

The present invention relates to a method for positioning components on a workpiece in accordance with the preamble of Claim 1, and to a device for carrying out the said method.

A preferred field of application of the invention can be seen, for example, in the placing of electronic components on a supporting element. Suitable supporting elements include thick-film circuits, thin-film circuits, printed circuit boards or similar workpieces. Such supporting elements include a motherboard composed of a ceramic or other suitable material, the surface thereof being equipped, on the one hand, with a certain pattern of electrically conductive traces and, on the other hand, with a plurality of connection points provided to receive discrete electrical or electronic components such as resistors, transistors, capacitors and the like. Particularly in view of the small dimensions and tight arrangement of thin-film and thick-film circuits, it is of paramount importance that the components to be placed onto the supporting element be situated with the highest possible precision at a required position before being connected to the conductive traces of the supporting element, e.g. by soldering.

In order to make the production of such circuits economically efficient and as fully automated as possible, component insertion machines are used which automatically, controlled by a suitable program, remove selected components from a magazine or storage bin or from a certain magazine or storage bin from a group of magazines or bins, transport them into the region of the printed circuit board and finally place the components at an exactly preselected position on the printed circuit board. With the knowledge of the prior art it is possible to control to the required high level of precision the transporting apparatus which takes the individual components from the selected magazine or storage bin to its preselected position on the printed circuit board. However, the position of the individual components inside the magazine or storage bin is not guaranteed to the required level of precision, so that it is not possible to guarantee the position of a component picked up by the transporting apparatus relative to a theoretically exact positioning axis of the transporting apparatus. In other words this means that a component picked up by the gripping member of the transporting apparatus from the magazine or storage bin may be more or less shifted and/or tilted with regard to the theoretical positioning axis of the transporting apparatus.

In order to correct this unforeseeable deviation in position it has hitherto been proposed that the gripping members of the transporting apparatus be provided with centring elements to bring a component that has been picked up imprecisely into the theoretically desired nominal position relative to the positioning axis, i.e. to shift the component mechanically until the symmetry axis thereof coincides with the positioning

axis of the transporting apparatus. Such an apparatus is described, for example, in U.S. Patent No. 4,135,630, which discloses an arrangement for centring electronic components that have been removed from a magazine and are to be placed on a printed circuit board. This is based on the consideration that during their removal from the magazine the components to be positioned may have been gripped eccentrically and as a result cannot be placed in the correct nominal position on the printed circuit board. In order to avoid this, the aforementioned U.S. patent proposes using a centring member, with the help of which the components removed from the magazine can be centred relative to the theoretical positioning axis of the transporting apparatus.

Basically this method and this device work satisfactorily, but mechanically they require complex means in order to grip and mechanically displace the components taken from the magazine, which are generally of very small dimensions, so as to bring them into the theoretical nominal position. The design and manufacture of such a centring device, which must be built with a very high degree of precision, is therefore complex and very costly.

In addition, wear impairing the precision of the centring device must be expected, and furthermore under certain circumstances damage to the components may result. A further disadvantage of the known arrangement is the fact that the masses moved are relatively large; in the interests of a low cycle time in placing the components on the printed circuit board, the driving means for the transporting apparatus, which also have to include the centring device, consequently have to be oversized.

Finally, it is a disadvantage of the known arrangement that in order to centre components of different sizes, usually a plurality of differently sized pincer-like centring devices must be available which can be removably connected to the pick-up member. Apart from the undesirably time-consuming job of changing the centring devices, it is also disadvantageous that a number of different centring devices have to be kept in stock.

EP-A-0 062 335 describes an automatic assembly system for arming circuit boards with electronic components according to the prior art, this system operating without mechanical centring means. With said system the component to be placed on the circuit board is brought from a magazine by a first transporting member into the region of the circuit board and placed in a receiving compartment in a second transporting member. By means of this second transporting member the component is moved to a given point above the circuit board, from where it is taken and lifted up by a vertically adjustable vacuum needle. The second transporting member now moves back into position and in its place a reflector plate is

pushed under the component, with the help of which said component is illuminated from below using a projector. A camera arranged above the reflector plate records the outline of the component and from the starting signal of the camera its current position is determined. Thereafter the reflector plate can be drawn back again to clear the path between the component and the circuit board.

The circuit board is positioned on a table which is displaceable in X and Y planes. A second camera takes an image of the surface of the circuit board and the starting signal derived from this provides information about the current position of the circuit board. Should the first camera register a deviation in the position of the component, this is then corrected on the one hand by rotation about the Z axis of the vacuum needle and on the other hand by X/Y displacement of the table carrying the circuit board, before the component is placed on the circuit board by displacing the vacuum needle in the Z plane.

The disadvantage of this method is primarily the fact that it is an intermittent process. The component must be transferred twice before being placed on the circuit board. The position of the component can only be detected by interposing the reflector plate, which impedes the path along which the component moves; in other words, position detection during transportation of the component without depositing the latter and without interrupting the transportation movement is not possible. The mechanical effort is very great and the cycle time is relatively long, i.e. the time from removing a component from the magazine or storage bin to placing it in the correct position on the circuit board, on the one hand because the component is transferred twice, and on the other because it is absolutely essential to interpose the reflector plate into, and retract it from, the path along which the component is to move.

It is a primary object of the present invention to propose a method of the prior art type that no longer exhibits these disadvantages and which, in particular, allows printed circuit boards or indeed other workpieces of any type to be armed in rapid succession and with great precision with elements or electrical components removed from a magazine. The invention therefore aims to dispense with the use of a complicated, mechanically complex and therefore expensive centring device.

With regard to the method, the invention therefore proceeds from a method for positioning elements on a workpiece as defined in the preamble of Claim 1. To achieve the object according to the invention, the features specified in the characterising part of Claim 1 are provided.

The method according to the invention therefore dispenses with bringing the picked-up component into the theoretically

optimal position, i.e. moving the component into a concentric position relative to the positioning axis of the component transporting means. On the contrary, the extent of the eccentricity with which the component has been gripped, and if applicable also the extent of its rotation, is measured in the course of transporting the component along its route towards the workpiece, while it is above the workpiece, and subsequently the transportation course of the component transporting apparatus and/or the position of the workpiece is so adjusted that finally the component is placed on or into the workpiece in the theoretically preselected nominal position. By dispensing with centring devices the moved mass of the component transporting means can be kept considerably smaller. The adjustment, whether it be to the path along which the transporting apparatus moves or to the position of the workpiece, can be part of the job of the system controlling the complete installation, which is in any case necessary, e.g. by appropriately supplementing the control program, and thus requires no additional apparative outlay.

An expedient step under the method of the invention is to record the position of the component without the latter being deposited. The component can be removed from a magazine or storage bin, or from one selected magazine or storage bin from a group of magazines or bins, and in the course of transportation towards the workpiece can be taken to a position detecting device. This position detecting device detects the extent of the component's deviation relative to the theoretical, centred nominal position, and supplies a correction signal to the control system, in order to influence and adjust the path along which the transportation apparatus moves and/or the position of the workpiece carrier.

In the simplest case it may be sufficient to determine the deviation in position of the component from the theoretical nominal position in a single, horizontally extending direction. This will be the case if the components in the magazine or magazines are positioned very accurately in a first horizontal plane but less accurately in a second horizontal plane perpendicular to the first. It will, however, usually be necessary to determine the actual position of the component after it has been registered by the transportation apparatus in two horizontal planes perpendicular to one another, namely in an X coordinate and in a Y coordinate. This can be performed in the position detecting device, the constructional design of which will be further described hereinafter.

In some cases it may also be necessary to detect a possible rotation of the component about the positioning axis of the component transporting apparatus as well as registering the position of the component in the X and Y coordinates. This too can be performed in the position detecting device, the latter producing an error signal in response to the angle of

tilt and activating a rotation device in order to bring the component into the correct position with regard to its angle.

In any case, one or more correction signals are derived from the position detecting device, which are used to correctly position the component on the workpiece. Alternatively, it is possible by means of this correction signal or signals either to influence just the transportation path of the component transporting apparatus or just the positioning of the workpiece, or, for the purposes of optimising the movements, to exert both effects simultaneously.

Finally it should be mentioned that the position of the component on the transporting apparatus with regard to the Z coordinate can be detected and measured in a similar way. Such a reading, which may likewise be supplied by the position detecting device, offers a reference point allowing the component to be placed on the workpiece in an optimum position with regard to its height.

It is a further object of the present invention to provide a device of the type defined in the preamble of Claim 5 which is suitable for carrying out the aforementioned method, which no longer exhibits the disadvantages cited, and in particular allows workpieces, e.g. circuit boards for electronic circuits, to be armed in rapid succession and with the utmost precision with components removed from a magazine. Thus it aims to dispense with the use of a complicated, mechanically complex and therefore expensive centring device. Moreover, this device is to be suitable for all the current sizes of component, thereby relieving the user of the tiresome necessity of perhaps having to change a centring device according to the component being used. Finally, the proposed device is intended to prevent any damage to the components and, further, impaired accuracy resulting from increasing wear.

In order to achieve this further object of the invention, with a device of the prior art type the measures shown in the characterising part of Claim 5 are taken.

The device according to the invention is therefore likewise based on the following consideration: It dispenses with using the pick-up member to bring the component picked up by the pick-up member, and using a centring device, into coincidence with the theoretically optimum position relative to the centring axis, i.e. in a concentric position with respect to this positioning axis. Rather, the extent of the eccentricity with which the component was gripped is measured and then the path of the component transporting apparatus and/or, if appropriate, the position of the workpiece carrier, is so adjusted that the component is finally placed with utmost precision in the theoretically preselected nominal position on the workpiece.

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As already mentioned, by dispensing with any centring device the moved mass of the component transporting apparatus may be kept much smaller; this can be reflected advantageously in a reduced cycle time with constant drive performance for the component transporting apparatus or alternatively in smaller proportioning of the drive apparatus with a constant cycle time. The adjustment operation, whether to the path along which the component transporting apparatus moves or to the position of the workpiece, can be part of the job of the system controlling the complete installation, which is in any case necessary, e.g. by appropriately modifying or supplementing the control program, and thus requires no additional apparative outlay.

According to the proposal of the invention, the position detecting device is arranged in the region of the displacement path of the pick-up member of the component transporting apparatus. An expedient solution may be to arrange this position detecting device substantially concentrically above the workpiece mounting assembly. This allows the component transporting apparatus during the course of its displacement to be stopped for a short time above the workpiece mounting assembly, namely when the workpiece gripped by the pick-up member has passed into the region of the position detecting device. During this short stop the actual position of the component relative to the positioning axis running through the pick-up member is determined, and a correction signal is created which is a measure of the deviation in position in the horizontal X and Y directions as well as any rotation. As the position detecting device is connected to a control apparatus which receives this correction signal, either the transportation path of the component transporting apparatus or the position of the workpiece can be adjusted by moving the workpiece mounting assembly, or correction can be made by carrying out both measures simultaneously.

Another possibility lies in arranging the position detecting device on the component transporting apparatus in at least an approximately concentric position beneath the pick-up member. This solution allows the actual position of the component on the pick-up member to be detected during the movement of the transportation apparatus without interrupting same; with regard to evaluating the correction signals supplied by the position detecting device the aforementioned applies *mutatis mutandis*.

There are various options for the design of the position detecting device. In one preferred embodiment this may comprise a frame-like support, through which the pick-up member of the component transporting apparatus can pass, whereby, as already mentioned, the component transporting apparatus may possibly come briefly to a standstill when the component taken by the pick-up member is situated inside the frame-like support. As the component passes through the

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position detecting device, i.e. during this stoppage, the actual position of the component relative to the theoretical positioning axis is determined and one or more correction signals formed.

The position of the component can be scanned with or without contact. In the former case, on the four sides of the preferably rectangular or square frame of the position detecting device, longitudinally displaceable needles can be provided which are extended until they come into contact with the respective component side. The extent of displacement of each individual needle after a corresponding logic operation forms a correction signal from which the deviation in position of the component from the theoretical nominal position in the horizontal X and Y direction can be deduced.

In the second case scanning may be carried out without contact, e.g. with the aid of one or more laser beams. Here, too, there are a number of possibilities which are defined in detail in the dependent claims and are discussed in further detail in the following description of embodiments. At this juncture it is merely observed that scanning a component's position without contact not only offers major advantages *per se* (as for example the absence of wear), but also allows detection of any swivelling of the component about the positioning axis by the pick-up member, in addition to the detection of incorrect positioning in the horizontal X and Y directions. Furthermore, it also enables the vertical position of the component to be determined.

Embodiments of the inventive device will now be described in detail with reference to the accompanying drawings, and with the aid of these the method according to the invention will also be explained in detail. In the drawings:

Fig. 1 shows a schematic side view of an arrangement for positioning components;

Fig. 2 shows a top view of the workpiece mounting assembly and the component magazine group of the arrangement according to Fig. 1;

Figs. 3 to 5 show schematic views of the position of a component within the position detecting device;

Fig. 6 shows a schematic top view of a position detecting device using mechanical scanning with contact;

Fig. 7 shows a schematic top view of a first embodiment of a position detecting device using scanning without contact;

Fig. 8 shows a schematic top view of a second embodiment of a position detecting device using scanning without contact;

Fig. 9 shows the same view as Fig. 8, but with a rotated component;

Fig. 10 shows a schematic top view of a third embodiment of a position detecting device using scanning without contact; and

Fig. 11 shows the same view as Fig. 10 but with a rotated component.

The apparatus according to Fig. 1 includes a console 1 on which is disposed a workpiece mounting assembly in the form of a worktable 2. Driving means (not shown) operated by a control system (likewise not shown) allow the worktable 2 to be displaced horizontally in the direction of arrows X as well as in the direction of arrows Y (Fig. 2), i.e. in two directions perpendicular to one another in one horizontal plane. On the worktable 2 is a workpiece 3, e.g. in the form of a ceramic substrate equipped with strip conductors, designed for manufacturing an electronic circuit arrangement. Positioning and mounting means 4 serve to fix the workpiece 3 in a predetermined position relative to the worktable 2.

A further console 5 arranged adjacent to console 1 bears a number of component magazines 6; these include a storage component 7 from which projects a tape 8 which is provided with a plurality of, for example, components 9a, 9b, etc. affixed to said tape. The component magazines 7 can of course be designed differently, and a row of operating members are required for said magazine; for the purposes of the present invention it is not necessary to go into these details as they lie within the purview of one skilled in the art.

Above the two consoles 1 and 5 is arranged a guide member 10 which receives a component transporting apparatus 11. The latter comprises a carriage-like section 12 which is longitudinally displaceable along the guide member 10 in the direction of arrow A. Preferably, the entire guide member 10 may also be diagonally displaceable along arrow B extending perpendicular to itself and in a horizontal direction. The transporting apparatus 11 includes a component pick-up member 13 which is equipped with a hollow needle 14 for removing the individual components 9a-9b from the magazines. The interior of the hollow needle 14 is connected to a vacuum source (not shown); as soon as the point of the needle 14 contacts the component 9 to be picked up, the vacuum is set up to the needle 14 so that the component 9 sticks to the point of the needle 14. For this purpose, the whole assembly or component pick-up member 13 is vertically displaceable in the direction of arrow C. This means that the needle 14 can be lowered from the position shown in Fig. 1 onto a selected component 9 in order to retain it by suction.

As already mentioned, the arrangement 11 is displaceable along the guide member 10 in the direction of arrow A, namely into a position (indicated by dashed lines in Fig. 1) above a position detecting device 15. The latter is disposed centrally above the worktable 2 and is substantially frame-like in shape, so that the component pick-up member 13 is able to pass through it with the needle 14 bearing the component 9.

Further details regarding the position detecting device 15 will be discussed more thoroughly hereinafter. In any case, the position detecting device is able to recognise the actual position of a component 9 relative to a vertical positioning axis running through the centre of the needle 14 and to derive one or more correction signals therefrom.

Figs. 3 to 5 schematically show different positions of a component 9 with regard to the positioning axis P inside the frame-like position detecting device 15. Whilst in Fig. 3 the component 9 is in the theoretically correct nominal position in the X and Y direction and is also not rotated in relation to the frame of the device 15, the component in Figs. 4 and 5 is in a rotated and linearly eccentric position, respectively.

The position detecting device 15 is able to recognise, in the case of the situation shown in Fig. 4, the angle of rotation of the component 9, to derive a correction signal therefrom, and to cause the needle 14 or the component bearing member 13 to rotate until the component 9 reaches the position shown in Fig. 3. Furthermore, the device 15 recognises a lateral displacement in the horizontal plane, in the situation shown in Fig. 5, by the amount x in the X direction and by the amount y in the Y direction. Correction signals are likewise derived therefrom which affect either the transportation path of the arrangement 11 in the direction of arrows A and B or the displacement of the worktable 2 in the X and Y planes, or a combination of the two.

In practice the method proceeds as follows:

The component transporting apparatus 11 is in a position above a selected magazine 6, as shown in Fig. 1. The needle 14 is lowered in the direction of arrow C until its point comes into contact with the surface of the component 9c to be picked up. Next the vacuum source is activated and the needle 14 retracted so that the component 9c will stick on the tip of the needle 14. Normally, a component 9c picked up in this way will not be exactly centred on the point of the needle 14, but will be displaced in the X and Y direction. Furthermore, it is also possible that the component will be rotated.

The transporting apparatus 11 now moves into the position shown by dashed lines in Fig. 1 above the worktable 2 and the needle 14 is lowered until the component 9c is inside the frame-like position detecting device 15. There the eccentricity in the position of the component 9c relative to

the theoretical positioning axis in the centre of the needle 14 is registered; a resulting correction signal now produces either a correction of the position of the transporting apparatus 11 in the direction of arrows A and/or B, a displacement of the worktable 2 in the X and/or Y direction, or a combination of both corrective movements. When this has taken place, the component 9c located on the point of the needle 14 is certain to be in the correct position above the workpiece 3, so that the needle 14 can then be lowered in order to place the component 9c onto the workpiece 3 with maximum precision.

As already mentioned earlier, the position detecting device 15 recognises any rotation of the component 9c relative to the theoretical nominal position. The correction signal obtained from this can be used to rotate the needle 14 until the desired parallel alignment of the component 9c is reached. With the aid of the control systems now available, this evaluation and correction can take place so quickly that no significant dwell-time of the component in the position detecting device 15 is necessary.

After the component 9c has been placed on the workpiece 3, the vacuum inside the needle 14 is removed and said needle withdrawn, during which time the transporting apparatus 11 returns to the starting position shown in Fig. 1, or to a position somewhat shifted in the direction of arrow A above one of the magazines 6. The needle 14 can now be lowered once more to pick up a further component 9a-9b and the process just described repeats itself again.

Some variations of embodiments of the device for carrying out the process will now be described in more detail with particular reference to the diagrams shown in Figs. 6 to 11.

The component shown in Figs. 9 and 11 is in a rotated and eccentric position, whilst the component shown in Figs. 6, 7, 8 and 10 is displaced merely in the X or Y direction. In the case of the situation shown in Figs. 9 and 11, the position detecting device 15 is capable of recognising the angle of rotation of the component 9, deriving a correction signal therefrom and causing the needle 14 or the bearing member 13 to rotate until the workpiece 9 adopts the position shown in Figs. 6, 7, 8 and 10, parallel to the side edges of the workpiece 3. Alternatively, by means of the device 15 a lateral displacement in the horizontal plane is recognised, e.g. in the situation shown in Fig. 6, by the value x in the X direction and by the value y in the Y direction. Correction signals are likewise derived therefrom which have an effect either upon the path of motion of the arrangement 11 in the direction of arrows A and B or the displacement of the worktable 2 in X and Y directions, or upon a combination of all these movements. Equally, the component may also be rotated.

Different embodiments of the position detecting device 15 are shown in Figs. 6 to 11 and are further described below.

In Fig. 6 a mechanical solution can be seen which works by scanning with contact the component 20 to be positioned. The device 15 comprises a square frame made up of four side members 21a-21d. Each of the frame members 21a-21d carries a needle 22a-22d which is longitudinally displaceable and is operatively connected to a driving and measuring means 23a-23d. By means of the latter the needles 22a-22d can be displaced longitudinally in the direction of arrows U1-U4, i.e. perpendicular to the lengths of the frame sides 21a-21d. The construction of the driving and measuring means 23a-23d is well-known in the art and does not require further explanation here. At any rate means 23a-23d are operatively connected to the central control unit of the entire system and function as follows:

In their starting position the needles 22a-22d are in a more or less retracted position, so that a component 20 carried by the hollow needle 14 can be introduced into the interior of the frame 21a-21d. The centre of the needle 14, i.e. the theoretical positioning axis, is designated by the letter M. After the component 20 has been introduced into the position detecting device 15, the needles 21a-21d, controlled by the driving and measuring means 23a-23d, are driven in the direction of the component 20 until their points rest on the side faces of the latter. The displacement of the needles 22a-22d is measured by the driving and measuring means 23a-23d; from these values one or more correction signals can be set up which form a measure of the deviation of the centre N of the component 20 from the theoretical nominal position, i.e. axis M. This correction signal affects the drive of the component transporting apparatus and/or the drive of the workpiece mounting assembly. Once the position of the component 20 has been determined, the needles 22a-22d are retracted and the component 20 can be lowered onto the workpiece 3 where it takes up the theoretically optimum position with the utmost accuracy. The foregoing arrangement of the position detecting device 15 shown in Fig. 3 can be applied to particular advantage when the nature of the side faces of the components 20 is irregular or not known in advance. On the other hand, a disadvantage of this arrangement is the fact that a pivoting movement of the component 20 about the axis M cannot be detected. It must therefore be a pre-requisite that the component 20 is removed from the magazine in the correct angular position and is displaced only in the X and Y direction relative to the nominal position referring to axis M.

A second embodiment of the position detecting device 15 is shown in Fig. 7. Again there is provided a square frame with four frame sides 21a-21d into which the pick-up member of the component mounting assembly, equipped with the component 20,

is introduced. The arrangement according to Fig. 7 comprises two laser diodes 24a and 24b which are disposed rotatably at two opposing corners of the frame. The laser diodes emit a sharply focussed beam which is reflected by a component located within the frame. The two remaining, likewise opposing corners of the frame each accommodate a receiver diode 25a and 25b which are designed to receive a reflected beam.

It can be seen from Fig. 7 that in the course of its rotation the laser diode 24b will emit one beam which is first reflected by the side face 20a of the component 20 in such a way that it falls upon the receiver diode 25a and is registered by same. In the course of further rotation of the laser diode 24b a situation will occur in which the laser beam is reflected by side face 20d of the component and received by the receiver diode 25b. At the moment of receipt of the laser beam reflected, on the one hand, by side face 20a and on the other hand by side face 20d, the laser diode 24b in each case assumes a very definite angular position. This is recognised and logged by the device's control apparatus. The same applies to the rotating laser diode 24a: during the course of its rotation it will adopt an angular position in which the emitted beam is reflected by side face 20c in such a way that it will be received by the receiver diode 25b, and thereafter such an angular position that the beam is reflected by side face 20b of the component in such a way that it falls upon the receiver diode 25a. These two angular positions are likewise registered by the control apparatus of the device. From the angle values registered in the control apparatus, using known mathematical laws one or more correction signals can be derived which is/are a measure of the deviation in position of the component 20 from the theoretically ideal nominal position. The foregoing considerations are based on the assumption that the component 20 is in a correct angular position relative to the frame sides 21a-21d; this is represented by solid lines in Fig. 7. However, the situation can also arise in which the component 20 is in a position tilted around the axis M. This position, as well as the path of the reflected laser beams in such a case, is represented in Fig. 7 by dashed lines. It will be understood that at the moment the beams are registered by the receiver diodes 25a and 25b, the angles of rotation of the laser diodes 24a and 24b consequently differ from those in the previous situation. By analysing the angle of both laser diodes at which reflection occurred, and by continuous rotation of the component 20, if necessary in both directions in succession, it is possible according to likewise known mathematical laws to determine that position of the component in which it is exactly parallel to the sides 21a-21d of the frame.

In Figs. 8 and 9 a further embodiment of the position detecting device 15 is represented which likewise functions by scanning without mechanical contact of the component 20. In

this embodiment one frame side 21c is equipped with a row of beam-emitting elements 26, e.g. with laser diodes. Their beam is sharply focussed and runs parallel to frame sides 21b and 21d. On frame side 21a opposite frame side 21c, a correspondingly arranged row of receiver elements 27, e.g. of light-sensitive diodes or similar semi-conductors, is provided in such a way that each of the laser diodes 26 directs a beam to an associated receiver diode 27.

In the situation shown in Fig. 8, the component 20 is shifted to the right in the X plane and downwards in the Y plane, relative to the centring axis M, but assumes a correct angular position, i.e. parallel to the sides 21 of the frame. As a result, a number of diodes 27 on the left side as well as a number of diodes 27 on the right side receive the beams emitted by the laser diodes 26, whilst the receiver diodes 27 situated centrally can receive no beams as they lie in the shadow of the component 20. The ratio of left-side and right-side receiver diodes 27 receiving a beam thus constitutes a measure of the eccentricity in position of the component 20 in the X plane. To measure the eccentricity in the Y plane the component 20 is rotated through exactly 90 degrees; a measure of the deviation in position can be achieved in the same way. These two measured values are processed in the system's control apparatus to give one or more correction signals which affect the movement of the component transporting apparatus and/or the workpiece mounting assembly.

Should the situation in Fig. 9 occur, i.e. if the component 20 is rotated relative to axis M, then only a smaller number of the right-side as well as the left-side receiver diodes 27 receive a beam emitted by the laser diode 26. Consequently, the component 20 is rotated about the axis M until the number of diodes 27 receiving a beam is maximised. This ensures that the component 20 is in a position parallel to the frame sides 21.

A further embodiment can be seen in Figs. 10 and 11 which likewise functions without contact and which is essentially a combination of the embodiment shown in Fig. 7, on the one hand, and those shown in Figs. 8 and 9, on the other. The position detecting device 15 once again comprises a frame with sides 21a-21d, one side 21a being equipped with a row of receiver diodes 31 similar to the embodiment shown in Figs. 8 and 9. The opposite side 21c comprises a fixedly mounted light source 30 in the form of a double laser diode, the halves 30a and 30b of which emit a sharply focussed beam in two diametrically opposed directions. The beams run substantially parallel to frame side 21c. In the region of the corners adjoining frame side 21c are mounted reflector elements 28a and 28b, e.g. in the form of mirrors, which are rotatable about axes 29a and 29b, respectively. The beams emitted by the halves 30a and 30b of the laser diode 30 hit the mirrors 28a and 28b and are reflected towards the interior

of the position detecting device 15 where the component 20 is to be found.

According to the position of the component 20, whether it is in the X and Y direction or whether rotation about the axis M is concerned, as can be seen in Fig. 11, more or less of the receiver diodes 31 are hit by the beams of light emitted by the laser diodes 30a and 30b and reflected by the rotating mirrors 28a and 28b. The most appropriate procedure will again be as follows: The component 20, which may be in a position as shown in Fig. 11, is pivoted about the axis M until its correct angular position is detected. Thereafter, any deviation in the X direction is deduced from the number of left-side and right-side receiver diodes within the diode line 31 that are hit by beams of light and an X-correction signal is derived therefrom. Now the component 20 is swivelled through exactly 90 degrees, any Y-deviation is measured and a Y-correction signal obtained therefrom. As previously mentioned, the central control apparatus processes these correction signals and accordingly adjusts the movement of the component transporting apparatus and/or the workpiece mounting assembly.

It will be understood that the devices and arrangements described by way of example may be subject to numerous modifications within the scope of the invention; the same is also true of the method. Furthermore, it is conceivable that the apparatus according to the invention may be used not only for positioning components on a printed circuit board for electronic circuitries, but for any other manufacturing process that requires exact positioning of a component at a preselected position on or in a workpiece.

Claims

1. Method for positioning components on a workpiece, wherein a component is removed from a magazine or storage bin, or from one selected magazine or storage bin from a group of magazines or bins, its position is scanned and recorded, the component is transported into the region of the workpiece, using a component transporting means and taking the component's recorded position into consideration, and placed in a preselected position onto the workpiece, characterised in that the workpiece and/or the component transporting means is/are moved into a relative nominal position in which a positioning axis of the component transporting means coincides with the nominal position of the component on the workpiece while the component is being removed, or in the case of moving the component transporting means only after removing the component, that thereafter, in the course of transporting the component along its route towards the workpiece, the actual position of the component is measured with reference to said positioning axis while it is above the workpiece and any deviation from the nominal position that occurs is recorded, that a correction signal is derived from the measured deviation in position, and that finally the position of the workpiece and/or the displacement path of the component transporting means is corrected as a function of the derived correction signal before the component is placed onto the workpiece.
2. Method according to Claim 1, characterised in that the positioning axis extends in the vertical direction and any deviation in the position of the component relative to the positioning axis is scanned and recorded in at least one direction within a horizontal plane.
3. Method according to Claim 2, characterised in that any deviation in the position of the component relative to the positioning axis is scanned and recorded in two directions, perpendicular to one another, within a horizontal plane.
4. Method according to Claim 1 or 2, characterised in that any deviation in the position of the component with regard to rotation relative to the positioning axis is scanned and recorded.
5. Apparatus for carrying out the method according to one or more of the preceding claims, said apparatus comprising at least one component magazine or storage bin, or a group of component magazines or storage bins, at least one component transporting apparatus having a pick-up member for gripping the component, and at least one workpiece mounting assembly for receiving at least one workpiece, said component transporting apparatus being displaceably mounted between the component magazine or storage bin, or group thereof, and the workpiece mounting assembly, and a position detecting device being provided for scanning the current position of the



component being transported, characterised in that the position detecting device (15) is disposed in the path along which a component (9, 20) carried by the pick-up member (13, 14) of the component transporting apparatus (10, 11) is moved and that it scans the relative deviation in position of said component (9, 20), while spaced above the workpiece mounting assembly (1, 2, 4), relative to a nominal position based on a positioning axis running through the pick-up member, and that there is provided a control apparatus connected to the position detecting device (15) and at least to the drive of the component transporting apparatus (10, 11), said control apparatus influencing said drive in response to the scanned deviation in position.

6. Apparatus according to Claim 5, characterised in that the position detecting device (15) is located on the component transporting apparatus (11) below the pick-up member (13, 14).

7. Apparatus according to either of Claims 5 or 6, characterised in that the position detecting device (15) has a frame (21a - 21d), through which the pick-up member (13, 14) of the component transporting apparatus, equipped with the component (20), passes.

8. Apparatus according to any of Claims 5 to 7, characterised in that the frame (21a - 21d) is rectangular or square in shape and is provided with position detecting means (22a-22d; 23a-23d or 24a,b; 25a,b or 26; 27 or 30; 31) along at least one frame side (21a or 21b or 21c or 21d, respectively).

9. Apparatus according to any of Claims 5 to 8, characterised in that at least certain of the frame sides (21a - 21d) are provided with a position detection needle (22a - 22d) which is longitudinally displaceable, extends substantially perpendicular to the frame side, and is arranged at least approximately in the centre of the frame side, and which is operatively connected to a driving and measuring means (23a - 23d) designed to displace the needle towards the centre of the frame, and which measures the extent to which the needle is displaced.

10. Apparatus according to Claim 9, characterised in that the driving and measuring means (23a - 23d) are operatively connected to the control apparatus of the system.

11. Apparatus according to any of Claims 5 to 8, characterised in that in the region of two opposing corners of the frame there is respectively provided an element (24a, 24b) adapted to be driven to a movement that can be swivelled by at least 90° and emitting a beam which the component (20) is able to reflect, and in the region of the other two opposing corners of the frame there is respectively provided an element (25a, 25b) which receives said beam.



12. Apparatus according to Claim 11, characterised in that the elements (24a, 24b) emitting the beams are rotatable by 360°.

13. Apparatus according to Claims 11 or 12, characterised in that the elements (24a, 24b) emitting the beams and the elements (25a, 25b) receiving the beams are connected to the control apparatus of the system.

14. Apparatus according to any of Claims 11 to 13, characterised in that the elements (24a, 24b) emitting the beams are laser diodes and the elements (25a, 25b) receiving the beams are light-sensitive semi-conductor elements.

15. Apparatus according to any of Claims 5 to 8, characterised in that a row of adjacent, beam-emitting elements (26) is provided along at least one frame side (21c) and a row of adjacent elements (27) receiving said beams is provided along at least one frame side (21a) situated opposite said frame side (21c).

16. Apparatus according to Claim 15, characterised in that the elements (26) emitting the beams are laser diodes and the elements (27) receiving the beams are light-sensitive semi-conductor elements, one light-sensitive semi-conductor element being associated with each laser diode.

17. Apparatus according to any of Claims 5 to 8, characterised in that a row of adjacent light-sensitive receiver elements (31) is provided along at least one frame side (21a), and that an element (30) emitting beams in the direction of two diametrically opposite sides is disposed in the centre of the opposite frame side (21c) and two reflector elements (28a, 28b) adapted to be driven to a rotating movement are disposed in the region of the ends of said frame side (21c).

18. Apparatus according to Claim 17, characterised in that said element (30) emitting beams is a double laser diode which sends a laser beam to each of the two reflector elements, which are constructed as mirrors (28a, 28b), in a direction substantially parallel to said frame side (21c).

19. Apparatus according to Claim 17 or 18, characterised in that the light-sensitive receiver elements (31) are semi-conductor elements.

20. Apparatus according to one or more of Claims 11 to 19, characterised in that the elements (24a, b or 26 or 30) which emit the beams and the elements (25a, b or 27 or 31, respectively) which receive the beams are operatively connected to the control apparatus of the system.

