This invention relates to an electric driving means for sewing machines, comprising at least two movable, cooperating working means, particularly a loop-taker and a sewing needle holder reciprocable in the longitudinal direction of the needle, at least one of said working means being driven by a pulse motor. In this specification the expression "pulse motor" denoting electro-magnetic motors, particularly with reciprocable motion, solenoid motors, electric-dynamic motors, step motors and the like, which are driven by pulses.

A suitable driving means of this kind would provide obvious advantages, such as elimination of comparatively expensive, mechanical transmissions, e.g. between the needle-bar and the loop-taker, and great liberty in the design of industrial sewing machines. Several suggestions for such driving means have also been made, e.g. comprising a solenoid motor for the needle-bar and a commutator motor rotating together with the loop-taker for the control of the current supply to said motor but such suggested driving means have, as far as we are aware, found no employment, probably on account of the fact that they have been too expensive, not permitted sufficiently high sewing speed and/or not permitted sufficient synchronization of the working means.

The principal object of the invention is to provide an improved driving means of the kind above referred to. This and other objects are attained principally by the provision of at least one contact-free pulse generator having a transducer movable in synchronism with the other working means for generating pulses in a pulse transmitter, and an electronic, preferably contact-free control assembly which is connected to a current source and preferably comprises semi-conductors, for transforming through suitable adaption and treatment said pulses to current pulses for driving the first-mentioned working means in step with said other working means.

In a particularly advantageous embodiment said one working means is a substantially vertically reciprocable needle-holder driven by an electromagnetic motor having a reciprocable motion, and the other working means is a loop-taker driven by an electric ordinary motor, connected to the current source, having a speed which is manually adjustable down to zero, said needle-holder being arranged to be in its upper limit position when the loop-taker is standing still and consequently no pulses are transmitted from the transmitter to the control assembly. This arrangement assists in improving the synchronization of said working means.

When the sewing machine is provided with a work-feeder for step-wise feeding of the work, the driving means according to the invention preferably comprises a control means governed by the movement of the needle-holder for inhibiting the next feeding step, when the needle-holder driven by the electromagnetic motor on account of abnormally great resistance from the work has not reached its stitch forming position with respect to the loop-taker.

In order to minimize the mass-forces (due to inertia) that must be overcome by the driving means according to the invention is suitably electrodynamic, preferably permanent-electrodynamic, its current coil being axially movable in an annular air gap in a magnet body, and secured to a rod projecting therethrough and preferably constituting said working means driven by said motor.

The invention will be more particularly described with reference to the accompanying drawings, in which FIG. 1 is a diagrammatical side view of a lock-stitch sewing machine according to the invention; and FIG. 2 is a diagrammatic side view of an extended or generalized version of the sewing machine according to FIG. 1 comprising a plurality of working means.

The frame of the machine shown in FIG. 1 comprises a base plate 1 supporting the work, and a cantilever bracket-arm 2 with a bead 3 which may be removable. In the head there is rigidly secured a permanent magnet 4, possibly a ferrite magnet, having an annular air gap 5 for an iron-free driving coil 6 and a central bore for a substantially vertical, non-rotatable needle-bar 8 constituting a holder for a sewing machine needle 9. The coil 6 is, preferably by means of a light frame 10, suitably of plastic, secured to the needle-bar 8, which is of non-magnetic material, suitably of stainless steel or aluminum, and supported in bushings 11 in the magnet 4 or the head 3. The vertical movement of the needle-bar is limited by stops 12, 13 which are provided on the needle-bar and preferably adjustable in the longitudinal direction thereof. The stops 12, 13 cooperate e.g. with the bushings 11 and are of an elastic material, such as rubber, said coil 6 being located substantially within the magnet 4 in its lower end position and substantially outside the magnet in its upper end position.

For forming lock-stitches the needle 9 may, as known in the art, cooperate with a rotating loop-taker 14 mounted on a spindle 15 journaled below the base plate 1 and rotated by an electric motor 16. Below the needle-bar 8 the base plate 1 has an opening 7 for a work-feeder (not shown in FIG. 1) which is movable vertically and horizontally in a substantially rectangular path for indexing the work one step perpendicularly to the plane of the drawing, when the needle has left the work after a stitch formation.

The coil 6 is through two leads 17, 18 which permit vertical movement of the coil, connected to an electronic, contact-free control assembly 19, 20 which is through terminals A, B, C also connected to a current source 21, comprising a transformer 22 which may be connectable to an alternating current lighting system by means of a plug, two rectifiers circuits 23, and two capacitors 24. The current source 21 gives the terminals A, B, C different, low direct voltages, e.g. B 12 volts higher potential than C but 12 volts lower potential than A. To the last-mentioned end, the current source 21 may also be comprised of two batteries connected in series. The electric motor 16 is connected to the assembly 21 through a potentiometer 25 which may be set or adjusted by hand or by foot for adjustment of the speed of the loop-taker 14, down to zero. The control assembly has associated with it an inductive pulse transmitter 27 in the shape of an induction coil provided with an iron core, and the motor 16 drives a transducer 26 in the shape of a wheel, with a permanent magnet 28 at its circumference, one revolution for each operation cycle of the loop-taker 14. The magnet 28 is substantially opposite to the transmitter 27 when the needle is in its lowermost position and excites pulses in the coil of the transmitter 27 when rotating. As an inductive pulse generator it is possible to utilize, instead of the members 26, 27, e.g. a pole wheel driven by the motor 16, or a coil with a permanent magnet, respectively.

The control assembly 19, 20 includes a bistable multivibrator circuit 19, preferably a Schmitt trigger comprising a variable resistor 29 and transistors 30, 31, 32, and a re-
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When the loop-taker 14 is stationary, the coil 6 receives a direct current and is thereby maintained in its upper end position. When the loop-taker has been started by means of a potentiometer 27. When the voltage at the transistor 30 attains a predetermined value set by the potentiometer 29, the transistor is switched from its conductive state to its non-conductive state, or vice versa, when receiving a pulse. When switching from one state to the other transistor 30 sets the other transistor 31 into the opposite state. Hereby there is generated at the transistor 31 a substantially rectangular pulse which makes transistor 32 conductive, after which transistors 35, 36 through transformer 34 alternately become conductive and non-conductive respectively and thereby re-pole or successively reverse the direction of current in the driving coil 6 which accordingly receives, in synchronism with the movements of the loop-taker 14, a train of substantially rectangular current pulses of alternating polarity and without any (appreciable) intervals, whereby the needle-bar 8 is rotated in synchronism with the movements of the loop-taker 14. A thread tighter or thread take up device on the arm head 3 (not shown in FIG. 1) may be driven mechanically from the needle-bar 8 or electrically from the current source 21, as shown in FIG. 2.

If the needle-bar 8 during a downward motion should meet an abnormally great resistance from the work, it may happen that it will become arrested by the work and not reach stitch forming position with respect to the loop-taker 14. To obviate faulty stitches at such occurrences the machine may be provided with control means, governed by the downward motion of the needle-bar, for inhibiting the next indexing step, when the needle-bar 8 has not reached stitch forming position with respect to the loop-taker. Such a device becomes as simple as possible if the work feeder is not driven mechanically from the spindle 15 but is driven at least in part electrically, e.g. if it is advanced, against the biasing force of a spring, by an electromagnet and is raised by a cam. The above-mentioned faulty stitch preventing control means may comprise a permanent magnet 37 which is attached to the needle-bar and in the lower end position thereof, or at least when the needle has penetrated the work, faces an impulse transmitter 38 and exerts an impulse thereto which after a suitable delay and possible amplification by means known per se is applied to the electromagnet and energizes it when the needle has left the work.

Such an expanded embodiment of the invention in which not only the work-feeder but also a thread take-up device are driven in at least in part electrically by means of impulses generated only when the needle-bar 8 has reached stitch forming position is illustrated in FIG. 2.

The work feeder 40 of FIG. 2 is supported by a supporting slide 40a the left hand end of which forms the armature of an electromagnet 42 fed by current pulses. The slide 40a and the electromagnet 42 form together a pulse motor. The work feeder 40 and the supporting slide 40a are moved in a substantially rectangular, closed path during each stitch forming cycle, that is are raised by a cam 41 secured to the spindle 15 (compare FIG. 1), are pulled leftwards (the work feeding stroke) by the electromagnet 42 when it is energized, are lowered during the return stroke of the cam 41 and are finally retracted rightwards by the return spring 48. The electromagnet 42 is supported by the armature portion of the supporting slide 40a and a leaf spring 42a secured to a nut member 43 which is maintained non-rotatable by guide means 43a. The stroke of the work feeder is limited by a stationary stop 60 at the right hand (return) end and a stop 61 at the left hand end of the electromagnet 42. The position of the electromagnet and the last-mentioned stop 61 and accordingly the length of the stitches is adjusted by means of a rotatable threaded bolt secured to an adjustment knob 44. The thread take-up device 51 is rotated upwards (clockwise) for tightening the thread by a rotary electromagnet 50 fed by current pulses and is returned downwards by a spring (not shown) to rotate the thread take-up device 51 are limited by stops (not shown).

The current pulses for driving the rotary magnet 50 and accordingly the thread take-up device 51 in synchronism with the needle-bar 8 originate in a feedback transformer comprising an annular permanent magnet 52 and a coil 53, both cooperate with a transistor in the shape of a magnetic or soft iron piece 47 attached to the needle-bar 8. When the iron piece 47 penetrates the coil 46 during the upward stroke of the needle-bar 8 a current pulse of one polarity which is utilized for energizing the magnet 50 is induced in the coil 46. Since the magnet 50 has its rotor movements imparted to itself by a spring, the current pulses of the opposite polarity which are generated during the downward stroke of the needle-bar 8 and the iron piece 47 have to be eliminated or filtered off. This could be brought about by a rectifier in a manner known per se. The pulses induced in the coil 46 are fed by the leads 63, 71 to the input of a pulse shaping control assembly 59 which is similar to the corresponding electronic control assembly 19, 20 of FIG. 1 with the single exception that the transformer 34 and the transistors 35, 36 thereof have been replaced by a transistor 65a and an adjustable resistor 66a as shown in FIG. 2. The output pulses of the control assembly 59 are applied to the pull magnet 52 for energizing it through leads 67, 68.

In the same way the pulses for actuating the pull magnet 42 of the work feeder are generated in a coil 53 cooperating with an annular permanent magnet 52 and the transducer 47. The components 47, 63, 64 to a pulse shaping control assembly 49 similar to the assembly 59 of the thread take-up device and comprising a transistor 65b and an adjustable resistor 66b corresponding to members 65a and 66a respectively, instead of the transistors 35, 36 of FIG. 1. The output pulses of the control assembly 49 are applied to the pull magnet 42 for energizing it through leads 69, 70 corresponding to the leads 67 and 68 respectively.

It is obvious that no pulses, at least no pulses of sufficient amplitude, are generated in the coils 46, 53, if the needle-bar 8 should not reach stitch forming position, and accordingly the impulse operation of the thread take-up device 51 and the work feeder 40 is inhibited and faulty stitches are thus prevented.

If the loop-taker 14 makes two revolutions per stitch, the transducer 26 may be driven mechanically from the spindle 15 at half of its speed. The transducer may also be arranged on the spindle 15 if the control assembly is correspondingly designed, e.g. arranged to suppress every second pulse. In this instance the wheel 26 may be omitted and the magnet 42 be placed directly on the loop-taker 14.

Of course, other embodiments are possible within the scope of the invention. Instead of an inductive pulse transmitter 27 it is also possible to utilize a photo-cell, a photo transistor or another light-electric pulse transmitter together with a light source and a transducer or trigger, e.g. in the shape of a rotating shutter with an aperture passing behind the transmitter and the width of which is adjustable for altering the width of the rectangular pulse. In inductive pulse generators the pulse width may be adjusted by the use of one permanent magnet provided with adjustable pole pieces, or of two magnets which are adjustable relative to each other. Those pulses which actuate the driving coil 6 in the one direction could be made longer or given a greater width than the other ones, e.g. to maintain the driving coil at its one extreme position (the upper end position) longer than at its other end position. When the demands upon the driving means are comparatively restricted, one of the terminals A, B, C may be omitted, the assembly 21 may...
be simplified in a corresponding degree or be replaced by a single battery, the transistors 35, 36 being replaced by a switching device for reversal of the connection between the remaining terminals and the leads 17, 18, and the transformer 34 being replaced, respectively, by the switching device and a rectifier being then connected in parallel at the location of the primary of the transformer. In zigzag sewing machines having a laterally oscillating needle-bar the magnet body 4 may be rigidly secured to a laterally oscillating bracket in the head 3. The invention may also be applied to sewing machines having an oscillating loop-taker or shuttle, possibly for driving said loop-taker or the like which is then not mechanically coupled to the transducer. In the embodiment illustrated, the needle-bar is driven electro-dynamically in both directions, and the mass-forces (due to inertia) are minimized. The needle-bar may also, generally to less advantage, be driven by a spring in one direction (upwards) and electro-dynamically in the other, the control assembly 19, 20 then being arranged to supply rectified pulses to the coil 6 at intervals corresponding to the operation of the spring. A control assembly according to the invention having a contact-free pulse generator may also be utilized for governing a solenoid motor having one or several, alternately operating driving coils and an armature which may possibly be driven by a spring in one direction.

It is also within the scope of the invention to drive the loop-taker by means of an electric motor, preferably a DC motor. On the motor shaft there is then secured a pole-wheel having a plurality of magnetic poles. When rotating, the pole-wheel generates electric pulses in an adjacent, associated winding. The number of pulses per revolution corresponds to the number of poles of the pole-wheel.

The pulses are made rectangular in pulse shaping circuitry and are applied to an electronic switching unit by which they are applied in a predetermined sequence to an electromagnetic step motor. This motor comprises a permanent-magnetic armature having a plurality of poles and e.g. two stators which may each have a pair of pole pieces. The stator field is created by direct current flux in the stator pole pieces. By alternating, successive reversal of the direction of the magnetic flux in the stators, the rotor is made to rotate stepwise. Each pulse created through the poles and the pulse transformer at the rotation of the pole-wheel rotates the rotor of the step motor through a predetermined angle. If the number of poles of the pole-wheel equals the number of magnetic poles (e.g. 24 or more) of the rotor of the step motor, each revolution of the pole-wheel corresponds to a total angular increment of 360° of the rotor of the step motor. The shaft of the step motor drives the needle-bar mechanically in its reciprocating movement in a manner known per se as well as the thread take-up device. This system brings about a complete synchronisation of the movements of the needle-bar and the loop-taker.

The pole wheel and the step motor may be stopped in correct mutual positions with the aid of a brake operating upon the shaft of the pole wheel, or by maintaining a field winding of the step motor interconnected. When starting it is possible to make the pole wheel supply a special recognition or sync-pulse for each revolution of the loop-taker and make the rotor of the step motor (which then presents a specific design) initially lag, before it is synchronized with the pole wheel when a predetermined rotational speed has been attained.

While the invention has been described with reference to two preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What we claim is:
1. In a sewing machine of the type adapted to have a reciprocating needle, electric driving means comprising:
   - at least two cooperating working devices, comprising a loop-taker and a sewing needle holder including a needle bar, said needle holder being mounted for reciprocation longitudinally of the longitudinal axis of the needle;
   - a pulse motor drivingly connected to one of said loop-taker and said needle holder and in combination therewith comprising first working means;
   - an electric motor drivingly connected to the other of said loop-taker and said needle holder and in combination therewith comprising second working means;
   - a pulse generator for generating exciting pulses; and
   - means driving said pulse generator in synchronism with said second working means;
   - a current source;
   - an electronic control assembly interconnected between said pulse generator and said pulse motor for receiving current from said current source and exciting pulses from said pulse generator and to put out current pulses; and
   - means transmitting said current pulses to said pulse motor as driving input thereof whereby said one working means is driven in timed relationship with said second working means.

2. The driving means of claim 1 wherein said first working means comprises a substantially vertically reciprocable needle holder having means providing an upper limit position and said second working means comprises a loop-taker, wherein said pulse motor comprises an electro magnet motor having a reciprocable output motion; said electric motor being connected to said current source; said motor speed control means interconnected between said electric motor and said current source for manual adjustment of the speed of said electric motor down to zero; means for stationing said needle holder in said upper limit position when said motor is not operating and consequently no exiting pulses are received by said electronic control assembly from said pulse generator.

3. The driving means of claim 2 further having third working means comprising a work feeder to feed work in a step-wise manner; control means responsive to the movement of the needle holder toward the loop-taker for inhibiting stepping of said work feeder when downward movement of said needle holder is arrested short of stitch-forming cooperation with said loop-taker by abnormally great resistance from the work.

4. The driving means of claim 3 wherein the control means comprises a transducer secured to the needle bar and a contact-free impulse transmitter sensitive to the proximity of said transducer; electrical means for stepping said work feeder; and means operatively connecting said electrical stepping means and said contact-free impulse transmitter for initiating stepping by said electrical stepping means only when the needle holder is positioned for said stitch-forming cooperation.

5. The driving means of claim 1 wherein said pulse motor is an electrodynamic motor comprising a magnet body having means defining an annular air gap therein and a current coil operatively associated with said magnet body so as to be axially movable in said annular air gap; said needle bar being secured to said current coil.

6. The driving means of claim 5 wherein said control assembly provides current pulses of alternating polarity and having a frequency which varies directly with the velocity of said transducer.

7. The driving means of claim 6 wherein said control assembly comprises a bi-stable multivibrator circuit and circuit means operatively connected thereto for successively reversing the current to the coil.

8. The driving means of claim 1, wherein the electronic control assembly for the pulse motor is transistorized and is connected to a direct current source of low voltage.

9. The driving means of claim 1, wherein said pulse motor drives said needle bar; and further comprising a
second and a third pulse motor respectively operatively connected to a work feeder and a thread take-up device respectively via second and third pulse transmitters and second and third electronic control assemblies.

10. The driving means of claim 9 including a transducer secured to the needle bar; the second and third pulse transmitter sensing the proximity of said transducer.

11. In a sewing machine: rotatable working means including a loop-taker; reciprocable working means including at least one of a said needle holder and work-feeder; a pulse motor for driving said reciprocable working means, said pulse motor comprising a first stationary member and a second member movable with respect to said stationary member, one of said members being a current coil and the other member being a magnet body associated with said current coil; an ordinary electric motor for driving at least said rotatable working means; a pulse generator for generating exciting pulses, said pulse generator being driven by said ordinary electric motor in synchronism with said rotatable working means; a current source; an electronic control assembly interconnected between said pulse generator and the current coil of said pulse motor and fed with current from said current source and with said exciting pulses for transforming them to current pulses to be applied to the current coil of said pulse motor for driving said reciprocable working means, and means mechanically connecting said reciprocable working means to said movable member of said pulse motor, in timed relationship with said rotatable working means.

12. Driving means for a sewing machine according to claim 10 characterized in that the movable member of the pulse motor and its associated reciprocable working means are reciprocated solely by current pulses of alternating polarity applied to said current coil from said electronic control assembly, said pulses having a frequency which varies in response to the velocity of said pulse generator.

13. Driving means for a sewing machine according to claim 12, characterized in that said electronic control assembly comprises a bistable multivibrator circuit and circuitry connected thereto for successively reversing the current to said current coil.

14. Driving means for a sewing machine according to claim 11, characterized in that the movable member of said pulse motor and its associated reciprocable working means are advanced by current pulses of the same polarity applied to said current coil from said electronic control assembly, said pulses having a frequency which varies in response to the velocity of said pulse generator; in that rectifying means is provided for filtering of the current pulses of opposite polarity; and in that spring means are provided for retracting said reciprocable working means.

15. In a sewing machine: a plurality of cooperating working means including a loop-taker and a sewing needle holder reciprocable in the longitudinal direction of the needle; a pulse motor for driving at least one of said working means; an electric motor for driving at least a second one of said working means; a pulse transmitter, a transducer driven by said electric motor in synchronism with said second working means and associated with said pulse transmitter for generating pulses therein; a bistable multivibrator circuit electrically connected with said pulse transmitter and triggered by the pulses thereof; switching circuitry electrically connected to said multivibrator circuitry for reversing the polarity of every second pulse received therefrom; a direct current source for feeding said multivibrator circuit and said switching circuitry, which form together an electronic, break-contact-free control assembly electrically connected with said one working means and applying current pulses of alternating polarity thereto for driving it in timed relation with the other of said working means.

17. Driving means for a sewing machine according to claim 16, characterized in that the working means driven by said pulse motors comprises a needle-bar, a work feeder and a thread take-up device; and in that each of said pulse-motor-driven working means has an individual pulse motor, an individual transmitter and an individual electronic control assembly.

18. Driving means for a sewing machine according to claim 17, characterized in that said work feeder and said thread take-up device have a common transducer driven by the pulse motor of the third pulse-motor-driven working means.

19. In a sewing machine: a plurality of cooperating working means including a loop-taker and a sewing needle holder reciprocable in the longitudinal direction of the needle; a pulse motor for driving at least one of said working means; an electric motor for driving at least a second one of said working means; a pulse transmitter; a transducer driven by said electric motor in synchronism with said second working means and associated with said pulse transmitter for generating pulses therein; a current source; an electronic control assembly interconnected between said pulse generator and said pulse motor and fed with current from said current source and with said exciting pulses for transforming them to current pulses to be applied to said pulse motor for driving said one working means in step with said second working means.

20. In a sewing machine: a plurality of cooperating working means including a loop-taker and a sewing needle holder reciprocable in the longitudinal direction of the needle; a pulse motor for driving at least one of said working means; an electric motor for driving at least a second one of said working means; a pulse generator for generating exciting pulses, said pulse generator being driven by said electric motor in synchronism with said second working means; a bistable multivibrator circuit electrically connected with said pulse generator and triggered by the pulses thereof; switching circuitry electrically connected to said multivibrator circuitry for reversing the polarity of every second pulse received therefrom; a direct current source for feeding said multivibrator circuit and said switching circuitry, which form together an electronic, break-contact-free control assembly electrically connected with said one working means and applying current pulses of alternating polarity thereto for driving it in step with said second working means.

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