**, **26**, **28**, **36** and **38** from a power supply **46** to produce a substantially constant electrical field between the walls of the container and the cathode and the plates. Since the cathode **12** and the plates are positioned at different distances from the walls of the container **10**, different voltages are applied to them to produce a substantially constant electrical field. Direct voltages are also applied to the grid **14**, the plate **20**, the anode **22**, the grid **24**, the plate **30**, the anode **32**, the grid **34**, the plate **40**, the anode **42** and the grid **44** from the power supply **46** through resistances **48**, **50**, **52**, **54**, **56**, **58**, **60**, **62**, **64** and **66**, respectively.

The grid **14** is connected through a coupling capacitance **68** to a pulse source **70** which introduces to the grid the negative pulses to be counted. The anodes **22**, **32** and **42** are connected to ground through resistances **72**, **74** and **76**, respectively. The anodes **22**, **32** and **42** are also connected to indicators, such as oscilloscopes **78**, **80** and **82**, respectively, to provide an indication when electrons are received by the anodes.

The plates **20**, **30** and **40** are connected to grids **24**, **34** and **44**, respectively, through R–C circuits generally indicated at **84**, **86** and **88**. The anodes **22**, **32** and **42** are connected to the grids **34**, **44** and **24**, respectively, through coupling capacitances **90**, **92** and **94**, respectively.

A magnetic field is provided within the region defined by the walls of the container **10** to act upon any electrons in the region. The magnetic field is provided by a pair of pole pieces **96** positioned above and below the container **10**. Because of the positioning of the pole pieces **96**, the magnetic flux lines are substantially parallel to the plane defined by the ends of the container **10** and the flux lines are disposed substantially perpendicular to the electric field provided between the plates and the walls of the container.

When the cathode **12** is heated, electrons are emitted by the cathode towards the grid **14**. Since the grid **14** is normally provided with a bias for passing electrons, substantially all of the electrons are passed by the grid. Because of the action of the electric field and the magnetic field in the region defined by the walls of the container **10**, the electrons passed by the grid **14** are made to travel in a cycloidal path towards the plate **16** as shown by the broken line **100** in Figure 2 of the drawings. When the electrons impinge upon plate **16**, the plate emits electrons which follow a cycloidal path to the plate **18**. The plate **18** in turn emits electrons in the direction of the grid **24**. To start a count of pulses, the grid **24** is initially pre-set at a bias to provide for the passage of electrons. The gate may be pre-set and later re-set for the initiation of a new count by suitable external means (not shown) adapted to impose a positive bias on the grid **24** relative

to the plate 18. With such a bias on the grid 24, the electrons emitted by the plate 18 pass through the grid 24 and continue in a circular path towards the plate 20. The plate 20 receives the electrons and emits electrons which impinge upon the anode 22 for detection by the oscilloscope 78. This provides an indication of a zero count or that no pulses have been introduced to the grid 14 from the pulse source 70.

Since the grid 24 passes the electrons emitted by the plate 18, substantially no electrons reach the plate 26. Figure 2 of the drawings illustrates the path of the electron flow when the grid 24 is biased to pass electrons.

Upon the introduction of a negative pulse to the grid 14 from the pulse source 70, the grid 14 becomes biased more negatively and the number of electrons passed by the grid is instantaneously cut down. The instantaneous interruption of the electrons flowing through the grid 14 produces a decrease in the number of electrons passed by the grid 24 for impingement upon the plate 20. The plate 20, therefore, emits a proportionately decreased number of electrons. In this way an excess amount of electrons remain on the plate 20 thus causing a current to flow through the resistance 50 from the power supply to make the bias upon the plate 20 more negative.

This increased negative bias is applied to the grid 24 through the R-C coupling circuit 84 and the grid becoming more negative acts to further cut off the number of electrons passing through the grid. This in turn further cuts the supply of electron flow to the plate 20 and causes the plate and the grid 24 to become more negative. The cycle described above is repeated regeneratively until the grid 24 blocks the passage of substantially all the electrons. The grid 24 may therefore be viewed as a gate that is initially open and closes the first time a negative pulse is placed on the grid 24. The electrons blocked by the grid 24 are actually repelled by the grid and travel in a cycloidal path 102 (Figure 3) towards the plate 26.

At the same time that the grid 24 becomes more negatively biased as a result of the action described above, fewer and fewer electrons impinge upon the anode 22 because of the decrease in the number of electrons that are emitted by the plate 20. This causes the anode 22 to become instantaneously more positive. The anode 22 reaches ground potential at the time that the grid 24 blocks the entire flow of electrons through it. Because of the connection between the plate 22 and the grid 34, the grid 34 also becomes instantaneously more positive and maintains this positive bias to provide for the passage of electrons.

As previously disclosed, the electrons blocked by the grid 24 travel in a cycloidal path to the plate 26. When these electrons impinge upon the plate 26, the plate emits electrons which travel in a cycloidal path to the plate 28. The plate 28 in turn emits electrons for travel in a cycloidal path to the grid 34.

Since the grid 34 is biased to provide for the passage of electrons in the manner disclosed above, the electrons pass through the grid and impinge upon the plate 30. The plate 30 in turn emits electrons which are received by the plate 32 for indication upon the oscilloscope 80. Figure 3 illustrates the path of electron flow upon the introduction of a single negative pulse to the grid 14 from the pulse source 68. A detection of a signal by the oscilloscope 80 provides a count of "one" indicating that one pulse has been introduced to the grid 14 from the source 70.

Upon the introduction of a second pulse to the grid 14, the number of electrons passed by the grid are again instantaneously decreased. Because of the regenerative action described relative to the plate 20 and the grid 24, the plate 30 and the grid 34 become negatively biased in the same manner and the electron flow through the grid is blocked. The anode 32 becomes more positive in the same manner as the anode 22 became more positive upon the introduction of the first pulse to the grid 14. Since the grid 44 is connected to the plate 32, the grid 44 becomes more positively biased to provide for the passage of electrons.

The electrons blocked by the grid 34 proceed in a cycloidal path to the plate 36 which emits electrons for reception by the plate 38. The plate 38 in turn emits electrons which pass through the grid 44 and impinge upon the plate 40. The plate 40 in turn emits electrons which are received by the plate 42 and the signal produced is indicated upon the screen of the oscilloscope 82. Figure 4 illustrates the path of the electron flow upon the introduction of the second pulse to the grid 14. Accordingly, the signal on the screen of the oscilloscope 82 provides a count of "two" indicating that two pulses have been introduced to the grid 14.

Upon the introduction of the third pulse to the grid 14, the grid 44 blocks the passage of electrons in the manner previously disclosed and the grid 24 becomes biased more positively because of its connection to the plate 42 and the grid 24 commences to pass electrons. In this way the electrons follow the path illustrated in Figure 2 which is the path that was initially followed by the electrons, prior to the introduction of any pulses to the grid 14. When this occurs a signal appearing on the screen oscilloscope 78 indicates a count of 3. Thereafter the grids 34, 44 and 24 successively provide for the passage of electrons upon the introduction of each successive pulse to the grid 14.

It will be recognized that additional plates and grids may be provided in the apparatus disclosed above so that the grids will successively pass electrons upon a progression in the count. For example, eight sets of plates and grids similar to the plates 36, 38, 40, 42 and the grid 44 may be included to the right of the grid 44 in the embodiment shown. In this way ten electrical pulses can be indicated by the passage of electrons through a different grid as the count progresses from 1 to 10.

It will also be recognized that a plurality of such apparatus may be arranged in cascaded relationship to provide for counts in 10 digits, 100 digits, 1000 digits and for higher counts as is the practice for other types of counters. It is also possible to arrange the plates and grids in the above apparatus in a circular manner so that a more compact structure results.

The apparatus disclosed above can also be used as a binary counter with the use of only two sets of plates and grids. For example, if no plates or grids are provided to the right of the grid 34, the remaining plates and grids could be utilized to act in the same manner as a multivibrator with electrons being alternately passed by the grids 24 and 34.

Although the embodiment shown makes use of oscilloscopes to provide an indication of electrons received by the anodes 22, 32 and 42, other means for indicating that electrons are impinging upon the anodes may be used. For example, signals could be provided by fluorescent screens which may be positioned beneath holes which may be provided in the anodes 22, 32 and 42.

The apparatus disclosed above has several important advantages. It can be used to count electrical pulses at extremely high rates, such as 10 megacycles or more. If used as a binary type counter, it can count pulses at an appreciably higher rate than the multivibrators which are in wide use at present. Another advantage is that relatively weak signals may be detected and counted since the plates in the electron multiplier operate to amplify signals prior to their detection by the anodes 22, 32 and 42.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is therefore to be limited only as indicated by the scope of the appended claims.

I claim:

1. In combination, means for providing a flow of elec-

trons, an electrode disposed to pass the electrons, a plurality of gates, each gate being operative to pass electrons upon an opening of the gate and to block the passage of electrons upon a closure of the gate, the first gate in the plurality being normally open and disposed to pass electrons passed by the electrode, the other gates in the plurality being normally closed and disposed to receive electrons blocked by the preceding gates in the plurality, means for introducing a series of pulses to the electrode to interrupt the passage of electrons by the electrode upon the introduction of each pulse, and means operative upon each interruption of the passage of electrons by the electrode to close the open gate in the plurality and to open the succeeding gate in the plurality for the passage of electrons blocked by the preceding gates.

2. In combination, means for providing a flow of electrons, a grid disposed to receive the electrons and normally biased to pass the electrons through the grid, a plurality of electrodes disposed in laterally contiguous relationship to one another, each electrode being operative to pass electrons upon a biasing of the electrode in a first direction and to block the passage of electrons upon a biasing of the electrode in a second direction, the first electrode in the plurality being normally biased in the first direction and disposed to receive electrons passed by the grid, the other electrodes in the plurality being normally biased in the second direction and disposed to receive electrons blocked by the preceding electrodes in the plurality, means for introducing electrical pulses to the grid to instantaneously interrupt the passage of electrons through the grid upon the introduction of each pulse, and means operative upon each interruption of the passage of electrons by the grid to produce a bias in the second direction on the electrode biased in the first direction so as to block the passage of electrons and to produce a bias in the first direction on the succeeding electrode in the plurality for the passage of electrons blocked by the preceding electrodes.

3. Apparatus for counting electrical pulses, including, means for providing a flow of electrons, a grid disposed to receive the electrons and normally biased to pass the electrons, a first gate disposed to receive the electrons passed by the grid and normally open to pass the electrons, a first plate disposed relative to the first gate to detect the electrons passed by the gate, means for introducing electrical pulses to the grid for the instantaneous interruption of the passage of electrons through the grid upon the introduction of each pulse, a first electrical circuit connected between the first gate and the first plate to produce a closure of the gate upon the introduction of a first pulse to the grid to block the passage of electrons by the gate, a second gate disposed to receive the electrons blocked by the first gate and normally closed to block the passage of the electrons, a second electrical circuit connected between the first plate and the second gate to open the second gate, upon the closure of the first gate, to provide for the passage of electrons blocked by the first gate, and a second plate disposed relative to the second gate to detect the electrons passed by the second gate.

4. In combination, means for providing a flow of electrons, an electrode disposed to receive the electrons and normally biased to pass the electrons, a plurality of grids for passing or blocking electrons in accordance with the bias imposed upon each grid, the first grid in the plurality being disposed to receive electrons passed by the electrode and normally biased to pass the electrons, the other grids in the plurality being disposed to receive the electrons blocked by the preceding grids in the plurality and normally biased to block the electrons, means for introducing electrical pulses to the electrode to decrease the flow of electrons through the electrode upon the introduction of each pulse, means for biasing the first grid to block electrons upon the introduction of the first pulse to the electrode and for biasing the succeeding grid in the plurality to pass the electrons blocked by the first grid, means operative upon the introduction of a sequence of pulses to the electrode to sequentially bias succeeding grids in the plurality so as to allow the passage of electrons through that grid so biased at a particular time and to simultaneously bias all other grids in the plurality so as to cause them to block the flow of electrons, and a plurality of plates disposed relative to the grids to successively detect the electrons passed in succession by the grids.

5. In combination, means for providing a flow of electrons, an electrode disposed to receive the electrons and to pass the electrons, means for introducing electrical pulses to the electrode for interrupting the flow of electrons through the electrode upon the introduction of each pulse, first and second grids, the first grid being disposed to receive the electrons passed by the electrode and the second grid being disposed to receive the electrons blocked by the first grid, means for biasing the first grid with a first potential and the second grid with a second potential and for alternating the bias of the grids between the first and second potentials upon the introduction of each pulse to the electrode to provide for an alternate passage of the electrons through the grids, and means disposed relative to the first and second grids to detect electrons passed by each grid.

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