(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 June 2002 (13.06.2002)

PCT

(10) International Publication Number
WO 02/45768 A2

(51) International Patent Classification[7]: A61M

(21) International Application Number: PCT/IL01/01121

(22) International Filing Date: 5 December 2001 (05.12.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
140136 6 December 2000 (06.12.2000) IL

(71) Applicant *(for all designated States except US)*: **IN-TUMED LTD.** [IL/IL]; Yehoshua Hatsoref Street 15, 84103 Be'er Sheva (IL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BESHARIM, Shlomo** [IL/IL]; Balfur Street 24/4, 84291 Be'er Sheva (IL). **BESHARIM, Eliyahu** [IL/IL]; Hativa Shemone Street 11/5, 84253 Be'er Sheva (IL).

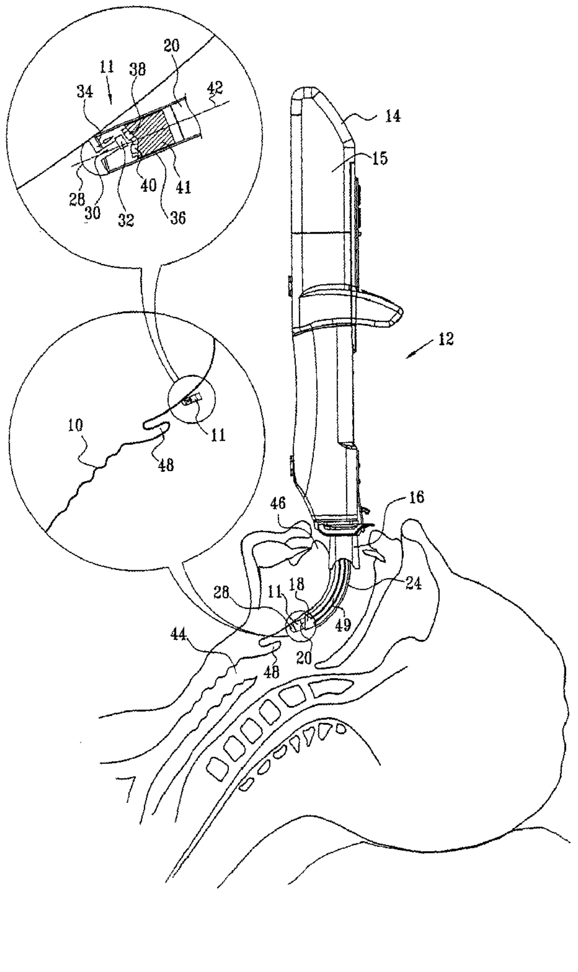
(74) Agents: **SANFORD T. COLB & CO.** et al.; P.O. Box 2273, 76122 Rehovot (IL).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,

[Continued on next page]

(54) Title: APPARATUS FOR SELF-GUIDED INTUBATION



(57) Abstract: An automatically operative medical insertion device and method including an insertable element which is adapted to be inserted within a living organism in vivo, a surface following element, physically associated with the insertable element and being arranged to follow a physical surface within the living organism in vivo, a driving subsystem operative to at least partially automatically direct the insertable element along the physical surface and a navigation subsystem operative to control the driving subsystem based at least partially on a perceived location of the surface following element along a reference pathway stored in the navigation subsystem.

WO 02/45768 A2

GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

APPARATUS FOR SELF-GUIDED INTUBATION

FIELD OF THE INVENTION

The present invention relates to systems and methods for automatic insertion of an element into a living organism in vivo.

REFERENCE TO CO-PENDING APPLICATIONS

Applicants hereby claim priority of Israel Patent Application No. 140,136 filed December 6, 2000, entitled "Apparatus For Self-Guided Intubation".

BACKGROUND OF THE INVENTION

The following patents are believed to represent the current state of the art: 6,248,112; 6,236,875; 6,235,038; 6,226,548; 6,211,904; 6,203,497; 6,202,646; 6,196,225; 6,190,395; 6,190,382; 6,189,533; 6,174,281; 6,173,199; 6,167,145; 6,164,277; 6,161,537; 6,152,909; 6,146,402; 6,142,144; 6,135,948; 6,132,372; 6,129,683; 6,096,050; 6,096,050; 6,090,040; 6,083,213; 6,079,731; 6,079,409; 6,053,166; 5,993,424; 5,976,072; 5,971,997; 5,957,844; 5,951,571; 5,951,461; 5,885,248; 5,720,275; 5,704,987; 5,592,939; 5,584,795; 5,506,912; 5,445,161; 5,400,771; 5,347,987; 5,331,967; 5,307,804; 5,257,636; 5,235,970; 5,203,320; 5,188,111; 5,184,603; 5,172,225; 5,109,830; 5,018,509; 4,910,590; 4,672,960; 4,651,746

Reference is also made to: http://www.airwaycam.com/system.html

SUMMARY OF THE INVENTION

The present invention seeks to provide improved systems and methods for automatic insertion of an element into a living organism in vivo.

There is thus provided in accordance with a preferred embodiment of the present invention an automatically operative medical insertion device including an insertable element which is adapted to be inserted within a living organism in vivo, a surface following element, physically associated with the insertable element and being arranged to follow a physical surface within the living organism in vivo, a driving subsystem operative to at least partially automatically direct the insertable element along the physical surface and a navigation subsystem operative to control the driving subsystem based at least partially on a perceived location of the surface following element along a reference pathway stored in the navigation subsystem.

There is also provided in accordance with a preferred embodiment of the present invention an automatically operative medical insertion method, which includes inserting an insertable element within a living organism in vivo, physically associating a surface following element with the insertable element and causing the surface following element to follow a physical surface within the living organism in vivo, automatically and selectably directing the insertable element along the physical surface and controlling direction of the insertable element based at least partially on a perceived location of the surface following element along a reference pathway stored in the navigation subsystem.

Further in accordance with a preferred embodiment of the present invention the driving subsystem is operative to fully automatically direct the insertable element along the physical surface.

Still further in accordance with a preferred embodiment of the present invention the driving subsystem is operative to automatically and selectably direct the insertable element along the physical surface.

Additionally in accordance with a preferred embodiment of the present invention the navigation subsystem receives surface characteristic information relating to the physical surface from the surface following element and employs the surface characteristic information to perceive the location of the surface following element along the reference pathway.

Preferably, the surface characteristic information includes surface contour information.

Additionally in accordance with a preferred embodiment of the present invention the surface characteristic information includes surface hardness information.

Preferably, the surface contour information is three-dimensional,

Preferably, the surface contour information is two-dimensional.

Further in accordance with a preferred embodiment of the present invention the insertable element is a endotracheal tube and wherein the physical surface includes surfaces of the larynx and trachea.

Still further in accordance with a preferred embodiment of the present invention the insertable element is a gastroscope and wherein the physical surface includes surfaces of the intestine.

Additionally in accordance with a preferred embodiment of the present invention the insertable element is a catheter and wherein the physical surface includes interior surfaces of the circulatory system.

Further in accordance with a preferred embodiment of the present invention the insertion device also includes a reference pathway generator operative to image at least a portion of the living organism and to generate the reference pathway based at least partially on an image generated thereby.

Preferably, the reference pathway includes a standard contour map of a portion of the human anatomy.

Further in accordance with a preferred embodiment of the present invention the standard contour map is precisely adapted to a specific patient.

Still further in accordance with a preferred embodiment of the present invention the standard contour map is automatically precisely adapted to a specific patient.

Further in accordance with a preferred embodiment of the present invention the reference pathway is operator adaptable to designate at least one impediment.

Additionally in accordance with a preferred embodiment of the present invention the insertable element includes a housing in which is disposed the driving subsystem, a mouthpiece, a tube inserted through the mouthpiece and a flexible guide inserted through the tube, the surface following element being mounted at a front end of the guide.

Preferably, the mouthpiece includes a curved pipe through which the tube is inserted and the driving subsystem operates to move the guide in and out of the housing, through the curved pipe and through the tube.

Preferably, the driving subsystem also operates to selectably bend a front end of the guide and to move the insertable element in and out of the living organism.

Additionally, the driving subsystem is also operative to selectably bend a front end of the insertable element.

Further in accordance with a preferred embodiment of the present invention the surface following element includes a tactile sensing element.

Preferably, the surface following element includes a tip sensor including a tip integrally formed at one end of a short rod having a magnet on its other end, the rod extends through the center of a spring disk and is firmly connected thereto, the spring disk being mounted on one end of a cylinder whose other end is mounted on a front end of the insertable element.

Further in accordance with a preferred embodiment of the present invention the tip sensor also includes two Hall effect sensors, which are mounted inside the cylinder on a support and in close proximity to the magnet, the Hall effect sensors being spaced in the plane of the curvature of the curved pipe. Each Hall effect sensor includes electrical terminals operative to provide electric current representing the distance of the magnet therefrom. The tip sensor operates such that when a force is exerted on the tip along an axis of symmetry of the cylinder, the tip is pushed against the spring disk, causing the magnet to approach the Hall effect sensors and when a force is exerted on the tip sideways in the plane of the Hall effect sensors, the tip rotates around a location where the rod engages the spring disk, causing the magnet to rotate away from one of the Hall effect sensors and closer to the other of the Hall effect sensors.

Still further in accordance with a preferred embodiment of the present invention the driving subsystem operates, following partial insertion of the insertable element into the oral cavity, to cause the guide to extend in the direction of the trachea and bend the guide clockwise until the surface following element engages a surface of the tongue, whereby this engagement applies a force to the surface following element.

Additionally in accordance with a preferred embodiment of the present invention the navigation subsystem is operative to measure the changes in the electrical outputs produced by the Hall effect sensors indicating the direction in which the tip is bent.

Moreover in accordance with a preferred embodiment of the present invention the navigation subsystem operates to sense the position of the tip and the past history of tip positions and to determine the location of the tip in the living organism and relative to the reference pathway.

Preferably, the navigation subsystem operates to navigate the tip according to the reference pathway and operates to sense that the tip touches the end of the trough beneath the epiglottis.

Further in accordance with a preferred embodiment of the present invention the navigation subsystem is operative to sense that the tip reaches the tip of the epiglottis.

Still further in accordance with a preferred embodiment of the present invention the navigation subsystem operates to sense that the tip reached the first cartilage of the trachea.

Additionally in accordance with a preferred embodiment of the present invention the navigation subsystem operates to sense that the tip reached the second cartilage of the trachea.

Further in accordance with a preferred embodiment of the present invention the navigation subsystem is operative to sense that the tip reached the third cartilage of the trachea.

Preferably, the navigation subsystem operates to load the reference pathway from a memory.

Further in accordance with a preferred embodiment of the present invention the driving subsystem is operative to push the tube forward.

Still further in accordance with a preferred embodiment of the present invention the driving subsystem includes a first motor which operates to selectably move the insertable element forward or backward, a second motor which operates to selectably bend the insertable element and electronic circuitry operative to control the first motor, the second motor and the surface following element.

Preferably, the electronic circuitry includes a microprocessor operative to execute a program, the program operative to control the first and second motors and the surface following element and to insert and bend the insertable element inside the living organism along the reference pathway

Further in accordance with a preferred embodiment of the present invention the driving subsystem is operative to measure the electric current drawn by at least one of the first and second motors to evaluate the position of the surface following element.

Still further in accordance with a preferred embodiment of the present invention the reference pathway is operative to be at least partially prepared before the insertion process is activated.

Preferably, the medical insertion device includes a medical imaging system and wherein the medical imaging system is operative to at least partially prepare the reference pathway.

Preferably, the medical imaging subsystem includes at least one of an ultrasound scanner, an X-ray imager, a CAT scan system and an MRI system.

Further in accordance with a preferred embodiment of the present invention the medical imaging system operates to prepare the reference pathway by marking at least one contour of at least one organ of the living organism.

Additionally in accordance with a preferred embodiment of the present invention the medical imaging system operates to prepare the reference pathway by creating an insertion instruction table including at least one insertion instruction.

Preferably, the insertion instruction includes instruction to at least one of extend, retract and bend the insertable element.

Further in accordance with a preferred embodiment of the present invention the navigation subsystem is operative to control the driving subsystem based at least partially on a perceived location of the surface following element and according to the insertion instruction table stored in the navigation subsystem.

Additionally in accordance with a preferred embodiment of the present invention the operative medical insertion device operates to at least partially store a log of a process of insertion of the insertable element and transmits the log of a process of insertion of the insertable element.

Further in accordance with a preferred embodiment of the present invention the computer operates to aggregate the logs of a process of insertion of the insertable element and to prepare the reference pathway based at least partially on the aggregate.

Still further in accordance with a preferred embodiment of the present invention the computer transmits the reference pathway to the medical insertion device.

Further in accordance with a preferred embodiment of the present invention the insertable element includes a guiding element and a guided element.

Additionally in accordance with a preferred embodiment of the present invention the driving subsystem operates to direct the guiding element and the guided element at least partially together.

Further in accordance with a preferred embodiment of the present invention the driving subsystem operates to direct the guiding element and the guided element at least partially together.

Still further in accordance with a preferred embodiment of the present invention the step of directing includes automatically and selectably directing the insertable element in a combined motion, including longitudinal motion and lateral motion.

There is further provided in accordance with a preferred embodiment of the present invention an automatically operative medical insertion device including an insertable element which is adapted to be inserted within a living organism in vivo, a surface following element, physically associated with the insertable element and being arranged to follow a physical surface within the living organism in vivo, a driving subsystem operative to at least partially automatically direct the insertable element along the physical surface and a navigation subsystem operative to control the driving subsystem based at least partially on a perceived location of the surface following element along a reference pathway stored in the navigation subsystem. The insertable element preferably includes a disposable mouthpiece.

There is further provided in accordance with yet another preferred embodiment of the present invention an automatically operative medical insertion method. The method includes inserting an insertable element within a living organism in vivo, physically associating a surface following element with the insertable element and causing the surface following element to follow a physical surface within the living organism in vivo, automatically and selectably directing the insertable element along the physical surface and controlling direction of the insertable element based at least partially on a perceived location of the surface following element along a reference pathway stored in the navigation subsystem. The insertable element preferably includes a disposable mouthpiece.

It is appreciated that the distances and angles referenced in the specification and claims are typical values and should not be construed in any way as limiting values.

BRIEF DESCRIPTION OF THE DRAWINGS AND APPENDICES

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings and appendices in which:

Figs. 1A to 1L are a series of simplified pictorial illustrations of a process of employing a preferred embodiment of the present invention for the intubation of a human;

Figs. 2A to 2F taken together are a flowchart illustrating a preferred implementation of the present invention, operative for an intubation process as shown in Figs. 1A to 1L;

Fig. 3 is a simplified illustration of the internal structure of a preferred embodiment of the present invention for intubation of a human;

Fig. 4 is a simplified block diagram of a preferred embodiment of the present invention;

Figs. 5A to 5H are electrical schematics of a preferred embodiment of the present invention for intubation of a human;

Figs. 6A to 6K are a series of simplified pictorial illustrations of a process of employing a preferred embodiment of the present invention for insertion of an element into the intestine of a human;

Fig. 7 is a preferred embodiment of a table comprising instruction, operative in accordance with a preferred embodiment of the present invention, for insertion of an element into the intestine of a human as shown in Figs. 5A to 5K;

Fig. 8 is a flowchart illustrating a preferred implementation of the present invention, operative for a process of insertion of an element into the intestine of a human as shown in Figs. 6A to 6K.

LIST OF APPENDICES

Appendices 1 to 3 are computer listings which, taken together, form a preferred software embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Figs. 1A to 1L, which are a series of simplified pictorial illustrations of a system and methodology for the intubation of a human in accordance with a preferred embodiment of the present invention.

It is appreciated that the general configuration of the mouth and trachea is generally the same for all humans except for differences in scale, such as between an infant, a child and an adult. In a preferred implementation of the present invention, a standard contour map 10 of the human mouth and trachea is employed. The scale of the map 10 may be further precisely adapted to the specific patient, preferably automatically. Alternatively, the scale of the map 10 is adapted to the specific patient semi-automatically. In this alternative the operator can select the scale of the map 10, for example by selecting between a child and an adult. Thereafter the scale of the map 10 is automatically adapted to size of the specific patient as a part of the intubation process. As a further alternative or in addition the operator is enabled to designate one or more typical impediments such as: a tumor, a swelling, an infection and an injury. Selecting an impediment preferably creates a suitable variation of the general map 10.

Fig. 1A shows the map 10 and the location therein where a tip sensor 11 of an intubator engages the mouth and trachea of the patient. It is a particular feature of the present invention that intubation is at least partially automatically effected by utilizing the contour map 10 to monitor the progress of tip sensor 11 and thus to navigate the intubator accordingly.

As seen in Fig. 1A, an intubator assembly 12, suitable for the intubation of a human, is partially inserted into an oral cavity of a patient. The intubator assembly 12 preferably comprises a housing 14 in which is disposed a guide driver 15, a mouthpiece 16, a tube 18 inserted through the mouthpiece 16, a flexible guide 20 inserted through the tube 18, and tip sensor 11 mounted at the distal end of the guide 20. The mouthpiece 16 preferably comprises a rigid curved pipe 24 through which the tube 18 is inserted. Preferably the curved pipe 24 comprises a slit 49 on each side. Alternatively, the curved pipe 24 is eliminated.

It is appreciated that some of the components comprising the intubator assembly 12 may be disposable, for example, the tube 18 and the mouthpiece 16.

The guide driver 15 is operative to move the guide 20 in and out of the housing 14, through the curved pipe 24 and through the tube 18. The guide driver 15 is also operative to selectably bend the distal end of the guide 20 clockwise and counterclockwise in the plane of the curvature of the curved pipe 24 in the sense of Fig. 1A.

Referring now to an enlargement of the tip sensor 11, it is seen that tip sensor 11 preferably comprises a tip 28 preferably integrally formed at one end of a short rod 30 having a magnet 32 on its other end. The rod 30 preferably extends through the center of a spring disk 34 and is firmly connected thereto. The spring disk 34 is preferably mounted on one end of a cylinder 36 whose other end is mounted on the distal end of the guide 20. Preferably, the tip sensor 11 also comprises two Hall effect sensors, 38 and 40, which are mounted inside the cylinder 36 on a support 41 and in close proximity to the magnet 32. The Hall effect sensors 38 and 40 are preferably spaced in the plane of the curvature of the curved pipe 24. Typically, each Hall effect sensor has electrical terminals operative to provide electric current representing the distance of the magnet 32 therefrom.

When a force is exerted on the tip 28 along the axis of symmetry 42 of cylinder 36, the tip 28 is pushed against the spring disk 34, causing the magnet 32 to approach the Hall effect sensors 38 and 40. Since the distance between the magnet 32 and each of the Hall effect sensors 38 and 40 decreases, both Hall effect sensors 38 and 40 produce an increase in their output electric current. When a force is exerted on the tip 28 sideways in the plane of the Hall effect sensors 38 and 40, the tip 28 rotates around the location where the rod 30 engages the spring disk 34, as is shown in Fig. 1A. This causes the magnet 32 to rotate away from the Hall effect sensor 40 and closer to the Hall effect sensor 38. The output electric current of the Hall effect sensor 40 typically decreases and the output electric current of the Hall effect sensor 38 typically correspondingly increases. Thus, it may be appreciated that the tip sensor 11 enables electronic circuitry (not shown) to measure the amplitude and the direction of force exerted on the tip 28 in the plane of the Hall effect sensors 38 and 40 and to compute the orientation of a surface of a tissue against which the sensor tip 28 is depressed, relative to the axis of symmetry 42.

It is appreciated that sensors other than Hall effect sensors can be used to measure the direction and the amplitude of the force exerted on the tip 28, or otherwise to measure the proximity and the orientation of the adjacent surface.

During automatic operation of the system, following partial insertion of the intubator assembly 12 into the oral cavity, as shown in Fig. 1A, the guide driver 15 typically causes the guide 20 to extend in the direction of the trachea 44 and bends the guide 20 clockwise until the tip 28 engages a surface of the tongue 46. This engagement applies a force to tip 28, which causes the tip to rotate counterclockwise wherein the magnet 32 approaches the Hall effect sensor 38. Electronic circuitry (not shown) inside the housing 14, which measures the changes in the electrical outputs produced by the Hall effect sensors 38 and 40, indicates that the tip 28 is bent clockwise.

By sensing the position of the tip and employing the past history of tip positions, the system of the present invention determines the location of the tip sensor 11 in the oral cavity and relative to the map 10. This location is employed in order to navigate the intubator correctly, as described hereinbelow.

Reference is now made to Fig. 1B, which illustrates a further step in the intubation in accordance with the present invention. Fig. 1B shows the guide 20 extended further and reaching an area between the base of the tongue 46 and the epiglottis 48 of the patient.

As seen in Fig. 1C, the guide 20 extends further forward until the tip 28 touches the end of the trough beneath the epiglottis 48.

As seen in Fig. 1D, the guide 20 bends counterclockwise and touches the bottom surface of the epiglottis 48. Then the guide 20 retracts a little, while preserving continuous tactile contact between the tip 28 with the bottom surface of the epiglottis 48.

As seen in Fig. 1E, the guide 20 retracts further until the tip 28 of the tip sensor 11 reaches the tip 165 of the epiglottis 48 and then the tip 28 loses tactile contact with the surface of the tip 165 of the epiglottis 48.

As seen in Fig. 1F, the guide 20 bends further counterclockwise, then extends forward and then bends clockwise until the tip 28 touches the upper surface of the epiglottis 48.

As seen in Fig. 1G, the guide 20 extends forward, preserving continuous tactile contact with the epiglottis 48, until the tip 28 senses the first trough of the trachea 44.

As seen in Figs. 1H and 1I, the guide 20 extends further forward until the tip 28 senses the second trough of the trachea 44.

As seen in Figs. 1J and 1K, the guide 20 extends further forward until the tip 28 senses the trough of the third cartilage of the trachea 44. Then the guide 20 further extends, typically for adults by 5 centimeters, to ensure that the tube 16 reaches to the third cartilage.

As seen in Fig. 1L, the guide driver 15 is pulled out with the guide 20 leaving the mouthpiece 16 and the tube 18 inside the patient's mouth and trachea 44.

Reference is now made to Figs. 2A to 2F, which, taken together, are a flowchart of the process of the intubation of a human shown in Figs. 1A to 1K.

Fig. 2A and 2B, taken together, correspond to the step of the intubation process shown in Fig. 1A.

In step 100 of Fig. 2A the intubator assembly 12 is set to perform intubation.

In step 102 the intubator loads an intubation pattern map 10 from its memory.

In steps 104, 106 and 108 the intubator enables the operator to set the scale of the intubation pattern map to the corresponding size of the patient by selecting between an infant, a child and an adult.

In steps 110, 112 and 114 the intubator enables the operator to adapt the intubation pattern map 10 to a type of intubation impediment, preferably by selecting from a menu. As seen in Fig. 2A the menu typically provides the operator with four optional impediments: an infection, a swelling, a tumor and an injury, and a fifth option not to select any impediment. It is appreciated that various types of impediments can be defined as is typical for a specific organ.

As seen in Fig. 2B, steps 120, 122, 124, 126, 128 and 130 cause the guide 20 to extend in the direction of the throat and simultaneously bend clockwise until the tip sensor is depressed against the surface of the tongue or until extension and bending limits are reached. As seen in step 128, the bending limit is preferably 50 degrees and the extension limit is preferably 2 centimeters. If the tip sensor is depressed, the scale of the intubation pattern map 10 is preferably updated (step 132) to match the particular scale or size of the intubated patient. If at least one of the extension limit and the bending limit is reached an error message is displayed (step 134) and the intubation process is stopped.

Reference is now made to Fig. 2C, which corresponds to Figs. 1B and 1C. As illustrated in Fig. 2C, the guide driver 15 performs sequential steps 140, 142, 144 and 146 in a loop, extending (step 140) guide 20 further into the patient's throat and along the throat surface, following the intubation pattern map 10 and keeping the tip in contact with the surface (steps 144, 146). When the output electric currents from both Hall effect sensors 38 and 40 increase, the intubator assumes (step 142) that the tip 28 has reached the end of the trough beneath the epiglottis 48. The point of engagement between the tip 28 and the body is designated in Fig. 1C by reference numeral 147. The scale of the intubation pattern map 10 is then preferably updated to match the patient's organ structure (step 148).

Reference is now made to Fig. 2D, which corresponds to Figs. 1D and 1E. As seen in Fig. 2D the guide driver 15 performs steps 150, 152 and 154 in a loop, bending the distal end of the guide 20 counterclockwise until the tip 28 touches the epiglottis 48, or until a bending limit, preferably of 45 degrees is reached (step 154) and the intubation stops (step 156). The preferred point of engagement between the tip 28 and the surface of the epiglottis is designated in Fig. 1D by reference numeral 155. After sensing an engagement between the tip 28 and the surface of the epiglottis, the guide driver 15 performs steps 158, 160, 162, and 164 in a loop, retracting the guide 20 further (step 158), and increasing the bending of the guide 20 (step 164), until the tip of the guide reaches the tip of the epiglottis 48, designated in Fig. 1E by reference numeral 165. When the tip 28 reaches the tip of the epiglottis 48, the tip 28 is released and the output electric currents from both Hall effect sensors decrease to a minimum. Preferably the intubation pattern map 10 is updated (step 166) to match the patient's organ structure.

Reference is now made to Fig. 2E, which corresponds to Figs. 1E and 1F. As seen in Fig. 2E, the guide driver 15 causes the guide 20 to move above and around the tip of the epiglottis 48 by causing the guide 20 to bend counterclockwise, preferably by 45 degrees, then to move forward down the throat by 5 millimeters and then to bend clockwise, preferably by 10 degrees (Step 170). Then the guide driver 15 performs steps 172, 174 and 176 in a loop, bending and extending (step 174) until the tip 28 of the guide touches the upper surface of the epiglottis 48 or until an extension limit, preferably of 1 centimeter, or a bending limit, preferably of 50 degrees, is reached, and the intubation is stopped (step 178). A preferred point of engagement between the tip28 and the epiglottis is designated in Fig. 1F by reference numeral 177.

Reference is now made to Fig. 2F, which corresponds to Figs. 1G to 1K. As seen in Fig. 2F, a "cartilage crest counter N" is first zeroed (step 180). Then the guide driver 15, performing steps 182 to 198 in a loop, causes the guide 20 to move the sensor tip 11 forward (step 182) along the surface of the trachea 44, preserving contact between the tip 28 and the surface of the trachea (steps 186 and 188) by increasing the bend (step 188) as needed. Each time a crest (189 in Figs. 1H, 1I, 1J) of a cartilage of the trachea 44 is located the "cartilage crest counter" is incremented (step 190), the tip 28 is moved about the crest (steps 192, 194, 196 and 198) and the loop process repeats until the third cartilage is located. Then the guide 20 further extends, typically for adults by 5 centimeters, to ensure that the tube 16 reaches to the third cartilage. The guide driver 15 then signals to the operator that the insertion is completed successfully (step 200).

Reference is now made to Fig. 3, which is a simplified illustration of the internal structure of a preferred embodiment of the present invention useful for intubation of a human. The intubator assembly 12 preferably comprises the housing 14, the guide driver 15, the mouthpiece 16, the tube 18, the flexible guide 20 inserted inside the tube 18 and the tip sensor 11 mounted at the distal end of the guide 20. Preferably the mouthpiece comprises a curved pipe 24.

Preferably, the guide driver 15 comprises a first motor 210 that drives a gearbox 212 that rotates a threaded rod 214. A floating nut 216 is mounted on the threaded rod 214. As the motor 210 rotates the threaded rod 214, the floating nut 216 is moved forward or backward according to the direction of the rotation. The floating nut 216 is operative to move a carriage 218 along a bar 220 and thus to push or pull the guide 20. When the carriage 218 touches a stopper 222 the stopper 222 moves with the carriage 218 along the bar 220 and pushes the tube 18 forward.

A second motor 224 is connected to a disk 226 to which two guide angulation wires 228 are attached at first end thereof. The guide angulation wires 228 are threaded inside the guide 20 and their other ends are connected to the distal end of the guide just short of the tip sensor 11. When the motor 224 rotates the disk 226 clockwise one of the wires 228 is pulled and the second wire is loosened. The wire that is pulled pulls and bends the distal end of the guide 20 counterclockwise in the sense of Fig. 3. Accordingly, when the motor 224 rotates counter-clockwise the second wire of the two wires 228 is pulled and the first wire is loosened. The wire that is pulled pulls and bends the distal end of the guide 20 clockwise in the sense of Fig. 3.

Electronic circuitry 229 is provided within the housing 14 and is preferably electrically connected to operating switches 230, a display 232, the motors 210 and 224 and to the Hall effect sensors 38 and 40 (Fig. 1A) in the tip sensor 11. Preferably, the electronic circuitry 229 also comprises a microprocessor, operative to execute a program. The program is preferably adapted to control the switches 230, the display 232, motors 210 and 224 and the Hall effect sensors 38 and 40 and to insert and bend the guide inside a living organism, according to a predefined map until the tip of the guide reaches a destination point inside the living organism. Preferably the program is operative to cause the tip 28 of the guide 20 to follow a predefined internal contour of an organ of the living organism. Preferably program is operative employ tactile sensing to measure the position of the tip of the guide relative to the surface organ of the living organism.

It is appreciated that the term "microprocessor" also includes inter alia a "microcontroller".

Electrical batteries (not shown) are preferably provided within the housing 14 to supply electric power to the electronic circuitry, the tip sensor 11, the motors 210 and 224, the display 232 and all other elements of the present invention that consume electricity. It is appreciated that external sources of electricity can also be employed to provide power to the intubator assembly 12.

Communication interface (not shown), preferably employing infra-red communication technology, is provided to enable communication with external data processing equipment.

Preferably, a balloon 234 is provided at the distal end of the tube 18 and a thin pipe (not shown) is inserted through the pipe 18 and is connected, through the side of the pipe, to the balloon. The thin pipe enables an operator to inflate the balloon when the distal end of the pipe 18 reaches the appropriate place in the trachea, thus securing the distal end of the pipe to the trachea.

Reference is now made to Fig. 4, which is a simplified functional block diagram of a preferred embodiment of the guide driver 15 described hereinabove. In Fig. 4 the guide 20 is driven by two drivers. A longitudinal driver 240 preferably comprises a motor 210, the gear 212, the threaded rod 214, the floating nut 146 and the carriage 218 of Fig. 3. A bending guide driver 242 preferably comprises the motor 224, the disk 226 and wires 228 (Fig. 3). The longitudinal driver 240 and the bending guide driver 242 are controlled by two software driver modules. A longitudinal software driver module 244 controls the longitudinal driver 240 and comprises two functions: an extend function 246 and a retract function 248. A bending software driver 250 controls the bending guide driver 242 and comprises two functions: a bend counterclockwise function 252 and a bend clockwise function 254. The functions 246, 248, 252 and 254 are operated by a propagation control software module 256.

At the other end of the guide 20, the tip sensor 11 measures the proximity and orientation of an adjacent surface. In a preferred embodiment of the present invention the tip sensor 11 performs the proximity and orientation measurements by measuring the force applied to a tactile tip by a surface of an adjacent tissue. A tip sensor software driver module 260, operative to receive input signals from the tip sensor 11, provides two input functions: a counterclockwise tip rotation function 262 and a clockwise tip rotation function 264. The measurements of the tip positions as provided by the tip sensor software driver module 260 are collected and stored by a sensor log module 266.

The map 10 is loaded into memory and serves as an updatable map 268. A comparator 270 compares the accumulated measurements from the tip sensor 11 with the updated reference map 268. The results of the comparisons are calculated by an update scale module 272 to provide a scaling factor that is applied to update the updated map 268. Consequently a navigation module 274 employs the updated map information to instruct the propagation control 256 to execute the next step of the insertion program.

It is appreciated that a measurement of the electric current drawn by at least one of the longitudinal guide drive and the bending guide drive can also serve as an input to the comparator 270 to evaluate the position of the tip sensor.

Reference is now made to Figs. 5A to 5H, which are, taken together, an electrical schematic of a preferred embodiment of the present invention useful for intubation of a human. Reference is especially made to microprocessor 278, which is preferably operative to operate a program to control the elements of the intubator assembly 12, such as the operating switches 230, the display 232, the motors 210 and 224 (Fig. 3), and the Hall effect sensors 38 and 40 in the tip sensor 11 (Fig. 1A), and to perform the intubation process, such as the process shown and described hereinabove with reference to Figs. 2A to 2F.

Reference is now made to Figs. 6A to 6K, which are a series of simplified pictorial illustrations of ten typical steps in a process of employing a preferred embodiment of the present invention useful for insertion of an element into the intestine of a human.

It is appreciated that some of the organ systems of a living organism are generally similar up to a scale factor, such as the mouth and trachea system. Other organs, such as the intestine system, are generally different from one human body to the other. Therefore, in order to employ the present invention to insert a medical device or apply a medicine to a specific location within a generally variable organ, a map of the organ, at least from the entry point and until the required location, is prepared before the insertion process is activated. The required map is preferably prepared by employing an appropriate medical imaging system, such as an ultrasound scanner, an X-ray imager, a CAT scan system or a MRI system. The map can be a two dimensional map or a three-dimensional map as appropriate for the specific organ. Typically for the intestine system a three dimensional map is required.

It is appreciated that an inserter according to a preferred embodiment of the present invention for use in organs that are variable in three dimensions is similar to the intubator assembly 12, preferably with the following modifications:

(1) The tube 18 may be replaced with a different insertable device;

(2) An additional guide bending system employing elements similar to motor 222, disk 224 and wires 226 is added and mounted perpendicularly to the first system of motor 222, disk 224 and wires 26, so that it is possible to bend the end of the guide in three dimensions. It is appreciated that three-dimensional manipulation is possible also by employing three or more motors; and

(3) The tip sensor 11 preferably comprises four Hall effect sensors to sense the motion of the tip 28 in three dimensions. It is appreciated that it is possible to operate the tip sensor in a three-dimensional space also by employing three Hall effect sensors. It is also appreciated that other types of sensors can be employed to measure the proximity and orientation of an adjacent surface in three dimensions.

In a preferred embodiment of the present invention, when the guide 20 performs longitudinal motion, such as insertion or retraction, the guide 20 also performs a small and relatively fast lateral motion. The combined longitudinal and lateral motions are useful for sensing the surface of the organ in three dimensions and hence to better determine the location of the tip sensor 11 in the organ and relative to the map 10.

Due to limitations of the graphical representation, a two-dimensional imaging and map is shown in Figs. 6A to 6K.

As seen in Fig. 6A, a human organ, the intestine in this example, is imaged, typically by a CAT scan system 280, and an image 282 of the internal structure of the organ is produced.

In Fig. 6B the image 282 of the organ is used to create an insertion map 284. Typically the image 282 is displayed on a computer screen (not shown) and a pointing device, such as a computer mouse or a light pen, is used to draw a preferred path 286 that the tip of the guide is to follow. The path is typically drawn by marking a contour of the organ, and optionally marking the guide bending points, as is shown and described with reference to Figs. 1A to 1 K. Alternatively, a preferred path is created, such as path 286, not necessarily continuously following the contours of the organ. As a further alternative, the map 10 or the path 286 is converted into a set of insertion steps as is shown and described hereinbelow with reference to Fig. 7.

Reference is now made to Fig. 7 together with Fig. 8 and with Figs. 6C to 6K. As shown in Fig. 7, a table 290 is provided for storage in a computer memory and for processing by a computer processor. The table 290 contains rows 292, wherein each row 292, preferably comprises an instruction to perform one step in the process of insertion of a medical insertion device into a living organism such as shown and described with reference to Figs. 6C to 6K. Preferably each row 292 contains the expected values or the maximal values for the extension of an insertion guide such as guide 20, the bending of the insertion guide and the electrical outputs from the Hall effect sensors 38 and 40 (Fig. 1A). In a preferred embodiment of the present invention the row 292 contains five sets of values:

(a) Initial bend 294 contains two values for bending the guide from a straight position, in two perpendicular planes.

(b) Initial insertion 295 contains a longitudinal value for extending or retracting the guide in centimeters.

(c) Initial sensor measurements 296 contains expected output values of four sensors such as four Hall effect sensors, for example, Hall effect sensors 38 and 40 of Fig. 1A. The initial sensors measurements 296 are expected to be measured by the time the guide reaches the value of the initial insertion 295.

(d) Insert distance 297 contains a longitudinal value for further extending or retracting the guide in centimeters. Typically the initial sensor measurements 296 are expected to be preserved, while the guide is extended or retracted, by adapting the bending of the guide.

(e) Final sensor measurements 298 contain expected output values of the four sensors of step (c). The initial sensor measurements 298 are expected to be measured by the time the guide reaches the value of the insert distance 297.

It is appreciated that the path drawn in Fig. 6B can be employed to prepare a table of instructions, such as table 290 of Fig. 7.

Referring to Fig. 8, which is a flowchart illustrating a preferred implementation of the present invention, operative for a process of insertion of an element into the intestine of a human as shown in Figs. 6A to 6K. The flowchart of Fig. 8 is a preferred embodiment of a program, operative to be executed by a processor, such as microprocessor 278 of Fig. 5A, comprised in a preferred embodiment of the present invention, for insertion of an element into a living organism, preferably by employing a table 290 shown and described with reference to Fig. 7.

The preferred flowchart shown in Fig. 8 starts by loading the table (step 300) such as the map shown in Fig. 7. The program then reads a first row 292 from the map (step 302) and causes the distal end of the guide 20 to bend according to the initial bending values 294. Then the program causes the guide 20 to extend or retract according to the initial insertion distance 295 of the first row in the map. The program continues to bend and insert the guide 20 until output values of the sensors match the expected initial sensor measurement 296 of the row (steps 304, 306 and 308), or until a limit is surpassed, an error message is displayed and the program is stopped (step 310).

Preferably, the initial values of the sensors are measured and then the program continues to extend or retract the guide 20 (step 312) until the sensors produce the final sensors measurements 298 values (step 314), while keeping in contact with the surface (steps 316 and 318) or until at least one of predefined limits is surpassed (step 320) where the program is stopped (step 310). If the final sensor measurements 298 values are measured the program proceeds to step 320 and loops through steps 302 and 320 until all the rows 292 of the table are processed. Then the program displays an insertion success message on the display 232 and halts (step 322).

As indicated by row No. 1 of Fig. 7 and Fig. 6C the guide is bent, preferably by up to 45 degrees, to the left in the plane of Fig. 6C and, while preserving contact with the left side of the intestine, is extended up to 5 centimeters or until the sensor tip engages the internal surface of the intestine head on at a point in the map 284 designated by reference numeral 330.

As indicated by row No.2 of Fig. 7 and Fig. 6D the guide is bent by up to 45 degrees to the right in the plane of Fig. 6D and, while preserving contact with the left side of the intestine, is extended up to 2.5 centimeters or until the sensor tip does not sense the internal surface of the intestine at a point in the map 284 designated by reference numeral 332.

As indicated by row No.3 of Fig. 7 and Fig. 6E the guide is bent by up to 110 degrees to the left in the plane of Fig. 6E and, while preserving contact with the left side of the intestine, is extended by 1 centimeter to a point in the map 284 designated by reference numeral 334.

In accordance with row 4 of Fig. 7 and Fig. 6F the guide is bent by up to 45 degrees to the right in the plane of Fig. 6F and is extended by 6 centimeter to a point in the map 284 designated by reference numeral 336.

As indicated by row No.5 of Fig. 7 and Fig. 6G the guide is bent by up to 20 degrees to the right in the plane of Fig. 5G and, while preserving contact with the right side of the intestine, is extended by 4 centimeters to a point in the map 284 designated by reference numeral 338.

As indicated by row No.6 of Fig. 7 and Fig. 6H the guide is bent by up to -60 degrees to the left in the plane of Fig. 6H and is extended by up to 3 centimeters or until the sensor tip engages the internal surface of the intestine head on at a point in the map 284 designated by reference numeral 340.

As indicated by row No.7 of Fig. 7 and Fig. 6I the guide is bent by up to 45 degrees to the right in the plane of Fig. 6I and is extended by up to 1 centimeter or until the sensor tip engages the internal surface of the intestine with its right side in a point in the map 284 designated by reference numeral 342.

As indicated by row No.8 of Fig. 7 and Fig. 6J the guide is extended by up to 1 centimeters or until the sensor tip engages the internal surface of the intestine with its left side at a point in the map 284 designated by reference numeral 344.

As indicated by row No.9 of Fig. 7 and Fig. 6K the guide is bent by up to 45 degrees to the right in the plane of Fig. 6K and is extended by up to 1 centimeter or until the sensor tip engages the internal surface of the intestine head on at a point in the map 284 designated by reference numeral 346.

In a preferred embodiment of the present invention the system and the method are operative for automatic operation. Alternatively the present invention can be operated manually, by providing to the operator the information collected by the sensor log 266 form the tip sensor 11 and enabling the operator to control manually the guide 20. In another alternative part of the procedure is performed automatically and another part is performed manually. For example, the guide 20 may be inserted automatically and a medical device, such as the tube 18 may be inserted manually.

It is appreciated that a log of the process of insertion of an insertable element into a living organism such as a human body is preferably stored in an internal memory of the present invention and that this log can be transmitted to a host computer. It is appreciated that the host computer can aggregate insertion process logs and thereby continuously improve relevant insertion pattern maps such as the standard contour map 10. Thereafter, from time to time or before starting an insertion process, the present invention is capable of loading an updated map such as standard contour map 10.

It is also appreciated that the accumulated logs of processes of insertions cab be employed to improve the algorithm for processing the maps, such as the algorithms shown and described with reference to Figs. 2A – 2F and Fig. 8. The improved algorithm can be transmitted to the present invention as necessary.

Appendices 1 to 3 are software listings of the following computer files:

Appendix 1: containing file intumed.asm.

Appendix 2: containing file c8cdr.inc.

Appendix 3: containing file ram.inc.

The method for providing the software functionality of the microprocessor 278, in accordance with a preferred embodiment of the present invention includes, the following steps:

1. Provide an Intel compatible computer with a Pentium II CPU or higher, 128MB RAM, a Super VGA monitor and an available serial port.
2. Install Microsoft Windows 95 or Microsoft Windows 98 Operating System.
3. Install the Testpoint Development kit version 40 available from Capital Equipment Corporation, 900 Middlesex Turnpike, Building 2, Billereca, MA 0821, USA.
4. Connect a flash processor loading device COP8EM Flash, COP8 In Circuit Emulator for Flash Based Families to the serial port of the Intel compatible computer. The COP8EM

flash processor loading device is available from National Semiconductors Corp. 2900 Semiconductor Dr., P.O.Box 58090, Santa Clara, CA 95052-8090, USA

5. Place a COP8CDR9HVA8 microcontroller available from National Semiconductors Corp., 2900 Semiconductor Dr., P.O.Box 58090, Santa Clara, CA 95052-8090, USA in the COP8EM Flash.

6. Copy the files intumed.asm, c8cdr.inc, and ram.inc, respectively labeled Appendix 1, Appendix 2 and Appendix 3 to a temporary directory.

7. Load the file intumed.asm by using the operating software available with the COP8EM Flash device from National Semiconductors.

8. To run the intumed.asm; Install the COP8CDR9HVA8 microcontroller in its socket in the electrical circuit, which detailed electronic schematics are provided in Figs. 5A to 5H, where the microcontroller is designated by reference numeral 278.

It is appreciated that the software components of the present invention may, if desired, be implemented in ROM (read-only memory) form. The software components may, generally, be implemented in hardware, if desired, using conventional techniques.

It is appreciated that the particular embodiment implemented by the Appendix is intended only to provide an extremely detailed disclosure of the present invention and is not intended to be limiting.

It is appreciated that various features of the invention which are, for clarity, described in the contexts of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment may also be provided separately or in any suitable subcombination.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove as well as variations and modifications which would occur to persons skilled in the art upon reading the specification and which are not in the prior art.

Appendices 1 through 3 are as follows:

Appendix 1

```
; Files:   intumed.asm, ram.inc and c8cdr.inc.

#UPPERCASE
        ; verify
        .TITLE  intumed
        .LIST   0ff     ;complete listing.    ; X'040
        .CONTRL 3              ; 0- disable all code alteration, 3- re-enable code alteration.

        .incld c8cdr.inc   ; File that include all the definitions of cop8cdr.
        .incld ram.inc     ; File that include all the variables, constants, registers and
                           ; bits definitions.

;----------------CONFIGURATION----------------------
.sect option,conf

        .db 01    ; 5=0 security dis, 2=0 wdog dis, 1=0 halt dis, 0=1 flex.
                  ; flex=1 -execution following reset will be from flash memory.
                  ; flex=0 -flash memory is erased. execution following reset will be from
                  ;        boot rom with the mictowire plus isp routines.

;--------------------------------------------
.sect begin_rst,rom,abs=0
reset: rpnd

;------------ Clear memory -------------------
        ld s,#0        ; Clean segment0 0-6fH.
        ld b,#0        ;
        ld a,#06f          ; Cleans the memory between
st00:   ld [b+],#0     ; b to a
        ifgt a,b       ;
        jmp st00       ;

        LD SP,#01e    ; Stack Pointer in Memory 1eH. The stack works in LIFO (last
        ld 01e,#0ff ; in first out) with "push a" and "pop a" instructions.
        ld 01f,#0ff ;  The stack starts from 1eH until 0H.

        ld s,#1        ; Clean s1 0-7fH.
        ld b,#0        ;
        ld a,#07f          ; Cleans the memory between
st01:   ld [b+],#0     ; b to a
        ifgt a,b       ;
        jmp st01     ;

        ld s,#2      ; Clean s2 0-7fh.
        ld b,#0      ;
        ld a,#07f       ; Cleans the memory between
st02:   ld [b+],#0   ; b to a
        ifgt a,b     ;
        jmp st02     ;


        ld 05c,#'E'  ; when the pc send moving command, the cop8 transmit packets of

        ld 05d,#'D'  ; information every 160 msec. in every packet We have 10 blockes of
                     ; 9 bytes in s1 and 10 in s2. At the end of the packet there is 1
                     ; byte of check sum and then the 2 bytes of 'E','D' to signal
                     ; end of transmition.
        ld s,#0
; ---   port    definitions ---     see ram.inc for bits definitions.
        ld pgc,#033; clkdly enabled   ; g2=t1b=cha2,g3=t1a=cha1 - inputs
        ld pg,#0     ; sk idle phase=0
        ld plc,#057
        ld pl,#0af
        ld pbc,#010; b0-3 = a2d(in), b5-7 = limit switches(in)
        ld pb,#0f0
        ld pac,#0ff
        ld pa,#03

; ----- UART initialization -------------
        ld enu,#0           ; no parity, 8 bit data
        ld enur,#0
        ld enui,#022        ; 1 stop bit, Asynch. mode,psr+baud clock
                     ; enable receive int.,disable trans. int.
        ld baud,#4      ; 38400 baud rate.
        ld psr,#060     ; 10MHz*2 /(16*(4+1)*6.5)

; ----- LCD initialization -------------
        jsr init_lcd
        ld temp,#low(wordmm); type in line 1 of lcd "   mm   ", in the left side there is
        jsr type_string0   ; space for 3 digits of mm, and in the right side 3 spaces for
                     ; direction (+/-  up/down) and 2 digits of movement.
        ld temp,#low(wordpoweron)
        jsr type_string1

; ----- PWM,T0,interupts initialization  -----------
```

```
          ld cntrl,#080     ; timer 1 - pwm mode - stopped.
          ld a,#0ff        ; timer 1 would be used in capture mode, meaning that pulse
          x a,tmr1lo       ; received from linear motor will capture the value of timer1
          ld a,#0ff        ; in timer 1 auto reload A (t1rahi/lo) and pulse from angular
          x a,tmr1hi       ; motor in B (t1rbhi/lo).

          ld t2cntrl,#0a0; timer 2 - pwm toggle mode stopped.
          ld t3cntrl,#0a0; timer 3 - pwm toggle mode stopped.
          sbit t2a,pl      ; enable linear motor and lock it by putting 0 in control1,2.
          sbit t3a,pl      ; enable angular motor and lock it by putting 0 in control3,4.

          sbit t2hs,hstcr
          sbit t3hs,hstcr
          ld cntrl,#060     ; timer 1 - capture mode.

          rbit t1pndb,icntrl
          sbit t1enb,icntrl  ; timer 1 - capture mode, t2enB=1
          rbit t1pnda,psw
          sbit t1ena,psw     ; timer 1 - capture mode, t2enA=1
          sbit itsel0,itmr; 8,192 inst. cycles - 4,096 m. sec timer 0 interrupts.
          rbit t0pnd,icntrl
          sbit t0en,icntrl; start timer0.

; ----- Program initialization -----------

          sbit 7,pls_y1       ; pls_y=08000H
                        ; over 80 is positive angle and under 80 is negative angel.
          ld data_cntr,#21
          sbit stop2,aflags
;         sbit direction,lflags
          sbit stop1,lflags
          sbit en_calc,lflags
          ld pls_x1,#068
          sbit limits_c_en,limits_flags
          sbit home_command,buttons_flags
          sbit gie,psw        ; enable interupts.
          jmp main

;*************************************************
.sect pc_module,rom
main: ifbit limits_c_en,limits_flags
          jsr limits_check

          ifbit start_stop,buttons_flags
          jsr autorun_states
```

```
        ifbit stop_command,buttons_flags
        jsr stop_operation

        ifbit buttons_t_en,buttons_flags
        jsr buttons_test

        ifbit home_command,buttons_flags
        jsr home_p_states
        ifbit self_t_command,buttons_flags
        jmp self_t_states

main0:  jmp linear_states       ; linear_states + angular_states.

main1:  jsr updatelcd

        ifbit a2den,flags2      ; a2d check.
        jsr a2d00

        ld a,#0
        add a,linear_stat
        add a,ang_stat
        add a,autorun_stat
        add a,selft_stat
        add a,home_stat
        ifeq a,#0
        sbit enddata,flags1         ; if 2 motors are stopped, set enddata bit to stop transmitting
to PC.
        ld a,buttons_flags
        and a,#09e          ; if one of the commands flags is set, reset enddata bit.
        ifgt a,#0
        rbit enddata,flags1
        ifbit enddata,flags1
        rbit start,flags1
        ifbit fix_t_en,flags2
        jsr data_send

        jmp main
;*************************************************
.sect autorun_select,rom,inpage
autorun_states:ld a,autorun_stat
        add a,#low(jmp_a_r_stat)
        jid             ; jmp pcu,[a]
```

```
jmp_a_r_stat: .addr
a_r0,a_r1,a_r2,a_r3,a_r4,a_r5,a_r6,a_r7,a_r8,a_r9,a_r10,a_r11,a_r12;,a_r13,a_r14

a_r0: jmp a_r_stat0
a_r1: jmp a_r_stat1
a_r2: jmp a_r_stat2
a_r3: jmp a_r_stat3
a_r4: jmp a_r_stat4
a_r5: jmp a_r_stat5
a_r6: jmp a_r_stat6
a_r7: jmp a_r_stat7
a_r8: jmp a_r_stat8
a_r9: jmp a_r_stat9
a_r10:   jmp a_r_stat10
a_r11:   jmp a_r_stat11
a_r12:   jmp a_r_stat12
;a_r13:  jmp a_r_stat13
;a_r14:  jmp a_r_stat14

end_a_r_stat:ret
;************************************
.sect autorun,rom
a_r_stat0:ld autorun_stat,#1
       ld home_stat,#0
       sbit home_command,buttons_flags

a_r_stat1:ifbit home_command,buttons_flags
       ret

       ld linear_stat,#1   ; move linear forwards 1mm.
       ld rbyte1,#08       ; 0,1,2=0= speed1    ; 3=1= direction forwards  ; 4=0= linear motor.
       ld rbyte2,#136
       ld rbyte3,#0        ; 1mm*136pulse per mm = 136 pulses.
       ld autorun_stat,#2
       ld temp,#low(wordautorun)
       jsr type_string1

a_r_stat1_1:rbit limits_c_en,limits_flags
       rbit stop1,lflags
       rbit stuck,flags1
a_r_stat1_2:sbit fix_t_en,flags2
       jmp end_a_r_stat

a_r_stat2:ifeq linear_stat,#0   ; wait until linear motor complete mission.
       jmp a_r_stat2_0
```

```
        jmp end_a_r_stat

a_r_stat2_0:ld a,hall1
        x a,zero_h1
        ld a,hall2
        x a,zero_h2
        rbit home,flags1
        ld ang_stat,#1 ; move angular down 2000 pulses.
        ld rbyte1,#010    ; 0,1,2=0= speed1    ; 3=0= direction down  ; 4=1= angular motor.
        ld rbyte2,#low(2000)
        ld rbyte3,#high(2000)
        rbit stop2,aflags
        ld autorun_stat,#3
        rbit stuck,flags1
        jmp a_r_stat1_2

a_r_stat3:ld linear_stat,#1 ; move linear forwards 40mm.
        ld rbyte1,#08      ; 0,1,2=0= speed1    ; 3=1= direction forwards ; 4=0= linear motor.
        ld rbyte2,#low(5440)
        ld rbyte3,#high(5440)  ; 40mm*136pulse per mm = 5440.
        ld autorun_stat,#4
        jmp a_r_stat1_1

a_r_stat4:jsr epi_check      ; check if epiglotis sensed.
        ifbit epi,flags1
        jmp a_r_stat4_0
        ifeq linear_stat,#0    ; wait until linear motor complete mission.
        jmp a_r_stat7_0
        jmp end_a_r_stat

a_r_stat4_0:ld linear_stat,#1  ; move linear backwards 6mm.
        ld rbyte1,#0        ; 0,1,2=0= speed1    ; 3=0= direction backwards   ; 4=0= linear
motor.
        ld rbyte2,#low(816)
        ld rbyte3,#high(816); 6mm*136pulse per mm = 816.
        ld autorun_stat,#5
        jmp a_r_stat1_1

a_r_stat5:ifeq linear_stat,#0   ; wait until linear motor complete mission.
        jmp a_r_stat5_0
        jmp end_a_r_stat

a_r_stat5_0:ld ang_stat,#1; move angular up 70 pulses.
        ld rbyte1,#018     ; 0,1,2=0= speed1    ; 3=1= direction up  ; 4=1= angular motor.
        ld rbyte2,#70
```

```
          ld rbyte3,#0
          ld autorun_stat,#6
          rbit stop2,aflags
          jmp a_r_stat1_2

a_r_stat6:ifeq ang_stat,#0 ; wait until angular motor complete mission.
          jmp a_r_stat6_0
          jmp end_a_r_stat

a_r_stat6_0:rbit epi,flags1
          ld linear_stat,#1   ; move linear forwards 10mm.
          ld rbyte1,#08       ; 0,1,2=0= speed1    ; 3=1= direction forwards  ; 4=0= linear motor.
          ld rbyte2,#low(1360)
          ld rbyte3,#high(1360)  ; 10mm*136pulse per mm = 1360.
          ld autorun_stat,#7
          jmp a_r_stat1_1

a_r_stat7:ifeq linear_stat,#0   ; wait until linear motor complete mission.
          jmp a_r_stat7_0
          jmp end_a_r_stat


a_r_stat7_0:ld ang_stat,#1; move angular down 2000 pulses.
          ld rbyte1,#010      ; 0,1,2=0= speed1    ; 3=0= direction down  ; 4=1= angular motor.
          ld rbyte2,#low(2000)
          ld rbyte3,#high(2000)
          ld autorun_stat,#8
          rbit stop2,aflags
          rbit stuck,flags1
          jmp a_r_stat1_2

a_r_stat8:;ld linear_stat,#1     ; move linear forwards 50mm.
          ;ld rbyte1,#08      ; 0,1,2=0= speed1    ; 3=1= direction forwards  ; 4=0= linear motor.
          ;ld rbyte2,#low(8160)
          ;ld rbyte3,#high(8160) ; 50mm*136pulse per mm = 6800.
          ld pls_cntr0,#low(6800)
          ld pls_cntr1,#high(6800)   ; 50mm*136pulse per mm = 6800.
          sbit direction,lflags  ; turn motor forwards
          rbit t2c0,t2cntrl
          sbit t2a,pl
          rbit control2,pa
          sbit control1,pa
          ld linear_stat,#6
          rbit en_calc,lflags
          ld autorun_stat,#9
```

```
        jmp a_r_stat1_1

a_r_stat9:ifeq linear_stat,#0   ; wait until linear motor complete mission.
        jmp a_r_stat9_0
        jmp end_a_r_stat


a_r_stat9_0:ld ang_stat,#1 ; move angular up 2000 pulses.
        ld rbyte1,#018     ; 0,1,2=0= speed1     ; 3=1= direction up  ; 4=1= angular motor.
        ld rbyte2,#low(2000)
        ld rbyte3,#high(2000)
        ld autorun_stat,#10
        rbit stop2,aflags
        jmp a_r_stat1_2

a_r_stat10:;ld linear_stat,#1   ; move linear forwards 70mm.
        ;ld rbyte1,#08      ; 0,1,2=0= speed1     ; 3=1= direction forwards ; 4=0= linear motor.
        ;ld rbyte2,#low(9520)
        ;ld rbyte3,#high(9520)  ; 70mm*136pulse per mm = 9520.

        ld pls_cntr0,#low(9520)
        ld pls_cntr1,#high(9520)   ; 70mm*136pulse per mm = 9520.
        sbit direction,lflags  ; turn motor forwards
        rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control2,pa
        sbit control1,pa
        ld linear_stat,#6

        ld autorun_stat,#11
        jmp a_r_stat1_1

a_r_stat11:ifeq linear_stat,#0 ; wait until linear motor complete mission.
        jmp a_r_stat11_0
        jmp end_a_r_stat


a_r_stat11_0:sbit stop2,aflags
        rbit t3c0,t3cntrl
        sbit t3a,pl
        sbit control3,pa    ; turn off motor 2
        sbit control4,pa

        ;ld linear_stat,#1  ; move linear forwards 50mm.
        ;ld rbyte1,#08      ; 0,1,2=0= speed1     ; 3=1= direction forwards  ; 4=0= linear motor.
```

```
          ;ld rbyte2,#low(6800)
          ;ld rbyte3,#high(6800)  ; 50mm*136pulse per mm = 6800.

          ld pls_cntr0,#low(6800)
          ld pls_cntr1,#high(6800)   ; 50mm*136pulse per mm = 6800.
          sbit direction,lflags  ; turn motor forwards
          rbit t2c0,t2cntrl
          sbit t2a,pl
          rbit control2,pa
          sbit control1,pa
          ld linear_stat,#6

          ld autorun_stat,#12
          jmp a_r_stat1_1

a_r_stat12:ifeq linear_stat,#0 ; wait until linear motor complete mission.
          jmp a_r_stat12_0
          jmp end_a_r_stat

a_r_stat12_0:ld autorun_stat,#0
          jsr stop2motors
          sbit en_calc,lflags
          rbit start_stop,buttons_flags
          rbit stuck,flags1
          ld temp,#low(wordinplace)
          jsr type_string1
          jmp end_a_r_stat

;************************************************
epi_check:;ld a,#4
          ;ifgt  a,pls_x1
          ;ret
          sc
          ld a,hall1
          ifgt a,zero_h1
          jmp epi_check0_1
          ld a,zero_h1
          subc a,hall1
          jmp epi_check0_2
epi_check0_1:subc a,zero_h1
epi_check0_2:ifgt a,#20
          sbit epi,flags1

          sc
          ld a,hall2
```

```
        ifgt a,zero_h2
        jmp epi_check0_3
        ld a,zero_h2
        subc a,hall2
        jmp epi_check0_4
epi_check0_3:subc a,zero_h2
epi_check0_4:ifgt a,#20
        sbit epi,flags1
        ret
;**********************************************
.sect l_s_select,rom,inpage
linear_states:ld a,linear_stat
        add a,#low(jmp_l_stat)
        jid             ; jmp pcu,[a]

jmp_l_stat: .addr l_s0,l_s1,l_s2,l_s3,l_s4,l_s5,l_s6

l_s0: jmp l_stat0
l_s1: jmp l_stat1
l_s2: jmp l_stat2
l_s3: jmp l_stat3
l_s4: jmp l_stat4
l_s5: jmp l_stat5
l_s6: jmp l_stat6

end_l_stat:jmp angular_states
;*********************************
.sect linear_states,rom

l_stat0:  ifbit pulse,lflags
        jmp l_stat0_01        ; the motor made another pulse after stop order.
        jmp e_l_stat0

l_stat0_01:rbit pulse,lflags

        ifbit direction,lflags ; x update
        jmp l_stat0_03         ; x forwards

        ld a,pls_x1     ; before decreasing pls_x, check if pls_x>1
        ifne a,#0
        jmp l_stat0_02
;       ld a,pls_x0
;       ifgt a,#0
;       jmp l_stat0_02
        ifeq pls_x0,#0
        jmp e_l_stat0       ; do not decrease pls_x if 0.

l_stat0_02:sc
        ld a,pls_x0         ; x downwards
        subc a,#1
        x a,pls_x0
        ld a,pls_x1
        subc a,#0
        x a,pls_x1
        jmp e_l_stat0

l_stat0_03:rc                  ; x forwards
        ld a,pls_x0
        adc a,#1
        x a,pls_x0
        ld a,pls_x1
        adc a,#0
        x a,pls_x1

e_l_stat0:jmp end_l_stat       ; ->O

;*******************************************
l_stat1:  ifbit direction,lflags ; check the previous direction.
        jmp l_stat1_02

                          ; the direction was backwards.
        ifbit new_direction,rbyte1 ; check the new direction.
        jmp l_stat1_01
        jmp l_stat3

l_stat1_01:ld nxt_l_stat,#4       ; change direction to forwards.
        jmp l_stat1_05

                          ; the direction was forwards.
l_stat1_02:ifbit new_direction,rbyte1  ; check the new direction.
        jmp l_stat4

        ld a,pls_x1         ; before changing diretion to backwards
        ifne a,#0           ; check if pls_x=0.
        jmp l_stat1_04            ; if not then...
        ld a,pls_x0
        ifne a,#0
        jmp l_stat1_04

l_stat1_03:ld linear_stat,#0       ; if 0 then just stop motor.
```

```
        sbit stop1,lflags       ; stop motor 1.
        rbit stop,flags1
        sbit limits_c_en,limits_flags
        sc
        ifbit stop2,aflags
        rc
        ifc
        jmp l_stat1_06
        rbit start,flags1
        sbit end,flags1
        sbit type_end,lcd_flags
        jmp l_stat1_06

l_stat1_04:ld nxt_l_stat,#3         ; stop motor, wait and then
                            ; change direction to backwards.
l_stat1_05:ld linear_stat,#2
        ld cd_dly,#020
l_stat1_06:rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control1,pa        ; stop motor 1.
        rbit control2,pa
        jmp end_l_stat          ; ->O
;*****************************************************************
l_stat2:  ifeq cd_dly,#0          ; delay before changing direction.
        jmp l_stat2_01
        jmp end_l_stat          ; ->O
l_stat2_01:ld a,nxt_l_stat
        x a,linear_stat
        jmp end_l_stat          ; ->O

l_stat3:  ld a,pls_x1           ; the direction is still backwards.
        ifne a,#0             ; check if pls_x=0
        jmp l_stat3_01            ; if not then...
        ld a,pls_x0
        ifne a,#0
        jmp l_stat3_01
        jmp l_stat1_03            ; if 0 then just stop motor and
                            ; return to linear stat 0.

l_stat3_01:ifbit home_limit,pbi
        jmp l_stat3_02
        jmp l_stat1_03
l_stat3_02:rbit direction,lflags   ; turn motor backwards.
        rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control1,pa
        sbit control2,pa
        rbit t2a,pl
        jmp l_stat4_02

l_stat4:  ;ld a,pls_x1          ; 255mm*128pulsepermm=7f80H
        ;ifgt a,#0fe          ; if pls_x>7f00H then stop motor1.
        ;jmp l_stat1_03
        ifbit bottom_limit,pbi
        jmp l_stat4_01
        jmp l_stat1_03
;       ld linear_stat,#0
;       sbit stop1,lflags
;       jmp end_l_stat

l_stat4_01:sbit direction,lflags   ; turn motor forwards
        rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control2,pa
        sbit control1,pa
        rbit t2a,pl
l_stat4_02:ld a,rbyte2          ; distanse update
        x a,pls_cntr0
        ld a,rbyte3
        x a,pls_cntr1
        ld a,rbyte1          ; velosity update
        and a,#7
        ifne a,#0
        jmp l_stat4_03
        ld t_ref0,#low(1000)    ; 1000 -> 500u per pulse
        ld t_ref1,#high(1000)
        jmp end_l_stat4
l_stat4_03:ifne a,#1
        jmp l_stat4_04
        ld t_ref0,#low(2000)    ; 2000 -> 1000u per pulse
        ld t_ref1,#high(2000)
        jmp end_l_stat4
l_stat4_04:ifne a,#2
        jmp l_stat4_05
        ld t_ref0,#low(3000)    ; 3000 -> 1500u per pulse
        ld t_ref1,#high(3000)
        jmp end_l_stat4
l_stat4_05:ifne a,#3
        jmp end_l_stat4
        ld t_ref0,#low(4000)    ; 4000 -> 2000u per pulse
        ld t_ref1,#high(4000)

end_l_stat4:
;**************************************************
l_stat5:  ifbit t2c0,t2cntrl  ; if motor 1 is already on.
        jmp e_l_stat5

        rbit first_pulse,lflags
        rbit t2c1,t2cntrl   ; turn off the toggle output.
        rbit t2a,pl

        ld pt1hi,#020
        ld pt2hi,#080

        ld tmr2lo,#0ff
        ld tmr2hi,#0ff
        ld t2ralo,#0ff
        ld t2rahi,#0ff
        ld t2rblo,#0ff
        ld t2rbhi,#0ff
        rbit t2pndb,t2cntrl
        sbit t2c0,t2cntrl   ; start timer 2 - pwm.
l_stat5_01:ifbit t2pndb,t2cntrl
        jp l_stat5_02
        jp l_stat5_01
l_stat5_02:rbit t2c0,t2cntrl     ; stop timer 2 - pwm.
        ld tmr2lo,#250           ; 250->t2.
        ld tmr2hi,#0
        ld t2ralo,#low(400)      ; 400->r2a.
        ld t2rahi,#high(400)
        ld t2rblo,#low(600)      ; 600->r2b.
        ld t2rbhi,#high(600)
        rbit t2a,pl
        sbit t2c1,t2cntrl   ; turn on the toggle output.
        sbit t2c0,t2cntrl   ; start timer 2 - pwm.
;       rbit stop1,lflags
e_l_stat5:ld a,int_cntr
        sc
        subc a,#20
        x a,nolpulsetmr
        sbit limits_c_en,limits_flags
        ld linear_stat,#6
        ld nxt_l_stat,#0
        jmp end_l_stat    ; ->O
```

```
;*******************************************************************

l_stat6:  ifbit pulse,lflags
          jmp l_stat6_01
          ld a,nolpulsetmr
          ifne a,int_cntr
          jmp l_stat6_05
;         sbit stop1,lflags
;         sbit stuck,flags1
          jmp l_stat6_05

l_stat6_01:rbit pulse,lflags
          ld a,int_cntr
          sc
          subc a,#20
          x a,nolpulsetmr
          sbit limits_c_en,limits_flags
          sc              ; dec. pls_cntr
          ld a,pls_cntr0
          subc a,#1
          x a,pls_cntr0
          ld a,pls_cntr1
          subc  a,#0
          x a,pls_cntr1
          ld a,pls_cntr1       ; check if pls_cntr=0
          ifne a,#0
          jmp l_stat6_02
          ld a,pls_cntr0
          ifne a,#0
          jmp l_stat6_02
          sbit stop1,lflags

l_stat6_02:;ifbit first_pulse,lflags
          sbit en_calc,lflags
          sbit first_pulse,lflags

          ifbit direction,lflags ; x_update
          jmp l_stat6_04
          ld a,pls_x1          ; check if pls_x>1
          ifne a,#0
          jmp l_stat6_03
          ld a,pls_x0
          ifgt a,#0
          jmp l_stat6_03
;         ld pls_x0,#0
```

```
        sbit stop1,lflags
        ld nxt_l_stat,#0
        jmp l_stat6_05

l_stat6_03:sc                   ; x_downwards
        ld a,pls_x0
        subc a,#1
        x a,pls_x0
        ld a,pls_x1
        subc a,#0
        x a,pls_x1
        jmp l_stat6_05
l_stat6_04:rc                   ; x_forwards
        ld a,pls_x0
        adc a,#1
        x a,pls_x0
        ld a,pls_x1
        adc a,#0
        x a,pls_x1
        ifgt a,#086  ; the lcd can show only 256 mm (= 256*136=34816=08800H).
        sbit stop1,lflags

l_stat6_05:ifbit stop1,lflags
        jmp e_l_stat6
        ifbit en1_calc,lflags
        jsr v_calc
        jmp end_l_stat     ; ->O

e_l_stat6:rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control1,pa    ; turn off motor 2.
        rbit control2,pa
        ld a,nxt_l_stat
        x a,linear_stat
        ifbit stop2,aflags
        jmp e_l_stat6_0
        jmp end_l_stat     ; ->O
e_l_stat6_0:rbit start,flags1
        rbit stop,flags1
        ifbit self_t_command,buttons_flags
        jmp end_l_stat     ; ->O
        ifbit start_stop,buttons_flags
        jmp end_l_stat     ; ->O
        ifbit home_command,buttons_flags
        jmp end_l_stat     ; ->O

        sbit type_end,lcd_flags
        sbit end,flags1
        jmp end_l_stat     ; ->O

;*************************************************
.sect a_s_select,rom,inpage
angular_states:ld a,ang_stat
        add a,#low(jmp_a_stat)
        jid              ; jmp pcu,[a]

jmp_a_stat: .addr a_s0,a_s1,a_s2,a_s3,a_s4,a_s5,a_s6,a_s7

a_s0: jmp a_stat0
a_s1: jmp a_stat1
a_s2: jmp a_stat2
a_s3: jmp a_stat3
a_s4: jmp a_stat4
a_s5: jmp a_stat5
a_s6: jmp a_stat6
a_s7: jmp a_stat7

end_a_stat:jmp main1
;************************************
.sect angular_states,rom
a_stat0:  ifbit pulse2,aflags
        jmp a_stat0_01
        jmp e_a_stat0

a_stat0_01:rbit pulse2,aflags
        ifbit direction2,aflags   ; y update
        jmp a_stat0_02
        jmp a_stat0_03

a_stat0_02:sc                  ; y down
        ld a,pls_y0
        subc a,#1
        x a,pls_y0
        ld a,pls_y1
        subc a,#0
        x a,pls_y1
        jmp e_a_stat0

a_stat0_03:rc                  ; y up
```

```
        ld a,pls_y0
        adc a,#1
        x a,pls_y0
        ld a,pls_y1
        adc a,#0
        x a,pls_y1

e_a_stat0:jmp end_a_stat      ; ->O
;**********************************
a_stat1:

;       ld a,pls_y1          ; check if the the probe is not too high or to low.
;       ifgt a,#094
;       jmp a_stat1_00
;       ld a,#066
;       ifgt a,pls_y1
;       jmp a_stat1_01
;       jmp a_stat1_03
;a_stat1_00:ifbit new_direction,rbyte1; if too high enable only down movment.
;       jmp a_stat1_02
;       jmp a_stat1_03
;a_stat1_01:ifbit new_direction,rbyte1; if too low enable only up movment.
;       jmp a_stat1_03
;       jmp a_stat1_02
;
;a_stat1_02:ld ang_stat,#0     ; just stop motor.
;       ld nxt_a_stat,#0
;       sbit stop2,aflags       ; stop motor 2.
;       sbit type_end,flags2
;       jmp a_stat1_08
;
a_stat1_03:ifbit direction2,aflags    ; check the previous direction.
        jmp a_stat1_05

        ifbit new_direction,rbyte1 ; the direction was down-check the new direction.
        jmp a_stat1_04
        jmp a_stat3

a_stat1_04:ld nxt_a_stat,#4       ; stop motor, wait and then change direction to up.
        jmp a_stat1_07

a_stat1_05:ifbit new_direction,rbyte1  ; the direction was up-check the new direction.
        jmp a_stat4

a_stat1_06:ld nxt_a_stat,#3       ; stop motor, wait and then change direction to down.
```

```
a_stat1_07:ld ang_stat,#2      ; delay for the motor to make a complete stop.
       ld cd_dly,#17
a_stat1_08:rbit t3c0,t3cntrl
       sbit t3a,pl
       sbit control3,pa        ; stop motor 2.
       sbit control4,pa
       jmp end_a_stat          ; ->O
;*******************************************************************
a_stat2:  ifeq cd_dly,#0       ; delay before changing direction.
       jmp a_stat2_01
       jmp end_a_stat          ; ->O
a_stat2_01:ld a,nxt_a_stat
       x a,ang_stat
       jmp end_a_stat          ; ->O
;*******************************************************************
a_stat3:  rbit direction2,aflags    ; turn motor backwards.
       rbit t3c0,t3cntrl
       sbit t3a,pl
       rbit control3,pa
       sbit control4,pa
       rbit t3a,pl
       jmp a_stat4_01
;*******************************************
a_stat4:  sbit direction2,aflags    ; turn motor forwards
       rbit t3c0,t3cntrl
       sbit t3a,pl
       rbit control4,pa
       sbit control3,pa
       rbit t3a,pl
a_stat4_01:ld a,rbyte2         ; distanse update
       x a,plsy_cntr0
       ld a,rbyte3
       x a,plsy_cntr1

       ld a,rbyte1          ; velosity update
       and a,#7
       ifne a,#0
       jmp a_stat4_02
       ld at_ref0,#low(6000)   ; 6000 -> 3000u per pulse
       ld at_ref1,#high(6000)
       jmp end_a_stat4
a_stat4_02:ifne a,#1
       jmp a_stat4_03
       ld at_ref0,#low(7000)   ; 7000 -> 3500u per pulse
```

```
        ld at_ref1,#high(7000)
        jmp end_a_stat4
a_stat4_03:ifne a,#2
        jmp a_stat4_04
        ld at_ref0,#low(8000)   ; 8000 -> 4000u per pulse
        ld at_ref1,#high(8000)
        jmp end_a_stat4
a_stat4_04:ifne a,#3
        jmp end_a_stat4
        ld at_ref0,#low(9000)   ; 9000 -> 4500u per pulse
        ld at_ref1,#high(9000)

end_a_stat4:ld nxt_a_Stat,#6
;*****************************************************
a_stat5:  ;ifbit t3c0,t3cntrl ; if motor 2 is already on.
        ;jmp e_a_stat5


        ld apt1hi,#020
        ld apt2hi,#080

;       rbit firsty_pulse,aflags
        rbit t3c1,t3cntrl   ; turn off the toggle output.
        rbit t3a,pl
        ld tmr3lo,#0ff
        ld tmr3hi,#0ff
        ld t3ralo,#0ff
        ld t3rahi,#0ff
        ld t3rblo,#0ff
        ld t3rbhi,#0ff
        rbit t3pndb,t3cntrl
        sbit t3c0,t3cntrl   ; start timer 3 - pwm.
a_stat5_01:ifbit t3pndb,t3cntrl
        jp a_stat5_02
        jp a_stat5_01
a_stat5_02:rbit t3c0,t3cntrl    ; stop timer 3 - pwm.
        ld tmr3lo,#250          ; 250->t3.
        ld tmr3hi,#0
        ld t3ralo,#low(500)     ; 500->r3a.
        ld t3rahi,#high(500)
        ld t3rblo,#low(500)     ; 500->r3b.
        ld t3rbhi,#high(500)
        rbit t3a,pl
        sbit t3c1,t3cntrl   ; turn on the toggle output.
        sbit t3c0,t3cntrl   ; start timer 3 - pwm.
```

```
e_a_stat5:;ld a,int_cntr
        ;sc
        ;subc a,#50
        ;x a,noapulsetmr
        ld a,nxt_a_stat
        x a,ang_stat
        ld nxt_a_stat,#0
        jmp end_a_stat        ; ->O
;*********************************
a_stat6: ifbit pulse2,aflags
        jmp a_stat6_01

        ;ld a,noapulsetmr
        ;ifne a,int_cntr
        ;jmp a_stat6_06
        ;sbit stop2,aflags
        ;sbit stuck,flags1
        jmp a_stat6_06

a_stat6_01:rbit pulse2,aflags
        ;ld a,int_cntr
        ;sc
        ;subc a,#50
        ;x a,noapulsetmr
        sc              ; dec. plsy_cntr
        ld a,plsy_cntr0
        subc a,#1
        x a,plsy_cntr0
        ld a,plsy_cntr1
        subc  a,#0
        x a,plsy_cntr1
        ld a,plsy_cntr1          ; check if plsy_cntr=0
        ifne a,#0
        jmp a_stat6_02
        ld a,plsy_cntr0
        ifne a,#0
        jmp a_stat6_02
        sbit stop2,aflags
        ld nxt_a_stat,#0

a_stat6_02:;ifbit firsty_pulse,aflags
;       sbit en_calc2,aflags
        sbit firsty_pulse,aflags

        ifbit direction2,aflags   ; y_update
        jmp a_stat6_04
        ld a,pls_y1         ; check if pls_y>6500H
        ifgt a,#0           ; 065
        jmp a_stat6_03
        sbit stop2,aflags
        ld nxt_a_stat,#0
        jmp a_stat6_06

a_stat6_03:sc                  ; y_down
        ld a,pls_y0
        subc a,#1
        x a,pls_y0
        ld a,pls_y1
        subc a,#0
        x a,pls_y1
        jmp a_stat6_06

a_stat6_04:ld a,#0ff           ; 096
        ifgt a,pls_y1
        jmp a_stat6_05
        sbit stop2,aflags
        ld nxt_a_stat,#0
        jmp a_stat6_06

a_stat6_05:rc                  ; y_up
        ld a,pls_y0
        adc a,#1
        x a,pls_y0
        ld a,pls_y1
        adc a,#0
        x a,pls_y1

a_stat6_06:ifbit stop2,aflags
        jmp e_a_stat6
        ifbit en1_calc2,aflags
        jsr v2_calc
        jmp end_a_stat         ; ->O

e_a_stat6:
        rbit t3c0,t3cntrl
        sbit t3a,pl
        sbit control3,pa    ; turn off motor 2
        sbit control4,pa
        ld a,nxt_a_stat
        x a,ang_stat
        ifbit stop1,lflags
        jmp e_a_stat6_0
        jmp end_a_stat          ; ->O
e_a_stat6_0:rbit start,flags1
        rbit stop,flags1
        ifbit self_t_command,buttons_flags
        jmp end_a_stat          ; ->O
        ifbit start_stop,buttons_flags
        jmp end_a_stat          ; ->O
        ifbit home_command,buttons_flags
        jmp end_l_stat      ; ->O

        sbit end,flags1
        sbit type_end,lcd_flags
        ifbit stuck,flags1
        sbit type_stuck,lcd_flags
        jmp end_a_stat          ; ->O

;*************************************************
a_stat7: ifbit pulse2,aflags
        jmp a_stat7_01
        jmp e_a_stat7

a_stat7_01:rbit pulse2,aflags
        ifbit direction2,aflags   ; y update
        jmp a_stat0_03

a_stat7_02:sc                   ; y down
        ld a,pls_y0
        subc a,#1
        x a,pls_y0
        ld a,pls_y1
        subc a,#0
        x a,pls_y1
        jmp e_a_stat7

a_stat7_03:rc                   ; y up
        ld a,pls_y0
        adc a,#1
        x a,pls_y0
        ld a,pls_y1
        adc a,#0
        x a,pls_y1

e_a_stat7:jmp end_a_stat        ; ->O
```

```
;*************************************************
.sect stop_subroutines,rom
stop2motors:sbit stop1,lflags ; turn off motor 1
        rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control1,pa
        rbit control2,pa
        ld linear_stat,#0
        ld nxt_l_stat,#0
        sbit stop2,aflags  ; turn off motor 2
        rbit t3c0,t3cntrl
        sbit t3a,pl
        sbit control3,pa
        sbit control4,pa
        ld ang_stat,#0
        ld nxt_a_stat,#0
        ret
stop_operation:rbit stop_command,buttons_flags
        jsr stop2motors
        sbit en_calc,lflags
        sbit fix_t_en,flags2
        rbit enddata,flags1
        rbit start,flags1
        rbit end,flags1
        sbit stop,flags1
        sbit type_stop,lcd_flags
        rbit self_t_command,buttons_flags
        ld selft_stat,#0
        rbit start_stop,buttons_flags
        ld autorun_stat,#0
;       rbit home_command_pc,buttons_flags
        rbit home_command,buttons_flags
        ld home_stat,#0
        ret
;*************************************************
.sect s_t_select,rom,inpage
self_t_states:ld a,selft_stat
        add a,#low(jmp_st_stat)
        jid             ; jmp pcu,[a]

jmp_st_stat: .addr s_t0,s_t1,s_t2,s_t3,s_t4,s_t5,s_t6

s_t0: jmp self_test0
s_t1: jmp self_test1
s_t2: jmp self_test2
```

```
s_t3: jmp self_test3
s_t4: jmp self_test4
s_t5: jmp self_test5
s_t6: jmp self_test6

end_st_stat:jmp main0
;************************************
.sect self_test,rom
self_test0:ld temp,#low(wordselftest)
      jsr type_string1
      ifbit home_limit,pbi
      jmp self_test0_0      ; 1-micro switch open - not in home position.
      rbit home_command,buttons_flags
      ld home_stat,#0
      jmp self_test1_0      ; 0-micro switch closed - in home position.

self_test0_0:sbit home_command,buttons_flags
      ld home_stat,#0
      ld selft_stat,#1
      jmp end_st_stat

self_test1:ifbit home_command,buttons_flags
      jmp end_st_stat

self_test1_0:ld linear_stat,#1 ; move linear forwards 50mm.
      ld rbyte1,#08      ; 0,1,2=0= speed1    ; 3=1= direction forwards  ; 4=0= linear motor.
      ld rbyte2,#low(6850)
      ld rbyte3,#high(6850)  ; 50mm*136pulse per mm = 6800.
      ld selft_stat,#2
self_test1_1:rbit limits_c_en,limits_flags
      rbit stop1,lflags
self_test1_2:jmp end_st_stat

self_test2:ifeq linear_stat,#0  ; wait until linear motor complete mission.
      jmp self_test2_0
      jmp end_st_stat

self_test2_0:ld ang_stat,#1     ; move angular up 150 pulses.
      ld rbyte1,#018     ; 0,1,2=0= speed1    ; 3=1= direction up       ; 4=1= angular motor.
      ld rbyte2,#150
      ld rbyte3,#0
      ld selft_stat,#3
      rbit stop2,aflags
      sbit en_calc2,aflags
      jmp self_test1_2
```

```
self_test3:ifeq ang_stat,#0 ; wait until angular motor complete mission.
        jmp self_test3_0
        jmp end_st_stat

self_test3_0:rbit en_calc2,aflags
        ld ang_stat,#1  ; move angular down 400 pulses.
        ld rbyte1,#010     ; 0,1,2=0= speed1     ; 3=0= direction down  ; 4=1= angular motor.
        ld rbyte2,#low(300)
        ld rbyte3,#high(300)
        ld selft_stat,#4
        rbit stop2,aflags
        jmp self_test1_2


self_test4:ifeq ang_stat,#0 ; wait until angular motor complete mission.
        jmp self_test4_0
        jmp end_st_stat

self_test4_0:ld ang_stat,#1     ; move angular again up 150 pulses.
        ld rbyte1,#018     ; 0,1,2=0= speed1     ; 3=1= direction up       ; 4=1= angular motor.
        ld rbyte2,#150
        ld rbyte3,#0
        ld selft_stat,#5
        rbit stop2,aflags
        sbit en_calc2,aflags
        jmp self_test1_2

self_test5:ifeq ang_stat,#0 ; wait until angular motor complete mission.
        jmp self_test5_0
        jmp end_st_stat


self_test5_0:rbit en_calc2,aflags
        ld linear_stat,#1   ; move linear backwards 50mm.
        ld rbyte1,#0         ; 0,1,2=0= speed1     ; 3=0= direction backwards   ; 4=0= linear
motor.
        ld rbyte2,#low(6850)
        ld rbyte3,#high(6850)  ; 50mm*136pulse per mm = 6800.
        ld selft_stat,#6
        jmp self_test1_1

self_test6:ifeq linear_stat,#0  ; wait until linear motor complete mission.
        jmp self_test6_0
        jmp end_st_stat
```

```
self_test6_0:ld selft_stat,#0
        rbit self_t_command,buttons_flags
        rbit stuck,flags1
        ld temp,#low(wordready)
        jsr type_string1
        jmp end_st_stat

;*************************************************
.sect h_p_select,rom,inpage
home_p_states:ld a,home_stat
        add a,#low(jmp_h_stat)
        jid             ; jmp pcu,[a]

jmp_h_stat: .addr h_p0,h_p1

h_p0:jmp home_p0
h_p1:jmp home_p1

;***********************************************************************
**
.sect home_positioning,rom
home_p0:   ifbit home_limit,pbi ; 0-micro switch closed - in home position,
        jmp home_p0_2           ; 1-micro switch open - not in home position.
        jmp home_p1_0

home_p0_2:jsr stop2motors
        ld lcd_flags,#0
        rbit direction,lflags  ; so the bottom wouldn't shut down the motor.
        ld linear_stat,#1  ; move linear backwards 200mm.
        ld rbyte1,#0        ; 0,1,2=0= speed1    ; 3=0= direction backwards   ; 4=0= linear
motor.
        ld rbyte2,#low(27200)
        ld rbyte3,#high(27200); 200mm*136pulse per mm = 27200.
        rbit stop1,lflags
        sbit fix_t_en,flags2
        rbit start,flags1
        rbit stop,flags1
        rbit end,flags1
        rbit enddata,flags1
        ld home_stat,#1
        ifbit self_t_command,buttons_flags
        ret
        ld temp,#low(wordhome)
        jsr type_string1

home_p1:  ifeq linear_stat,#0    ; wait until linear motor complete mission.
        jmp home_p1_0
        ret


home_p1_0:ld home_stat,#0
        rbit home_command,buttons_flags
        rbit epi,flags1
;       ifbit stuck,flags1
;       jmp home_p1_1
        ld pls_x0,#0
        ld pls_x1,#0
        ld pls_y0,#0
        ld pls_y1,#080
home_p1_1:ifbit self_t_command,buttons_flags
        ret

        ifbit stuck,flags1
        ret
        ld temp,#low(wordready)
        jsr type_string1
        ret
;*************************************************
.sect limits_check,rom
limits_check:ld a,pbi        ; general limits check (limits = b5,b6,b7).
        and a,#060      ; 0e0 - if the angular limit switch is on.
        ifne a,#060
        jmp limits_check0_0
        rbit home,flags1  ; signal to the pc that we are not in home position.
        rbit bottom,flags1         ; signal to the pc that we are not in buttom position.
        ret

limits_check0_0:x a,b
        ifbit home_limit,b
        jmp limits_check1_0

        sbit home,flags1       ; signal to the pc that we are in home position.
        rbit bottom,flags1          ; signal to the pc that we are not in buttom position.
        ifbit direction,lflags
        jmp limits_check0_1
        sbit stop1,lflags       ; turn off motor 1
        rbit t2c0,t2cntrl
        sbit t2a,pl
        rbit control1,pa
        rbit control2,pa
        ld linear_stat,#0
        ifbit stop2,aflags
        rbit start,flags1
        ld temp,#low(wordready)
        jsr type_string1
limits_check0_1:
        ld pls_x1,#0
        ld pls_x0,#0
        ld pls_y0,#0
        ld pls_y1,#080
        jmp limits_check2_1

limits_check1_0:rbit home,flags1   ; signal to the pc that we are not in home position.
        ifbit bottom_limit,b
        jmp limits_check2_0
        sbit bottom,flags1         ; signal to the pc that we are in buttom position.
        ifbit direction,lflags
        jmp limits_check1_1
        jmp limits_check1_2

limits_check1_1:jsr stop2motors
        rbit start,flags1
        ld temp,#low(wordbottom)
        jsr type_string1

limits_check1_2:ld pls_x1,#066 ; to be calibrated.
        ld pls_x0,#088
        jmp limits_check2_1

limits_check2_0:rbit bottom,flags1     ; signal to the pc that we are not in buttom position.
limits_check2_1:
        ;ifbit angular_limit,b
        ret

;**************************************************

buttons_test:rbit buttons_t_en,buttons_flags
        ld a,pli
        and a,#0a0
        x a,b
        ifeq b,#0a0
        jmp b_t0_01
        jmp b_t0_03

b_t0_01:    ifeq ritut,#0     ; no key was pressed.
        jmp b_t0_02
        ld a,ritut
        dec a
        x a,ritut
b_t0_02:    ld start_stop_cntr,#0
        ld home_position_cntr,#0
        jmp end_b_test

b_t0_03:    ifeq ritut,#0     ; a key was pressed. ritut checks if it is a real press on
        jmp b_t1_00       ;    a key, or just a vibration of the key.
b_t0_04:    ld ritut,#5
;       ld start_stop_cntr,#0
;       ld home_position_cntr,#0
        jmp b_t0_02

b_t1_00:    ifbit start_stop,b
        jmp b_t2_00           ; start-stop key was not pressed.
        ifbit start_stop,buttons_flags ; start-stop key was pressed to stop operatio.
        jmp b_t1_02
        ifbit home_command,buttons_flags
        jmp b_t1_02
        ifbit self_t_command,buttons_flags
        jmp b_t1_02
        ld a,start_stop_cntr  ; start-stop key was pressed to start operation.
        inc a
        x a,start_stop_cntr
        ifgt a,#150
        jmp b_t1_01
        jmp b_t2_00
        ;--------------- start/stop  autorun key was pressed ------------------
b_t1_01:    ifbit start_stop,buttons_flags
        jmp b_t1_02
        sbit start_stop,buttons_flags  ; start button was pressed to start operation.
        ld autorun_stat,#0
        jmp b_t0_04

b_t1_02:    sbit stop_command,buttons_flags; start button was pressed again to stop
operation.
        rbit start_stop,buttons_flags
        ld autorun_stat,#0
        jmp b_t0_04
```

```
b_t2_00:    ifbit home_position,b
        jmp end_b_test
        ld a,home_position_cntr
        inc a
        x a,home_position_cntr
        ifgt a,#150
        jmp b_t2_01
        jmp end_b_test
        ;--------------- home positon/self test  key was pressed ------------------
b_t2_01:    ifbit home_limit,pbi      ; 0-micro switch closed - in home position,
        jmp b_t2_03
b_t2_02:    rbit home_command,buttons_flags ; not in home position - go to home position.
        sbit self_t_command,buttons_flags
        ld selft_stat,#0
        sbit fix_t_en,flags2
        ld data_cntr,#21
        ld save_ptr,#0
        ld send_ptr,#0
        rbit enddata,flags1
        rbit start,flags1
        rbit end,flags1
        rbit stop,flags1
        jmp b_t0_04

b_t2_03:    ld a,pls_x0
        ifgt a,#0
        jmp b_t2_04
        ifeq pls_x1,#0
        jmp b_t2_02
b_t2_04:    sbit home_command,buttons_flags ; not in home position - go to home position.
        ld home_stat,#0
        sbit fix_t_en,flags2
        ld data_cntr,#21
        ld save_ptr,#0
        ld send_ptr,#0
        rbit enddata,flags1
        rbit start,flags1
        rbit end,flags1
        rbit stop,flags1
        jmp b_t0_04

end_b_test:ret
;***************************************************
.sect interups,rom,abs=0ff ;interrupts address
        push a
        ld a,s
        push a
        ld a,b
        push a
        ld a,x
        push a
        ld a,psw
        push a
        ld s,#0
        vis

end_intr:    rc
        rbit hc,psw
        pop a
        and a,#0c0      ;save only c and hc
        or a,psw
        x a,psw

        pop a
        x a,x
        pop a
        x a,b
        pop a
        x a,s
        pop a
        reti
;****************************
.sect int_addres,rom,abs=01e0
.addrw reset        ;vis without any interrupt
.addrw reset        ;port l or wake up interupts
.addrw reset        ;t3 b
.addrw reset        ;t3 a
.addrw reset        ;t2 b
.addrw reset        ;t2 a
.addrw trns0        ;transmit
.addrw rec0    ;receive
.addrw reset        ;reserved
.addrw reset        ;micro wire
.addrw tmr1b        ;tmr1       ;t1b
.addrw tmr1a        ;tmr1       ;t1a
.addrw tmr0         ;timer0
.addrw reset        ;external interrupt-g0
.addrw reset        ;reserved
.addrw reset        ;software intr interrupt
;************************
```

```
.sect timer0,rom

tmr0: rbit t0pnd,icntrl
        drsz lcd_cntr        ; lcd counter to enable lcd update every 0.1sec (25*4msec).
        jmp tmr0_01
        sbit lcdupdate,flags2

tmr0_01:    ld a,int_cntr         ; timer0 interrupts counter, used to help timing a2d,fix
        dec a          ; transmit, and other actions according to timer0 cycles.
        x a,int_cntr
        ifbit 0,int_cntr ; odd -   ; enable fix transmit.
        jmp tmr0_011
        sbit a2den,flags2 ; even -  ; enable a2d.
        jmp tmr0_02
tmr0_011:  sbit fix_t_en1,flags2
        sbit buttons_t_en,buttons_flags

tmr0_02:    ifbit stop1,lflags
        jmp tmr0_04

        ifbit en_calc,lflags
        jmp tmr0_03
        jmp tmr0_04

tmr0_03:    sc               ; pt=pt2-pt1 =time per pulse
        ld a,pt2lo
        subc a,pt1lo
        x a,ptlo
        ld a,pt2hi
        subc a,pt1hi
        x a,pthi

        sbit en1_calc,lflags

tmr0_04:    ifbit stop2,aflags
        jmp tmr0_06

        ifbit en_calc2,aflags
        jmp tmr0_05
        jmp tmr0_06

tmr0_05:    sc               ; pt=pt2-pt1 =time per pulse
        ld a,apt2lo
        subc a,apt1lo
        x a,aptlo
        ld a,apt2hi
        subc a,apt1hi
        x a,apthi

        sbit en1_calc2,aflags

tmr0_06:
end_tmr0:  ld a,cd_dly ; delay before changing direction.
        ifne a,#0
        dec a
        x a,cd_dly
        drsz uart_tmr
        jmp end_intr
        ld rec_stat,#0
        jmp end_intr
;**************************************************
.sect timer1,rom

tmr1a:   rbit t1c0,cntrl

        ifbit t1pnda,psw
        jmp tmr1a1
        jmp end_tmr1a

tmr1a1:  rbit t1pnda,psw
        ld a,pt1lo
        x a,pt2lo
        ld a,pt1hi
        x a,pt2hi
        ld a,t1ralo
        x a,pt1lo
        ld a,t1rahi
        x a,pt1hi
        sbit pulse,lflags

end_tmr1a:jmp end_intr
;*****************************************************
tmr1b:   rbit t1pndb,icntrl
        ld a,apt1lo
        x a,apt2lo
        ld a,apt1hi
        x a,apt2hi
        ld a,t1rblo
        x a,apt1lo
        ld a,t1rbhi
        x a,apt1hi

        sbit pulse2,aflags

end_tmr1b:jmp end_intr
;********************************************************
.sect uart_transmit,rom,inpage

trns0: ld a,trns_stat
        add a,#low(jmp_t_stat)
        jid             ; jmp pcu,[a]

jmp_t_stat: .addr t_s0,t_s1

t_s0:  jmp t_stat0
t_s1:  jmp t_stat1

end_t_stat:jmp end_intr
;**********************************************************
t_stat0:  rbit eti,enui
        ld trns_stat,#0
        jmp end_t_stat


t_stat1:  ld a,send_ptr
        ifgt a,#89        ; 0-89 => 90 bytes
        jmp t_stat1_01
        ld a,send_ptr
        x a,b
        ld s,#1
        ld a,[b+]
        x a,tbuf
        ld s,#0
        ld a,b
        x a,send_ptr
        jmp end_t_stat

t_stat1_01:ifgt a,#183        ; 90-179 => 90
bytes+1(buttons_flags)+1(t_check)+2('ED'[=END])
        jmp end_t_stat1
        ld a,send_ptr
        sc
        subc a,#90
        x a,b
        ld s,#2
        ld a,[b+]
        x a,tbuf
        ld s,#0
        ld a,b
        add a,#90
        x a,send_ptr
        jmp end_t_stat

end_t_stat1:ld send_ptr,#0
        rbit eti,enui
        ld trns_stat,#0
        jmp end_t_stat

;***********************************************
.sect uart_receive,rom,inpage

rec0:  ld a,rbuf        ; receive interrupt.
        x a,b
        ld a,check_sum
        add a,b
        x a,check_sum
        ld a,rec_stat
        add a,#low(jmp_r_stat)
        jid             ; jmp pcu,[a]

jmp_r_stat: .addr r_s0,r_s1,r_s2,r_s3

r_s0: jmp r_stat0
r_s1: jmp r_stat1
r_s2: jmp r_stat2
r_s3: jmp r_stat3

end_r_stat:jmp end_intr
;*********************************
.sect receive_states,rom

r_stat0:  ld check_sum,#0
        ld a,b
        ifne a,#0f5
        jmp e_r_stat0

        ld rec_stat,#1
        ld check_sum,#0f5
e_r_stat0:ld uart_tmr,#0ff
        jmp end_r_stat
```

```
r_stat1:  ld a,b
        ifeq a,#'A'      ; (041)   ; Advance - moving command.
        jmp r_stat2_00
        ifeq a,#'S'      ; Stop command.
        jmp r_stat1_01
        ifeq a,#'H'      ; Home position command.
        jmp r_stat1_02
        ifeq a,#'T'      ; Self Test command.
        jmp r_stat1_03
        ifeq a,#'O'      ; Operate auto run command.
        jmp r_stat1_04
        ifeq a,#'P'      ; Ping (test communication) command.
        jmp r_stat1_05
        ld rec_stat,#0
        jmp end_r_stat

r_stat1_01:sbit stop_command,buttons_flags    ; 'S' - Stop.
        ld tbyte1,#0f5
        jmp e_r_stat2

r_stat1_02:sbit home_command,buttons_flags  ; 'H' - Home position.
        ld home_stat,#0
e_r_stat1:ld tbyte1,#0f5
        sbit fix_t_en,flags2
        ld data_cntr,#21
        ld save_ptr,#0
        ld send_ptr,#0
        rbit enddata,flags1
        rbit start,flags1
        rbit end,flags1
        rbit stop,flags1
        jmp e_r_stat2

r_stat1_03:sbit self_t_command,buttons_flags  ; 'T' - Self Test.
        ld selft_stat,#0
        jmp e_r_stat1

r_stat1_04:sbit start_stop,buttons_flags    ; 'O' - Operate auto run command.
        ld autorun_stat,#0
        jmp e_r_stat1

r_stat1_05:ld tbyte1,#0f5                ; 'P' - Ping.
        ld pb,#0f0
        jmp e_r_stat2
```

```
r_stat2_00:ld rec_stat,#2
        ld rbyte_num,#4       ; number of bytes to be received
        ld receive_ptr,#rbyte1
        jmp end_r_stat
r_stat2:  ld a,receive_ptr        ; rbuf -> [receive_ptr]
        x a,x
        ld a,b                ; receive_ptr + 1 -> receive_ptr
        x a,[x+]
        ld a,x
        x a,receive_ptr
        drsz rbyte_num
        jmp end_r_stat
        sbit start,flags1
        rbit stop,flags1
        rbit end,flags1
        sbit fix_t_en,flags2
        ifeq trns_stat,#1
        jmp r_stat2_01
        ld data_cntr,#21      ; *************
        ld save_ptr,#0
        ld send_ptr,#0
r_stat2_01:ifbit motor,rbyte1 ; 0-motor1, 1-motor2.
        jmp r_stat2_03

        ld a,rbyte3      ; motor 1
        ifne a,#0
        jmp r_stat2_02
        ld a,rbyte2
        ifgt a,#0
        jmp r_stat2_02
        sbit stop1,lflags   ; distance=0  ->Stop motor!!
        rbit start,flags1
        sbit end,flags1
        ld nxt_l_stat,#0
        ld linear_stat,#6
        jmp r_stat2_05
r_stat2_02:ld linear_stat,#1
        sbit type_start,lcd_flags; type 'start' at line 2 of lcd.
        rbit limits_c_en,limits_flags
        rbit enddata,flags1
        rbit stop1,lflags
        jmp r_stat2_05

r_stat2_03:ld a,rbyte3        ; motor 2
```

```
        ifne a,#0
        jmp r_stat2_04
        ld a,rbyte2
        ifgt a,#0
        jmp r_stat2_04
        sbit stop2,aflags  ; distance=0  ->Stop motor!!
        rbit start,flags1
        sbit end,flags1
        ld nxt_a_stat,#0
        ld ang_stat,#6
        jmp r_stat2_05
r_stat2_04:ld ang_stat,#1  ; motor 2
        sbit type_start,lcd_flags; type 'start' at line 2 of lcd.
        rbit enddata,flags1
        rbit stop2,aflags


r_stat2_05:ld a,check_sum    ; load byte to transmit
        x a,tbyte1
e_r_stat2:ld a,tbyte1
        ifeq trns_stat,#0
        x a,tbuf
        ld rec_stat,#0
        rbit stuck,flags1
        jmp end_r_stat

r_stat3:  jmp end_r_stat
;*****************************************************
.sect datasend,rom

data_send:ifbit fix_t_en1,flags2
        jmp d_s0
        ret

d_s0: rbit fix_t_en1,flags2
        drsz data_cntr
        jmp d_s1

                ; transmit s2 and s3
        ld a,#13      ; 13 is the sync. sign.
        x a,tbuf      ; then send the data to the computer
        ld a,buttons_flags
        x a,b
        ld a,t_check
        ld s,#2
        x a,05a
        ld a,b
        x a,05b
        ld s,#1
        ld a,059
        ld s,#0
;       x a,0
;       ifbit enddata,0
        ifbit enddata,flags1
        rbit fix_t_en,flags2
        ld t_check,#0
        ld trns_stat,#1
        ld data_cntr,#21
        ld save_ptr,#0
        ld send_ptr,#0
        sbit eti,enui
        jmp end_d_s

d_s1:   ifeq data_cntr,#10
        ld save_ptr,#0
        ld a,#11
        ifgt a,data_cntr
        jmp d_s2

        ld b,#flags1      ; load data to stack.
        ld a,[b-]         ; flags1
        push a
        ld a,[b-]         ; pls_y1
        push a
        ld a,[b-]         ; pls_y0
        push a
        ld a,[b-]         ; pls_x1
        push a
        ld a,[b-]         ; pls_x0
        push a
        ld a,[b-]         ; hall2
        push a
        ld a,[b-]         ; hall1
        push a
        ld a,[b-]         ; current2
        push a
        ld a,[b-]         ; current1
        push a
        ld a,save_ptr        ; save data from stack.
        x a,b
```

```
ld a,b
x a,x
ld s,#1
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
pop a
x a,[b+]
ld a,t_check     ; compute check sum.
x a,b
ld a,[x+]     ; b=t_check, a = current1
add a,b       ; a = current1 + b
x a,b     ; b = a
ld a,[x+]
add a,b
x a,b
ld a,[x+]
add a,b
x a,b
ld a,[x+]
add a,b
x a,b
ld a,[x+]
add a,b
x a,b
ld a,[x+]
add a,b
x a,b
ld a,[x+]
add a,b
x a,b
ld a,[x+]
```

```
        add a,b
        x a,b
        ld a,[x+]     ; a = flags1
        add a,b       ; a = flags1 + b

        ld s,#0       ; t_check = a
        x a,t_check
        ld a,x
        x a,save_ptr

        jmp end_d_s

d_s2:   ld b,#flags1      ; load data to stack.
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,[b-]
        push a
        ld a,save_ptr         ; save data from stack.
        x a,b
        ld a,b
        x a,x
        ld s,#2
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        pop a
        x a,[b+]
        ld a,t_check    ; compute check sum.
        x a,b
        ld a,[x+]     ; b=13, a = current1
        add a,b       ; a = current1 + b
        x a,b      ; b = a
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]
        add a,b
        x a,b
        ld a,[x+]     ; a = flags1
        add a,b       ; a = flags1 + b

        ld s,#0       ; t_check = a
        x a,t_check
        ld a,x
        x a,save_ptr

end_d_s:   ret
;*****************************************************
```

```
.sect a2d_converter,rom
a2d00:  rbit a2den,flags2  ; the a2d prog. checks hall1+2 and current1+2
        ld enad,#082       ; c=>adch8=b0, 2=>psr=1=mclk divide by 16.
        sbit adbsy,enad
a2d01:  ifbit adbsy,enad
        jmp a2d01
        ld a,adrsth
        x a,hall1
        ld enad,#092       ; c=>adch9=b1, 2=>psr=1=mclk divide by 16.
        sbit adbsy,enad
a2d02:  ifbit adbsy,enad
        jmp a2d02
        ld a,adrsth
        x a,hall2
        ld enad,#0a2       ; c=>adch10=b2, 2=>psr=1=mclk divide by 16.
        sbit adbsy,enad
a2d03:  ifbit adbsy,enad
        jmp a2d03
        ld a,adrsth
        x a,current1
        ld enad,#0b2       ; c=>adch11=b3, 2=>psr=1=mclk divide by 16.
        sbit adbsy,enad
a2d04:  ifbit adbsy,enad
        jmp a2d04
        ld a,adrsth
        x a,current2
        ret
;*****************************************************
.sect velosity_caculation,rom

v_calc:  rbit en1_calc,lflags

        ld a,t_ref0
        x a,0
        ld a,t_ref1
        x a,1

        ld a,pthi
        ifgt a,1
        jmp tooslow
        ld a,1
        ifgt a,pthi
        jmp toofast
        ld a,ptlo
        ifgt a,0
        jmp tooslow
        ld a,0
        ifgt a,ptlo
        jmp toofast
        ret         ; if they are equal the speed is ok

tooslow: sc         ; err= (pt - t_ref) => (4,5)
        ld a,ptlo   ; if t2ra + err*k >1000 then pwm=1000 (fastest)
        subc a,0
        x a,4
        ld a,pthi
        subc a,1
        x a,5
        ld a,t2ralo
        x a,2
        ld a,t2rahi
        x a,3
        jsr mybyk
        ld a,0
        x a,2
        ld a,1
        x a,3
        ld a,4
        x a,0
        ld a,5
        x a,1
        jmp end_v_calc

toofast:  sc        ; err= (t_ref - pt) => (4,5)
        ld a,0      ; if t2rb + err*k >1000 then pwm=0 (slowest)
        subc a,ptlo
        x a,4
        ld a,1
        subc a,pthi
        x a,5
        ld a,t2rblo
        x a,2
        ld a,t2rbhi
        x a,3
        jsr mybyk
        ld a,4
        x a,2
        ld a,5
        x a,3
```

```
end_v_calc:ld b,#t2ralo
        ld x,#0
;       ld a,#1
;       ld tmr2hi,#2
;loop2:  ifgt a,tmr2hi
;       jp loop2
        ld a,[x+]
        x a,[b+]
        ld a,[x+]
        x a,[b+]
        ld a,[x+]
        x a,[b+]
        ld a,[x]
        x a,[b]
        ret
;*****************************************************
v2_calc: rbit en1_calc2,aflags

        ld a,at_ref0
        x a,0
        ld a,at_ref1
        x a,1

        ld a,apthi
        ifgt a,1
        jmp atooslow
        ld a,1
        ifgt a,apthi
        jmp atoofast
        ld a,aptlo
        ifgt a,0
        jmp atooslow
        ld a,0
        ifgt a,aptlo
        jmp atoofast
        ret         ; if they are equal the speed is ok

atooslow:  sc         ; err= (pt2 - at_ref) => (4,5)
        ld a,aptlo   ; if t3ra + err*k >1000 then pwm=1000 (fastest)
        subc a,0
        x a,4
        ld a,apthi
        subc a,1
        x a,5
        ld a,t3ralo
        x a,2
        ld a,t3rahi
        x a,3
        jsr mybyk
        ld a,0
        x a,2
        ld a,1
        x a,3
        ld a,4
        x a,0
        ld a,5
        x a,1
        jmp end_v2_calc

atoofast: sc        ; err= (at_ref - pt2) => (4,5)
        ld a,0    ; if t3rb + err*k >1000 then pwm=0 (slowest)
        subc a,aptlo
        x a,4
        ld a,1
        subc a,apthi
        x a,5
        ld a,t3rblo
        x a,2
        ld a,t3rbhi
        x a,3
        jsr mybyk
        ld a,4
        x a,2
        ld a,5
        x a,3


end_v2_calc:ld b,#t3ralo
        ld x,#0
;       ld a,#1
;       ld tmr3hi,#2
;loop3:  ifgt a,tmr3hi
;       jp loop3
        ld a,[x+]
        x a,[b+]
        ld a,[x+]
        x a,[b+]
        ld a,[x+]
        x a,[b+]
        ld a,[x]
        x a,[b]
        ret
;*****************************************************
.sect math_functions,rom

mybyk:  ld cntr,#6    ; div. by 64 (=2^6)
dvby2:  rc
        ld a,5
        rrc a
        x a,5
        ld a,4
        rrc a
        x a,4
        drsz cntr
        jmp dvby2
        rc          ; 4,5 <- err*k + t2
        ld a,4
        adc a,2
        x a,4
        ld a,5
        adc a,3
        x a,5

        ifeq 5,#0
        jmp lowedge
        ld a,5
        ifgt a,#high(980)
        jmp highedge
        ld a,#high(980)
        ifgt a,5
        jmp end_mybyk  ; not edge
        ld a,4
        ifgt a,#low(980)
        jmp highedge

        jmp end_mybyk  ; not edge

highedge:   ld 4,#low(980)
        ld 5,#high(980)
        ld 0,#20
        ld 1,#0
        ret

lowedge:    ld a,4
        ifgt a,#20
        jmp end_mybyk
        ld 0,#low(980)
        ld 1,#high(980)
        ld 4,#20
        ld 5,#0
        ret

end_mybyk:sc
        ld a,#low(1000)
        subc a,4
        x a,0
        ld a,#high(1000)
        subc a,5
        x a,1
        ld a,1
        ifgt a,#0
        ret
        ld a,0
        ifgt a,#20
        ret
        ld 0,#20
        ld 4,#low(980)
        ld 5,#high(980)
        ret

;****** FDV168 - Fast 16 by 8 division subroutine ******************
; 490 instruction cycles maximum - 245usec.
; dividend in [1,0] (dd)         divisor in [3]  (dr)
; quotient in [1,0] (quot)       remainder in [2] (test field)

fdv168: ld cntr,#16  ; load cntr with length of dividend field.
        ld 2,#0       ; clear test field.
fd168s: ld b,#0
fd168l: rc
        ld a,[b]
        adc a,[b]     ; left shift dividend lo
        x a,[b+]
        ld a,[b]
        adc a,[b]     ; left shift dividend hi
        x a,[b+]
        ld a,[b]
        adc a,[b]     ; left shift test field
        x a,[b]
        ld a,[b+]     ; test field to acc
        ifc          ; test if bit shiefted out of test field****
        jp fd168b
        sc
        subc a,[b]   ; test subtract divisor from test field
        ifnc         ; test if borrow from subtraction
        jp fd168t
fd168r: ld b,#2      ; subtraction result to test field
        x a,[b]
        ld b,#0
        sbit 0,[b]   ; set quotient bit
        drsz cntr    ; dectement and test cntr for zero
        jp fd168l
        ret          ; return from subroutine
fd168t: drsz cntr    ; dectement and test cntr for zero
        jp fd168s
        ret          ; return from subroutine
fd168b: subc a,[b]   ; subtract divisor from test field***
        jp fd168r
;******* BINDEC - Binary to Decimal (packed BCD) **********************
bindec: ld cntr,#8   ; Bindec - Binary to Decimal (packed BCD)
        rc           ; 856 cycles * 0.5 ~ 428 cycles = 213usec.
        ld b,#1      ; binary in 0 => decinmal in 1,2
bd1:    ld [b+],#0
        ifbne #3
        jmp bd1
bd2:    ld b,#0
bd3:    ld a,[b]
        adc a,[b]
        x a,[b+]
        ifbne #1
        jmp bd3
bd4:    ld a,[b]
        add a,#066
        adc a,[b]
        dcor  a
        x a,[b+]
        ifbne #3
        jmp bd4
        drsz cntr
        jmp bd2
        ret
;*********************************************
.sect lcd_update,rom
updatelcd:ifbit lcdupdate,flags2
        jmp updatelcd0
        ifeq lcd_flags,#0
        ret
        jmp updatelcd4

updatelcd0:rbit lcdupdate,flags2
        ld lcd_cntr,#50
        ld a,pls_x0
        x a,0
        ld a,pls_x1
        x a,1
        ld a,#lpulsepermm    ; linear pulses per mm
        x a,3
        jsr fdv168       ; mm = pls_x/linear_pulses_per_mm
        jsr bindec

        ld pd,#080       ; cursor home  - address 0.
        jsr lcd_com
        ld a,2
        and a,#0f
        add a,#'0'
        x a,pd
        jsr lcd_dat
        ld a,1
        swap a
        and a,#0f
        add a,#'0'
        x a,pd
        jsr lcd_dat
        ld a,1
        and a,#0f
        add a,#'0'
        x a,pd
        jsr lcd_dat

        ld pd,#085       ; cursor address 5.
        jsr lcd_com
        ifbit epi,flags1
        jmp updatelcd5

        ifbit 7,pls_y1
        jmp updatelcd1
        sc              ; angel= -  08000-pls_y
        ld a,#0
        subc a,pls_y0
        x a,0
        ld a,#080
        subc a,pls_y1
        x a,1
        ld pd,#'-'
        jmp updatelcd2
updatelcd1:ld a,pls_y1      ; angel= + pls_y-08000
        and a,#07f
        x a,1
        ld a,pls_y0
        x a,0
        ld pd,#'+'

updatelcd2:jsr lcd_dat
        ld cntr,#3
updatelcd3:rc
        ld a,1
        rrc a
        x a,1
        ld a,0
        rrc a
        x a,0
        drsz cntr
        jmp updatelcd3
        ld 1,#0
        jsr bindec
        ld a,1
        swap a
        and a,#0f
        add a,#'0'
        x a,pd
        jsr lcd_dat
        ld a,1
        and a,#0f
        add a,#'0'
        x a,pd
        jsr lcd_dat
        jmp updatelcd4
updatelcd5:ld pd,#'e'
        jsr lcd_dat
        ld pd,#'p'
        jsr lcd_dat
        ld pd,#'i'
        jsr lcd_dat

updatelcd4:ifeq lcd_flags,#0
        ret
        ifbit self_t_command,buttons_flags
        ld lcd_flags,#0
        ifbit start_stop,buttons_flags
        ld lcd_flags,#0
        ifeq lcd_flags,#0
        ret

        ifbit type_start,lcd_flags
        ld temp,#low(wordstart); type 'start' at line 2 of lcd.
        ifbit type_end,lcd_flags
        ld temp,#low(wordend)
        ifbit type_Stuck,lcd_flags
        ld temp,#low(wordstuck)
        ifbit type_stop,lcd_flags
        ld temp,#low(wordstop)

        jsr type_string1
        ld lcd_flags,#0


end_updatelcd:ret

;*********************************************
.sect lcd_orders,rom
clean_lcd:ld pd,#01
        jsr lcd_com
        jmp del16
;       ret
;*****************************************
type_string0:ld pd,#080         ; type string from the start of line 0.
        jsr lcd_com
        jmp type_string
type_string1:ld pd,#0c0         ; type string from the start of line 0.
        jsr lcd_com
type_string:ld a,temp
        inc a
        x a,temp
        jsr get_char
        ifeq a,#'@'
        ret
        x a,pd
        jsr lcd_dat
        jmp type_string

;********   subrutine to initialize lcd display
```

```
init_lcd: ld a,#10
init_lcd1:jsr del16
       dec a
       ifne a,#0
       jp init_lcd1

init_lcd2:ld pd,#01  ;display clear
       jsr lcd_com
       jsr del16

       ld pd,#06   ;increment cursor (cursor moves: left to right)
       jsr lcd_com

       ld pd,#0c   ;display on , cursor off
       jsr lcd_com

       ld pd,#03f  ;8 bits
;      jmp lcd_com

;      ret
;********** subrutine to transfer command to lcd display
lcd_com:   rbit rs,pa ;command
end_com_dat:
       sbit cs_lcd,pa
       rbit cs_lcd,pa
       ld cntr,#10
loop1:   drsz cntr
       jp loop1
       ret
********** subrutine to transfer data to lcd display
lcd_dat: sbit rs,pa ;command
       jmp end_com_dat

;******** delay ****************

del16:   ld cntr,#2
del160:  ld temp,#250 ;1.6 msec delay
del161:  drsz temp
       jmp del161
       ld temp,#150
del162:  drsz temp
       jmp del162
       drsz cntr
       jmp del160
       ret
```

```
;****************************************
.sect string_table,rom,inpage
get_char:laid
     ret
;***** ascii table ********************
wordmm:       .db '  mm  @'
wordstart:  .db 'start  @'
wordstop:       .db 'stop   @'
wordpoweron:.db 'power on@'
wordhome:     .db 'home    @'
wordstuck: .db 'stuck   @'
wordend:        .db 'end     @'
wordbottom:   .db 'bottom  @'
wordready:.db 'ready   @'
wordselftest:   .db 'selftest@'
wordautorun:  .db 'autorun @'
wordinplace:   .db 'in place@'

.endsect


   .END 0
              ;end of program listing of intumed.asm
```

Appendix 2

```
; This is c8cdr.inc
;*****************************************************************
****
; This file include cop8cdr.inc, cop8.inc, cop8c3r.inc, 8cdr.chp, ports.inc(shortcuts).


;port definitions in cop8 with flash.

ped   =090     ; port e data (output); pe is already taken by parity enable.
pec   =091     ; port e configuration
pei   =092     ; port e input

pf =094     ; port f data (output)
pfc   =095     ; port f configuration
pfi=096     ; port f input

pa =0a0     ; port a data (output)
pac   =0a1     ; port a configuration
pai   =0a2     ; port a input

pb =0a4     ; port b data (output)
pbc   =0a5     ; port b configuration
pbi   =0a6     ; port b input


pl =0d0     ; port l data (output)
plc   =0d1     ; port l configuration
pli=0d2     ; port l input

pg =0d4     ; port g data (output)
pgc   =0d5     ; port g configuration
pgi   =0d6     ; port g input


pc =0d8     ; port c data (output)
pcc   =0d9     ; port c configuration
pci   =0da     ; port c input

pd =0dc     ; port d data (output)
```

```
; This is cop8.inc
;*****************************************************************
*********/
;* Primary Chip Names with Designators
;*****************************************************************
*********/
ANYCOP  = 0
COP912C = 1    ; Basic Family
COP820  = 2
COP840  = 3
COP880  = 4
COP820CJ = 5
COP840CJ = 6
COP8620 = 7
COP8640 = 8
COP8720 = 9
COP8780 = 10
COP943  = 11

COP888CF = 20  ; Feature Family
COP888CG = 21
COP888CL = 22
COP888CS = 23
COP888EG = 24
COP888EK = 25
COP8ACC  = 26
COP888BC = 27
COP888EB = 28
COP888EW = 29
COP888FH = 30
COP888GD = 31
COP888GG = 32
COP888GW = 33
COP888HG = 34
COP888KG = 35
COP8SAA  = 36
COP8SAB  = 37
COP8SAC  = 38
COP8SGR  = 39
COP8SGE  = 40
COP8SEC  = 41
COP8SER  = 42
COP8AJC  = 43
```

```
COP8AKC  = 44

;--------------   Flash based devices from here on
COP8CBR  = 60
COP8CCR  = 61
COP8CDR  = 62
COP8SBR  = 63
COP8SCR  = 64
COP8SDR  = 65

COPy8 = 99
;
; ---------------- End of COP8.INC -----------------------------------

;*****************************************************
     COPCHIP = COP8CDR       ; Chip Definition



; This is cop8C3R.inc
;
; PLEASE: Consider update for CBR,CDR, and CCR.
;
; Predeclare I/O and control registers frequently used by COP8 programmer.
.macro   setopt
.mloc sec,wd,halt,flex
;
.ifb    @1    ; if null
sec     =  0  ; default value (not secure)
.else
sec     =  @1
.endif
.ifb    @2    ; if null
wd      =  0  ; default value (Watchdog enabled)
.else
wd      =  @2
.endif
.ifb    @3    ; if null
halt    =  0  ; default value (HALT enabled)
.else
halt    =  @3
.endif
.ifb    @4    ; if null
flex    =  1  ; default value (Execute from Flash)
.else
```

```
flex = @4
.endif

.sect OPTION, CONF
CONFIG: .db ((sec shl 3 or wd) shl 1 or halt) shl 1 or flex
.endm

; ---------------- End of setecon Macro Definition --------------------
;
; --------------------------------------------------------------------
; SFR Names and Register Bit Names Agree with the Feature Family User's
; Manual Redundant names match corresponding functions on Basic Family
; Documentation
;

    PORTED = 0x90:BYTE      ; Port E Data
    PORTEC = 0x91:BYTE      ; Port E Configuration
    PORTEP = 0x92:BYTE      ; Port E input pins (read only)
;
    PORTFD = 0x94:BYTE      ; Port F Data
    PORTFC = 0x95:BYTE      ; Port F Configuration
    PORTFP = 0x96:BYTE      ; Port F input pins (read only)
;
    PORTAD = 0xA0:BYTE      ; Port A Data
    PORTAC = 0xA1:BYTE      ; Port A Configuration
    PORTAP = 0xA2:BYTE      ; Port A input pins (read only)
;
    PORTBD = 0xA4:BYTE      ; Port B Data
    PORTBC = 0xA5:BYTE      ; Port B Configuration
    PORTBP = 0xA6:BYTE      ; Port B input pins (read only)
;
ISPADLO = 0xA8:BYTE     ; ISP Address Register Low Byte
ISPADHI = 0xA9:BYTE     ; ISP Address Register High Byte
ISPRD = 0xAA:BYTE       ; ISP Read Data Register
ISPWR = 0xAB:BYTE       ; ISP Write Data Register
;
TINTA = 0xAD:BYTE       ; High Speed Timers Interrupt A
TINTB = 0xAE:BYTE       ; High Speed Timers Interrupt B
HSTCR = 0xAF:BYTE       ; High Speed Timers Control Register
;
    TMR3LO = 0xB0:BYTE      ; Timer 3 low byte
    TMR3HI = 0xB1:BYTE      ; Timer 3 high byte
    T3RALO = 0xB2:BYTE      ; Timer 3 RA register low byte
    T3RAHI = 0xB3:BYTE      ; Timer 3 RA register high byte
    T3RBLO = 0xB4:BYTE      ; Timer 3 RB register low byte
```

```
        T3RBHI  =  0xB5:BYTE        ; Timer 3 RB register high byte
        T3CNTRL =  0xB6:BYTE        ; Timer 3 control register
;
        TBUF    =  0xB8:BYTE        ; UART transmit buffer
        RBUF    =  0xB9:BYTE        ; UART receive buffer
        ENU     =  0xBA:BYTE        ; UART control and status register
        ENUR    =  0xBB:BYTE        ; UART receive control and status reg.
        ENUI    =  0xBC:BYTE        ; UART interrupt and clock source reg.
        BAUD    =  0xBD:BYTE        ; BAUD register
        PSR     =  0xBE:BYTE        ; UART prescaler select register
;
        TMR2LO  =  0xC0:BYTE        ; Timer 2 low byte
        TMR2HI  =  0xC1:BYTE        ; Timer 2 high byte
        T2RALO  =  0xC2:BYTE        ; Timer 2 RA register low byte
        T2RAHI  =  0xC3:BYTE        ; Timer 2 RA register high byte
        T2RBLO  =  0xC4:BYTE        ; Timer 2 RB register low byte
        T2RBHI  =  0xC5:BYTE        ; Timer 2 RB register high byte
        T2CNTRL =  0xC6:BYTE        ; Timer 2 control register
;
        WDSVR   =  0xC7:BYTE        ; Watch dog service register
;
        WKEDG   =  0xC8:BYTE        ; MIWU edge select register
        WKEN    =  0xC9:BYTE        ; MIWU enable register
        WKPND   =  0xCA:BYTE        ; MIWU pending register
;
ENAD    =  0xCB:BYTE        ; A/D Converter Control register
ADRSTH  =  0xCC:BYTE        ; A/D Converter Result Register High Byte
ADRSTL  =  0xCD:BYTE        ; A/D Converter Result Register Low Byte
;
ITMR    =  0xCF:BYTE        ; Idle Timer Control Register
;
        PORTLD  =  0xD0:BYTE        ; Port L data
        PORTLC  =  0xD1:BYTE        ; Port L configuration
        PORTLP  =  0xD2:BYTE        ; Port L pin
;
        PORTGD  =  0xD4:BYTE        ; Port G data
        PORTGC  =  0xD5:BYTE        ; Port G configuration
        PORTGP  =  0xD6:BYTE        ; Port G pin
;
        PORTCD  =  0xD8:BYTE        ; Port C data
        PORTCC  =  0xD9:BYTE        ; Port C configuration
        PORTCP  =  0xDA:BYTE        ; Port C pin
;
        PORTD   =  0xDC:BYTE        ; Port D
;
```

```
PGMTIM  =  0xE1:BYTE       ; E2 and Flash Write Timing Register
ISPKEY =  0xE2:BYTE      ; ISP Key Register
;
    T1RBLO  =  0xE6:BYTE       ; Timer 1 RB register low byte
    T1RBHI  =  0xE7:BYTE       ; Timer 1 RB register high byte
;
    ICNTRL  =  0xE8:BYTE       ; Interrupt control register
;
    SIOR   =  0xE9:BYTE       ; SIO shift register
    SIO    =  0xE9:BYTE       ; SIO shift register
;
    TMR1LO  =  0xEA:BYTE       ; Timer 1 low byte
    TMR1HI  =  0xEB:BYTE       ; Timer 1 high byte
    T1RALO  =  0xEC:BYTE       ; Timer 1 RA register low byte
    T1RAHI  =  0xED:BYTE       ; Timer 1 RA register high byte
;
    CNTRL   =  0xEE:BYTE       ; control register
    PSW    =  0xEF:BYTE       ; PSW register
;
BYTECOUNTLO =  0xF1:BYTE    ; When JSRB Boot Rom used
;
    S     =  0xFF:BYTE       ; Segment register, only COP888CG/CS!
;

;----------------------------------------------------------------------
; Bit Constant Declarations.
;
;----- Alternate function bit definitions on port G

    INT    =  0        ; Interrupt input
    INTR   =  0        ; Interrupt input
    WDOUT  =  1        ; Watchdog output
    T1B    =  2        ; Timer T1B output
    T1A    =  3        ; Timer T1A output
    SO     =  4        ; Seriell output
    SK     =  5        ; Seriell clock
    SI     =  6        ; Seriell input
    CKO    =  7        ; Halt,restart input
;
;----- Alternate function bit definitions on port L
    CKX    =  1        ; ext. clock I/O-pin/UART
    TDX    =  2        ; transmit data/UART
    RDX    =  3        ; receive data/UART
    T2A    =  4        ; Timer T2A output
    T2B    =  5        ; Timer T2B output
```

```
        T3A    =  6        ; Timer T3A output
        T3B    =  7        ; Timer T3B output
;
;       Alternate function bit definitions on port A
        ACH0    =  0        ; A/D-Channel 0
        ACH1    =  1        ; A/D-Channel 1
        ACH2    =  2        ; A/D-Channel 2
        ACH3    =  3        ; A/D-Channel 3
        ACH4    =  4        ; A/D-Channel 4
        ACH5    =  5        ; A/D-Channel 5
        ACH6    =  6        ; A/D-Channel 6
        ACH7    =  7        ; A/D-Channel 7
;
;       Alternate function bit definitions on port B
        ACH8    =  0        ; A/D-Channel 8
        ACH9    =  1        ; A/D-Channel 9
        ACH10   =  2        ; A/D-Channel 10
        ACH11   =  3        ; A/D-Channel 11
        ACH12   =  4        ; A/D-Channel 12
        ACH13   =  5        ; A/D-Channel 13
MUXOUTN         =  5        ; A/D Mux Negative Output
        ACH14   =  6        ; A/D-Channel 14
MUXOUTP         =  5        ; A/D Mux Positive Output
        ACH15   =  7        ; A/D-Channel 15
ADIN    =  7            ; A/D Converter Input
;
;----- Bit definitions CNTRL register
        T1C3   =  7        ; Timer 1 mode control
        TC1    =  T1C3      ; COP880/840/820 control signal name
        T1C2   =  6        ; Timer 1 mode control
        TC2    =  T1C2      ; COP880/840/820 control signal name
        T1C1   =  5        ; Timer 1 mode control
        TC3    =  T1C1      ; COP880/840/820 control signal name
        T1C0   =  4        ; Start/Stop timer in modes 1 and 2
                           ; Underflow interrupt pending in mode 3
        TRUN    =  T1C0     ; COP880/840/820 control signal name
        MSEL    =  3        ; Enable Microwire
        IEDG   =  2        ; Selects external interr. edge polarity
        SL1    =  1        ; Microwire clock divide select
        SL0    =  0        ; Microwire clock divide select
;
;----- Bit definitions PSW register
        HC     =  7        ; Half Historical Redundant carry flag
        C      =  6        ; Carry flag
        T1PNDA =  5         ; Timer T1A interrupt pending
        TPND   =  T1PNDA     ; Historical Redundant
        T1ENA  =  4         ; Timer T1A interrupt enable
        ENTI   =  T1ENA      ; Historical Redundant
        EXPND  =  3         ; External interrupt pending
        IPND   =  EXPND      ; Historical Redundant
        BUSY   =  2         ; Microwire busy shifting
        EXEN   =  1         ; External interurpt enable
        ENI    =  EXEN       ; Historical Redundant
        GIE    =  0         ; Global interr. enable
;
;----- Bit definitions ICNTRL register
        LPEN   =  6         ; L-Port interr. enable
        T0PND  =  5          ; Timer T0 interr. pending
        T0EN   =  4         ; Timer T0 interr. enable
        WPND   =  3          ; Microwire interr. pending
        WEN    =  2         ; Microwire interr. enable
        T1PNDB =  1           ; Timer T1B interr. pending flag
        T1ENB  =  0          ; Timer T1B interr. enable
;
;----- Bit definitions T2CNTRL register
        T2C3   =  7         ; Timer T2 mode control
        T2C2   =  6         ; Timer T2 mode control
        T2C1   =  5         ; Timer T2 mode control
        T2C0   =  4         ; Timer T2A start/stop
        T2PNDA =  3           ; Timer T2A interr. pending flag
        T2ENA  =  2          ; Timer T2A interr. enable
        T2PNDB =  1           ; Timer T2B interr. pending flag
        T2ENB  =  0          ; Timer T2B interr. enable
;
;----- Bit definitions T3CNTRL register
        T3C3   =  7         ; Timer T3 mode control
        T3C2   =  6         ; Timer T3 mode control
        T3C1   =  5         ; Timer T3 mode control
        T3C0   =  4         ; Timer T3A start/stop
        T3PNDA =  3           ; Timer T3A interr. pending flag
        T3ENA  =  2          ; Timer T3A interr. enable
        T3PNDB =  1           ; Timer T3B interr. pending flag
        T3ENB  =  0          ; Timer T3B interr. enable
;
;       Bit definitions HSTCR register
T9HS    =  7     ; Timer T9 High Speed Enable
T8HS    =  6     ; Timer T8 High Speed Enable
T7HS    =  5     ; Timer T7 High Speed Enable
T6HS    =  4     ; Timer T6 High Speed Enable
T5HS    =  3     ; Timer T5 High Speed Enable
```

```
T4HS    =  2      ; Timer T4 High Speed Enable
T3HS    =  1      ; Timer T3 High Speed Enable
T2HS    =  0      ; Timer T2 High Speed Enable
;
;      Bit definitions TINTA register
T9INTA=  7      ; Timer 9 Interrupt A
T8INTA=  6      ; Timer 8 Interrupt A
T7INTA=  5      ; Timer 7 Interrupt A
T6INTA=  4      ; Timer 6 Interrupt A
T5INTA=  3      ; Timer 5 Interrupt A
T4INTA=  2      ; Timer 4 Interrupt A
T3INTA=  1      ; Timer 3 Interrupt A
;
;      Bit definitions TINTB register
T9INTB=  7      ; Timer 9 Interrupt B
T8INTB=  6      ; Timer 8 Interrupt B
T7INTB=  5      ; Timer 7 Interrupt B
T6INTB=  4      ; Timer 6 Interrupt B
T5INTB=  3      ; Timer 5 Interrupt B
T4INTB=  2      ; Timer 4 Interrupt B
T3INTB=  1      ; Timer 3 Interrupt B
;
;      Bit definitions ENAD register
      ADCH3  =  7      ; A/D Convertor Channel Select bit 3
ADCH2 =  6       ; A/D Convertor Channel Select bit 2
      ADCH1  =  5        ; A/D Convertor Channel Select bit 1
      ADCH0  =  4        ; A/D Convertor Channel Select bit 0
      ADMOD=  3        ; A/D Convertor Mode Select bit
ADMUX   =  2       ; A/D Mux Out Control
      PSC    =  1       ; A/D Convertor Prescale Select bit
ADBSY=  0      ; A/D Convertor Busy Bit
;
;----- Bit definitions ENU register
      PEN     =  7       ; Parity enable
      PSEL1   =  6        ; Parity select
      PSEL0   =  5        ; Parity select
      XBIT9   =  5        ; 9th transmission bit in 9bit data mode
      CHL1    =  4        ; Select character frame format
      CHL0    =  3        ; Select character frame format
      ERR     =  2       ; Error flag
      RBFL    =  1        ; Received character
      TBMT    =  0        ; Transmited character
;
;----- Bit definitions ENUR register
      DOE     =  7       ; Data overrun error
```

```
        FE    =  6        ; Framing error
        PE    =  5        ; Parity error
        BD =  4      ; Break Detect
RBIT9  =  3         ; Contains the ninth bit (nine bit frame!)
        ATTN   =  2         ; Attention mode
        XMTG   =  1         ; indicate transmitting mode
        RCVG   =  0         ; indicate framing error
;
;----- Bit definition ENUI register
        STP2   =  7         ; Select number of stop bits
        BRK  =  6          ; Holds TDX low to Generate a BREAK
        ETDX   =  5         ; Select transmit-pin l2
        SSEL   =  4         ; Select UART-mode
        XRCLK  =  3          ; Select clock source for the receiver
        XTCLK  =  2          ; Select clock source for the transmitter
        ERI    =  1        ; Enable interr. from the receiver
        ETI    =  0        ; enable interr. from the transmitter
;
;   Bit Definitions for ITMR Register
LSON   =  7        ; Low Speed Oscillator Enable
HSON   =  6        ; High Speed Oscillator Enable
DCEN   =  5      ; Dual Clock Enable - Switches T0 To
             ;  Low Speed Clock
CCKSEL   =  4      ; Core Clock Select - Switches Instr
             ;  Execution To Low Speed Clock
ITSEL2 =  2      ; IDLE Timer Period Select bit 2
ITSEL1 =  1      ; IDLE Timer Period Select bit 1
ITSEL0 =  0      ; IDLE Timer Period Select bit 0
;
KEY =   0x98 ; Required Value for ISP Key
;
; --------------- End of COP8C3R.INC ----------------------------------

;*************************************************************
*****

;This is 8cdr.chip

        .CHIP 8CDR           ; specifies max. ROM address 7FFF
                        ; RAM = 1K

;CHIP_SPEC (chip_table) for COP8CDR9xxxx parts
; PLEASE: Consider also update of files for CBR and CCR when modifying
this file.

; 0 value if undefined, address value otherwise
```

```
            mole   =    0
            romsize  = 0x8000        ; ROM size
            ramhi  =    0x6F        ; segment 0 high address
            eelo   =    0          ; on-chip eerom range
            eehi   =    0
            t3lo   =    0xB0        ; timer 3 registers
            t3hi   =    0xB6
            comp      =0           ; comparator
            uartlo    =    0xB8        ; uart registers
            uarthi    =    0xBE
            t2lo   =    0xC0        ; timer 2 registers
            t2hi   =    0xC6
            wdog      =    0xC7        ; watch dog service register
            miwulo    =    0xC8        ; miwu registers
            miwuhi    =    0xCA
            a2dlo     =    0xCB         ; a/d registers
            a2dhi     =    0xCD
            lportlo  =  0xD0        ; l port registers
            lporthi  =  0xD2
            gportlo  =  0xD4        ; g port registers
            gporthi  =  0xD6
            iport  =    0          ; i port
            cportlo  =  0xD8        ; c port
            cporthi  =  0xDA
            dport  =    0xDC         ; d port
            eecr   =    0          ; eerom control register
            eromdr    =    0          ; eerom data register
            eearlo    =    0          ; eerom address registers
            eearhi    =    0
            ;icntrl    =    0xE8        ; icntrl register      ; already defined
            microwire =    0xE9        ; uWire SIO
            t1alo  =    0xE6        ; t1 auto ld t1rb
            t1ahi  =    0xE7
            t1blo  =    0xEA         ; t1 reg
            t1bhi  =    0xED
            ;cntrl  =    0xEE        ; cntrl reg     ; already defined
            ;psw    =    0xEF        ; psw reg          ; already defined
            rnlo   =    0xF0        ; RAM reg range
            rnhi   =    0xFF
            segramlo =    0x0100        ; segments low to high
            segramhi =    0x077F
            cntrl2    =    0
      wdogctr  =   0
            modrel    =    0
            econ   =    0x7FFF        ; econ hex-file location
```

```
cfgsize  =  1             ; econ array cell address.

;family = 0 for basic family, family = 1 for feature family

family   =   1
```

Appendix 3

```
;************* Constants definitions ******************
lpulsepermm=136       ; 16 * 22 / 2.54 = 138.58  = linear pulse per mm
;************* Register Definitions ****************
f0     =0f0     ; not used
uart_tmr=0f1     ; used as receive watch dog - when 0, return rec_stat(receiving state) to 0.
rbyte_num =0f2     ; number of bytes to be received.
tbyte_num =0f3     ; number of bytes to be transmitted.
temp     =0f4     ; used for temporary calculations as variable or counter.
;        =0f5     ; not used
cntr      =0f6     ; used for temporary calculations as counter.
lcd_cntr =0f7     ; used to refresh lcd every 0.1 sec (according to timer0 - 25*4msec)
f8     =0f8     ; not used
data_cntr   =0f9     ; used to count 20 data packets.
fa     =0fa     ; not used
fb     =0fb     ; not used
;********** bits definitions   ****************
rs=2          ; pa       ; determines if the LCD gets command(0) or data(1).
cs_lcd=3        ; pa       ; send the information in the lcd data pins upon rise and fall(_/\_) of
cs_lcd.
control1=4 ; pa      ; \
control2=5 ; pa      ; / control 1+2 determine the direction of motor 1
control3=6 ; pa      ; \
control4=7 ; pa      ; / control 3+4 determine the direction of motor 2
;home_position=5; pl
;start_stop=7  ; pl
home_limit=5 ; pb
bottom_limit=6   ; pb
angular_limit=7; pb
;***********   flags ***************************************
direction=0; lflags  ; direction of motor 1
first_pulse=1  ; lflags  ; if set then there was already 1 pulse.
en_calc=2      ; lflags  ; enables calculation of time per pulse.
en1_calc=3; lflags  ; enables calculation of velosity every.
stop1=4      ; lflags  ; signals that motor1 sould be stopped
pulse=5      ; lflags  ; signals that there was a pulse from motor 1

direction2=0   ; aflags  ; direction of motor 2
firsty_pulse=1; aflags  ; if set then there was already 1 pulse.
en_calc2=2; aflags  ; enables calculation of time per pulse.
en1_calc2=3   ; aflags  ; enables calculation of velosity every.
stop2=4      ; aflags  ; signals that motor2 sould be stopped
pulse2=5       ; aflags  ; signals that there was a pulse from motor 2
```

```
start=0      ; flags1  ; 1 when start command is received, 0 when stop command is issued.
home=1       ; flags1  ; 1 when home micro switch (Normally Closed) is closed, o when
open.
bottom=2        ; flags1  ; 1 when bottoming micro switch (NO) is closed, o when open.
epi=3    ; flags1  ; 1 when Epiglottis is sensed.
stop=4       ; flags1  ; 1 when stop command is received, 0 when start command is issued.
end=5        ; flags1  ; 1 when planned mission ends.
stuck=6      ; flags1  ; 1 when a motor is stuck.
enddata=7       ; flags1  ;   additional bit for the PC to know when the micro stops sending
data.

fix_t_en=0 ; flags2  ; generatl enable for saving and transmitting the blockes of data.
fix_t_en1=1     ; flags2  ; enable 1 block saving, and set every 8msec by timer0.
a2den=2      ; flags2  ; enables a/d
lcdupdate=3     ; flags2  ; being set every 0.1sec by timer 0 to refresh lcd.


type_start=0    ; lcd_flags  ; if set lcd sould type "start" in line2.
type_stop=1     ; lcd_flags  ; if set lcd sould type "stop" in line2.
type_end=2; lcd_flags  ; if set lcd sould type "end" in line2.
type_stuck=3  ; lcd_flags  ; if set lcd sould type "stuck" in line2.

new_direction=3; rbyte1   ; the new direction for the motors as received from the pc.
motor=4      ; rbyte1  ; 0 - motor1, 1 - motor2.


buttons_t_en=0        ; buttons_flags
home_command=1        ; buttons_flags
home_command_pc=2 ; buttons_flags
self_t_command=3  ; buttons_flags
stop_command=4        ; buttons_flags
home_position=5; buttons_flags    + pl
start_stop=7       ; buttons_flags    + pl

limits_c_en=0 ; limits_flags          _______________to be shifted if it is the only bit in this
byte.
;****** s=0 *******bytes definitions ***************************
lflags=020     ; flags that belongs to linear motor (motor1).
aflags    =021     ; flags that belongs to angular motor (motor2).
ang_stat =022      ; angular motor work states.
nxt_a_stat=023        ; save the next ang_stat that come after a subroutine or an ang_stat.
plsy_cntr0=024        ; lsb   ; angular distance that motor 2 sould do in start command.
plsy_cntr1=025        ; msb
pls_cntr0    =026     ; lsb   ; linear distance that motor 1 sould do in start command.
pls_cntr1    =027     ; msb
```

```
linear_stat=028  ; linear motor work states.
nxt_l_stat=029      ; save the next linear_stat that come after a subroutine or an linear_stat.
flags2   =02a    ; save flags of lcd, a/d and fix_t_en.
cd_dly   =02b    ; delay before changing direction to alow the motor to reach a complete
stop.
rec_stat  =02c   ; usart receiving work state.
trns_stat=02d    ; usart transmitting work state.
int_cntr  =02e   ; counter to help with timming. decreased by 1 every 4msec.

current1 =030    ; digital current from motor 1.
current2 =031    ; digital current from motor 2.
hall1  =032   ; digital hall senssor from motor 1.
hall2  =033   ; digital hall senssor from motor 2.
pls_x0   =034 ; lsb  ; total linear distance in pulses.
pls_x1   =035    ; msb
pls_y0   =036 ; lsb  ; total angular distance in pulses.
pls_y1   =037    ; msb
flags1   =038    ;
t_check  =039    ; check sum of 1 packet of 20 blocks of current1+...+flags1
check_sum =03a      ; check sum of received bytes in 1 command from the pc.
save_ptr =03b    ; pointer to show where the next byte should be saved in the packet of 20
blocks (s1,s2).
send_ptr=03c     ; pointer to show from where the next byte should be sent in the packet of
20 blocks (s1,s2).
zero_h1 =03d
zero_h2 =03e

pt1lo =040    ; lsb  ; save the capture time of motor 1 last pulse.          ; timer 1a
pt1hi =041    ; msb
pt2lo =042    ; lsb  ; save the capture time of 1 pulse before motor 1 last pulse.
pt2hi =043    ; msb
ptlo      =044   ; lsb  ; save the time between the last 2 pulses of motor 1. calculated in
timer0.
pthi      =045   ; msb
t_ref0    =046   ; lsb  ; the desired time between pulses of motor 1 as received from the
pc.
t_ref1    =047   ; msb

apt1lo    =048   ; lsb  ; save the capture time of motor 2 last pulse.          ; timer 1b
apt1hi    =049   ; msb
apt2lo    =04a   ; lsb  ; save the capture time of 1 pulse before motor 2 last pulse.
apt2hi    =04b   ; msb
aptlo =04c    ; lsb  ; save the time between the last 2 pulses of motor 2. calculated in
timer0.
apthi =04d    ; msb
```

```
at_ref0  =04e     ; lsb  ; the desired time between pulses of motor 2 as received from the
pc.
at_ref1  =04f     ; msb

receive_ptr=050  ; pointer where to store the byte that will be received next.
rbyte1   =051    ;
rbyte2   =052    ;   received bytes.
rbyte3   =053    ;
rbyte4   =054    ;
rbyte5   =055    ;
trns_ptr =056    ; pointer where the next byte to be transmitted is stored.
tbyte1   =057    ;
tbyte2   =058    ;   bytes to be transmitted.
tbyte3   =059    ;
tbyte4   =05a    ;
tbyte5   =05b    ;
tbyte6   =05c    ;
tbyte7   =05d    ;

packet_cntr=05f  ; counts the packets that are send every 160msec untill the micro returns
to work state 0.

limits_flags=060 ; micro(limit) switches - normally closed.
buttons_flags  =061 ; buttons - normally closed.
ritut       =062 ; ritut - counter to prevent buttons vibrations, only 3sec push is considered a
prese.
start_stop_cntr=063 ; counter of 3 sec.
home_position_cntr=064  ; counter of 3 sec.
selft_stat=065    ; work states of self test.
autorun_stat=066; work states of auto run.
lcd_flags=067     ; lcd flags - if set, something should be typed.
nolpulsetmr=068 ; timer to turn off motor if no pulses received - assuming the motor is
stuck.
noapulsetmr=069
home_stat=06a       ; work states of home position.
```

CLAIMS

1. An automatically operative medical insertion device comprising:

an insertable element which is adapted to be inserted within a living organism in vivo;

a surface following element, physically associated with said insertable element and being arranged to follow a physical surface within said living organism in vivo;

a driving subsystem operative to at least partially automatically direct said insertable element along said physical surface; and

a navigation subsystem operative to control said driving subsystem based at least partially on a perceived location of said surface following element along a reference pathway stored in said navigation subsystem.

2. An automatically operative medical insertion device according claim 1 and wherein said driving subsystem is operative to fully automatically direct said insertable element along said physical surface.

3. An automatically operative medical insertion device according to claim 1 and wherein said driving subsystem is operative to automatically and selectably direct said insertable element along said physical surface.

4. An automatically operative medical insertion device according to any of the preceding claims and wherein said navigation subsystem receives surface characteristic information relating to said physical surface from said surface following element and employs said surface characteristic information to perceive the location of said surface following element along said reference pathway.

5. An automatically operative medical insertion device according to claim 4 and wherein said surface characteristic information comprises surface contour information.

6. An automatically operative medical insertion device according to claim 4 and

wherein said surface characteristic information comprises surface hardness information.

7. An automatically operative medical insertion device according to claim 4 and wherein said surface contour information is three-dimensional.

8. An automatically operative medical insertion device according to claim 4 and wherein said surface contour information is two-dimensional.

9. An automatically operative medical insertion device according to any of the preceding claims and wherein said insertable element is a endotracheal tube and wherein said physical surface comprises surfaces of the larynx and trachea.

10. An automatically operative medical insertion device according to any of claims 1 - 8 and wherein said insertable element is a gastroscope and wherein said physical surface comprises surfaces of the intestine.

11. An automatically operative medical insertion device according to any of claims 1 - 8 and wherein said insertable element is a catheter and wherein said physical surface comprises interior surfaces of the circulatory system.

12. An automatically operative medical insertion device according to any of the preceding claims and also comprising a reference pathway generator operative to image at least a portion of said living organism and to generate said reference pathway based at least partially on an image generated thereby.

13. An automatically operative medical insertion device according to claim 12 and wherein said reference pathway comprises a standard contour map of a portion of the human anatomy.

14. An automatically operative medical insertion device according to claim 13 and wherein said standard contour map is precisely adapted to a specific patient.

15. An automatically operative medical insertion device according to claim 13 or claim 14 and wherein said standard contour map is automatically precisely adapted to a specific patient.

16. An automatically operative medical insertion device according to any of claims 12 to 15 and wherein said reference pathway is operator adaptable to designate at least one impediment.

17. An automatically operative medical insertion device according to any of the preceding claims and wherein said insertable element comprises a housing in which is disposed said driving subsystem; a mouthpiece, a tube inserted through the mouthpiece and a flexible guide inserted through the tube, said surface following element being mounted at a front end of said guide.

18. An automatically operative medical insertion device according to claim 17 and wherein said mouthpiece comprises a curved pipe through which said tube is inserted.

19. An automatically operative medical insertion device according to claim 18 and wherein said driving subsystem is operative to move said guide in and out of said housing, through said curved pipe and through said tube.

20. An automatically operative medical insertion device according to claim 19 and wherein said driving subsystem is also operative to selectably bend a front end of said guide.

21. An automatically operative medical insertion device according to any of the preceding claims and wherein said driving subsystem is operative to move said insertable element in and out of said living organism.

22. An automatically operative medical insertion device according to any of the preceding claims and wherein said driving subsystem is also operative to selectably bend a front end of said insertable element.

23. An automatically operative medical insertion device according to any of the preceding claims and wherein said surface following element comprises a tactile sensing element.

24. An automatically operative medical insertion device according to any of the preceding claims and wherein said surface following element comprises a tip sensor including a tip integrally formed at one end of a short rod having a magnet on its other end, said rod extends through the center of a spring disk and is firmly connected thereto, said spring disk being mounted on one end of a cylinder whose other end is mounted on a front end of said insertable element.

25. An automatically operative medical insertion device according to claim 24 and wherein said tip sensor also comprises two Hall effect sensors which are mounted inside said cylinder on a support and in close proximity to said magnet, said Hall effect sensors being spaced in the plane of the curvature of the curved pipe, each Hall effect sensor having electrical terminals operative to provide electric current representing the distance of the magnet therefrom, said tip sensor being operative such that when a force is exerted on the tip along an axis of symmetry of said cylinder, said tip is pushed against said spring disk, causing said magnet to approach said Hall effect sensors and when a force is exerted on said tip sideways in the plane of said Hall effect sensors, said tip rotates around a location where said rod engages said spring disk, causing said magnet to rotate away from one of said Hall effect sensors and closer to the other of the Hall effect sensors.

26. An automatically operative medical insertion device according to claim 17 and wherein said driving subsystem is operative, following partial insertion of said insertable element into the oral cavity, to cause the guide to extend in the direction of the trachea and bend the guide clockwise until said surface following element engages a surface of the tongue, whereby this engagement applies a force to said surface following element.

27. An automatically operative medical insertion device according to claim 25 and wherein said navigation subsystem is operative to measure the changes in the electrical outputs produced by the Hall effect sensors indicating the direction in which the tip is bent.

28. An automatically operative medical insertion device according to claim 27 and wherein said navigation subsystem is operative to sense the position of said tip and the past history of tip positions and to determine the location of said tip in said living organism and relative to said reference pathway.

29. An automatically operative medical insertion device according to claim 27 and wherein said navigation subsystem is operative to navigate said tip according to said reference pathway.

30. An automatically operative medical insertion device according to claim 29 and wherein said navigation subsystem is operative to sense that said tip touches the end of the trough beneath the epiglottis.

31. An automatically operative medical insertion device according to claim 27 and wherein said navigation subsystem is operative to sense that said tip reaches the tip of the epiglottis.

32. An automatically operative medical insertion device according to claim 27 and wherein said navigation subsystem is operative to sense that the tip reached the first cartilage of the trachea.

33. An automatically operative medical insertion device according to claim 32 and wherein said navigation subsystem is operative to sense that the tip reached the second cartilage of the trachea.

34. An automatically operative medical insertion device according to claim 33 and wherein said navigation subsystem is operative to sense that the tip reached the third cartilage of the trachea.

35. An automatically operative medical insertion device according to any of the preceding claims and wherein said navigation subsystem is operative to load said reference pathway from a memory.

36. An automatically operative medical insertion device according to claim 17 and wherein said driving subsystem is operative to push said tube forward.

37. An automatically operative medical insertion device according to any of the preceding claims and wherein said driving subsystem comprises:

a first motor operative to selectably move said insertable element forward or backward;

a second motor operative to selectably bend said insertable element; and

electronic circuitry operative to control said first motor, said second motor and said surface following element.

38. An automatically operative medical insertion device according to claim 37 and wherein said electronic circuitry comprises a microcontroller operative to execute a program, said program operative to control the said first and second motors and said surface following element and to insert and bend said insertable element inside said living organism along said reference pathway

39. An automatically operative medical insertion device according to claim 37 or claim 38 and wherein said driving subsystem is operative to measure the electric current drawn by at least one of said first and second motors to evaluate the position of said surface following element.

40. An automatically operative medical insertion device according to any of the preceding claims and wherein said reference pathway is operative to be at least partially prepared before the insertion process is activated.

41. An automatically operative medical insertion device according to claim 40 and wherein said medical insertion device comprises a medical imaging system and wherein said medical imaging system is operative to at least partially prepare said reference pathway.

42. An automatically operative medical insertion device according to claim 41 and wherein said medical imaging subsystem comprises at least one of an ultrasound scanner, an X-ray imager, a CAT scan system and an MRI system.

43. An automatically operative medical insertion device according to claim 40 and wherein said medical imaging system is operative to prepare said reference pathway by marking at least one contour of at least one organ of said living organism.

44. An automatically operative medical insertion device according to claim 41 and wherein said medical imaging system is operative to prepare said reference pathway by creating an insertion instruction table comprising at least one insertion instruction.

45. An automatically operative medical insertion device according to claim 44 and wherein said insertion instruction comprises instruction to at least one of extend, retract and bend said insertable element.

46. An automatically operative medical insertion device according to claim 44 and wherein said navigation subsystem is operative to control said driving subsystem based at least partially on a perceived location of said surface following element and according to said insertion instruction table stored in said navigation subsystem.

47. An automatically operative medical insertion device according to any of the preceding claims and wherein said operative medical insertion device is operative to at least partially store a log of a process of insertion of said insertable element.

48. An automatically operative medical insertion device according to claim 46 and wherein said medical insertion device comprises a computer and wherein said medical insertion device is operative to transmit said log of a process of insertion of said insertable element.

49. An automatically operative medical insertion device according to claim 48 and wherein said computer is operative to aggregate said logs of a process of insertion of said insertable element.

50. An automatically operative medical insertion device according to claim 49 and wherein said computer is operative to prepare said reference pathway based at least partially on said aggregate.

51. An automatically operative medical insertion device according to claim 50 and wherein said computer transmits said reference pathway to said medical insertion device.

52. An automatically operative medical insertion device according to claim 1 and wherein said insertable element comprises a guiding element and a guided element.

53. An automatically operative medical insertion device according to claim 52 and wherein said driving subsystem is operative to direct said guiding element and said guided

element at least partially together.

54. An automatically operative medical insertion device comprising:

an insertable element which is adapted to be inserted within a living organism in vivo;

a surface following element, physically associated with said insertable element and being arranged to follow a physical surface within said living organism in vivo;

a driving subsystem operative to at least partially automatically direct said insertable element along said physical surface; and

a navigation subsystem operative to control said driving subsystem based at least partially on a perceived location of said surface following element along a reference pathway stored in said navigation subsystem;

said insertable element comprises a disposable mouthpiece.

55. An automatically operative medical insertion device according to claim 7 and wherein said driving subsystem is operative to at least partially automatically direct said guide in a combined motion comprising a longitudinal motion and lateral motion.

56. An automatically operative medical insertion method comprising:

inserting an insertable element within a living organism in vivo;

physically associating a surface following element with said insertable element and causing said surface following element to follow a physical surface within said living organism in vivo;

automatically and selectably directing said insertable element along said physical surface; and

controlling direction of said insertable element based at least partially on a perceived location of said surface following element along a reference pathway stored in said navigation subsystem.

57. An automatically operative medical insertion method according to claim 56 and

wherein said controlling comprises receiving surface characteristic information relating to said physical surface from said surface following element and employing said surface characteristic information to perceive the location of said surface following element along said reference pathway.

58. An automatically operative medical insertion method according to claim 57 and wherein said surface characteristic information comprises surface contour information.

59. An automatically operative medical insertion method according to claim 57 and wherein said surface characteristic information comprises surface hardness information.

60. An automatically operative medical insertion method according to claim 58 and wherein said surface contour information is three-dimensional.

61. An automatically operative medical insertion method according to claim 58 and wherein said surface contour information is two-dimensional.

62. An automatically operative medical insertion method according to any of claims 56 to 61 and wherein said insertable element is an endotracheal tube and wherein said physical surface comprises surfaces of the larynx and trachea.

63. An automatically operative medical insertion method according to any of claims 56 to 61 and wherein said insertable element is a gastroscope and wherein said physical surface comprises surfaces of the intestine.

64. An automatically operative medical insertion method according to any of claims 56 to 61 and wherein said insertable element is a catheter and wherein said physical surface comprises interior surfaces of the circulatory system.

65. An automatically operative medical insertion method according to any of the

claims 56 to 64 and also comprising generating reference pathway by imaging at least a portion of said living organism and generating said reference pathway based at least partially on an image generated by said imaging.

66. An automatically operative medical insertion method according to any of the claims 56 to 65 and also comprising generating said reference pathway comprising a standard contour map of a portion of the human anatomy.

67. An automatically operative medical insertion method according to claim 66 and also comprising precisely adapting said standard contour map to a specific patient.

68. An automatically operative medical insertion method according to claim 67 and also comprising automatically precisely adapting said standard contour map to a specific patient.

69. An automatically operative medical insertion method according to any of claims 56 to 68 and also comprising adapting said reference pathway to designate at least one impediment by an operator.

70. An automatically operative medical insertion method according to any of claims 56 to 69 and also comprising:

providing:

a flexible guide, said surface following element being mounted at a front end of said flexible guide;

a housing in which is disposed said driving subsystem;

a mouthpiece and a tube;

inserting said flexible guide through said tube;

inserting said tube trough said mouthpiece; and

driving said flexible guide employing said driving subsystem.

71. An automatically operative medical insertion method according to claim 70 and wherein said mouthpiece comprises a curved pipe through which said tube is inserted.

72. An automatically operative medical insertion method according to claim 71 and also comprising moving said guide in and out of said housing, through said curved pipe and through said tube employing said driving subsystem.

73. An automatically operative medical insertion method according to claim 72 and also comprising selectably bending a front end of said guide employing said driving subsystem.

74. An automatically operative medical insertion method according to any of claims 56 to 73 and also comprising moving said insertable element in and out of said living organism employing said driving subsystem.

75. An automatically operative medical insertion method according to any of claims 56 to 74 and also comprising selectably bending a front end of said insertable element.

76. An automatically operative medical insertion method according to any of claims 56 to 75 and wherein said surface following element comprises a tactile sensing element.

77. An automatically operative medical insertion method according to any of claims 56 to 77 and wherein said physically associating a surface following element with said insertable element comprises:

integrally forming a tip at one end of a short rod having a magnet on its other end;
extending said rod through the center of a spring disk;
firmly connecting said spring disk to said rod;
mounting said spring disk on one end of a cylinder;
mounting another end of said cylinder on a front end of said insertable element.

78. An automatically operative medical insertion method according to claim 78 and wherein said surface following element also comprises two Hall effect sensors, each Hall effect sensor having electrical terminals operative to provide electric current representing the distance of the magnet therefrom and also comprising:

mounting said Hall effect sensors inside said cylinder on a support and in close proximity to said magnet;

spacing said Hall effect sensors in the plane of the curvature of the curved pipe;

said tip sensor being operative such that when a force is exerted on the tip along an axis of symmetry of said cylinder, said tip is pushed against said spring disk, causing said magnet to approach said Hall effect sensors and when a force is exerted on said tip sideways in the plane of said Hall effect sensors, said tip rotates around a location where said rod engages said spring disk, causing said magnet to rotate away from one of said Hall effect sensors and closer to the other of the Hall effect sensors.

79. An automatically operative medical insertion method according to claim 70 and also comprising:

partially inserting said insertable element into the oral cavity;

causing the insertable element to extend in the direction of the trachea;

bending the guide clockwise until said surface following element engages a surface of the tongue, whereby this engagement applies a force to said surface following element.

80. An automatically operative medical insertion method according to claim 77 and also comprising measuring the changes in the electrical outputs produced by the Hall effect sensors indicating the direction in which the tip is bent by employing said navigation subsystem.

81. An automatically operative medical insertion method according to claim 80 and also comprising sensing the position of said tip and determining the location of said tip in

said living organism and relative to said reference pathway based on the past history of tip positions.

82. An automatically operative medical insertion method according to claim 80 and also comprising navigating said tip according to said reference pathway employing said navigation subsystem.

83. An automatically operative medical insertion method according to claim 82 and also sensing said tip touching the end of the trough beneath the epiglottis.

84. An automatically operative medical insertion method according to claim 80 and also comprising sensing said tip reaching the tip of the epiglottis.

85. An automatically operative medical insertion method according to claim 80 and also comprising sensing the tip reaching the first cartilage of the trachea.

86. An automatically operative medical insertion method according to claim 85 and also sensing the tip reaching the second cartilage of the trachea.

87. An automatically operative medical insertion method according to claim 86 and also sensing the tip reaching the third cartilage of the trachea.

88. An automatically operative medical insertion method according to any of claims 56 to 87 and also loading said reference pathway from a memory to said navigation subsystem.

89. An automatically operative medical insertion method according to claim 70 and also pushing said tube forward employing said driving subsystem.

90. An automatically operative medical insertion method according to claim any of claims 56 to 89 and wherein said driving subsystem comprises a first motor operative to selectably move said insertable element forward or backward and a second motor operative to selectably bend said insertable element; and

controlling said first motor, said second motor and said surface following element by employing said electronic circuitry.

91. An automatically operative medical insertion method according to claim 90 and wherein said electronic circuitry comprises a microprocessor and also comprising executing a program, said executing a program comprising:

controlling said first and second motors and said surface following element; and

inserting and bending said insertable element inside said living organism along said reference pathway.

92. An automatically operative medical insertion method according to claim 90 or claim 91 and also comprising:

measuring the electric current drawn by at least one of said first and second motors; and

evaluating the position of said surface following element;

by employing said driving subsystem.

93. An automatically operative medical insertion method according to any of claims 56 to 92 and also comprising preparing said reference pathway at least partially before the insertion process is activated.

94. An automatically operative medical insertion method according to claim 93 and wherein said medical insertion method comprises providing a medical imaging system and also comprising preparing said reference pathway at least partially by employing said medical imaging system.

95. An automatically operative medical insertion method according to claim 94 and wherein said medical imaging subsystem comprises at least one of an ultrasound scanner, an X-ray imager, a CAT scan system and an MRI system.

96. An automatically operative medical insertion method according to claim 93 and wherein also comprising preparing said reference pathway by marking at least one contour of at least one organ of said living organism.

97. An automatically operative medical insertion method according to claims 56 to 96 and also comprising preparing said reference pathway by creating an insertion instruction table comprising at least one insertion instruction.

98. An automatically operative medical insertion method according to claim 97 and wherein said insertion instruction comprises instruction to at least one of extend, retract and bend said insertable element.

99. An automatically operative medical insertion method according to claim 97 and wherein also comprising controlling said driving subsystem based at least partially on a perceived location of said surface following element and according to said insertion instruction table stored in said navigation subsystem.

100. An automatically operative medical insertion method according to any of claims 56 to 99 and also comprising storing at least partially a log of a process of insertion of said insertable element.

101. An automatically operative medical insertion method according to claim 100 and wherein said medical insertion method comprises providing a computer and also comprising transmitting said log of a process of insertion of said insertable element to said computer

102. An automatically operative medical insertion method according to claim 101 and aggregating said logs of a process of insertion of said insertable element by employing said computer.

103. An automatically operative medical insertion method according to claim 102 and also comprising preparing said reference pathway based at least partially on said aggregate.

104. An automatically operative medical insertion method according to claim 103 and also comprising transmitting said reference pathway from said computer to said medical insertion device.

105. An automatically operative medical insertion method according to any of the claims 56 to 104 and wherein said insertable element comprises a guiding element and a guided element.

106. An automatically operative medical insertion method according to claim 105 and wherein said driving subsystem is operative to direct said guiding element and a said guided element at least partially together.

107. An automatically operative medical insertion method according to claim 60 and wherein said directing comprises automatically and selectably directing said insertable element in a combined motion comprising a longitudinal motion and lateral motion.

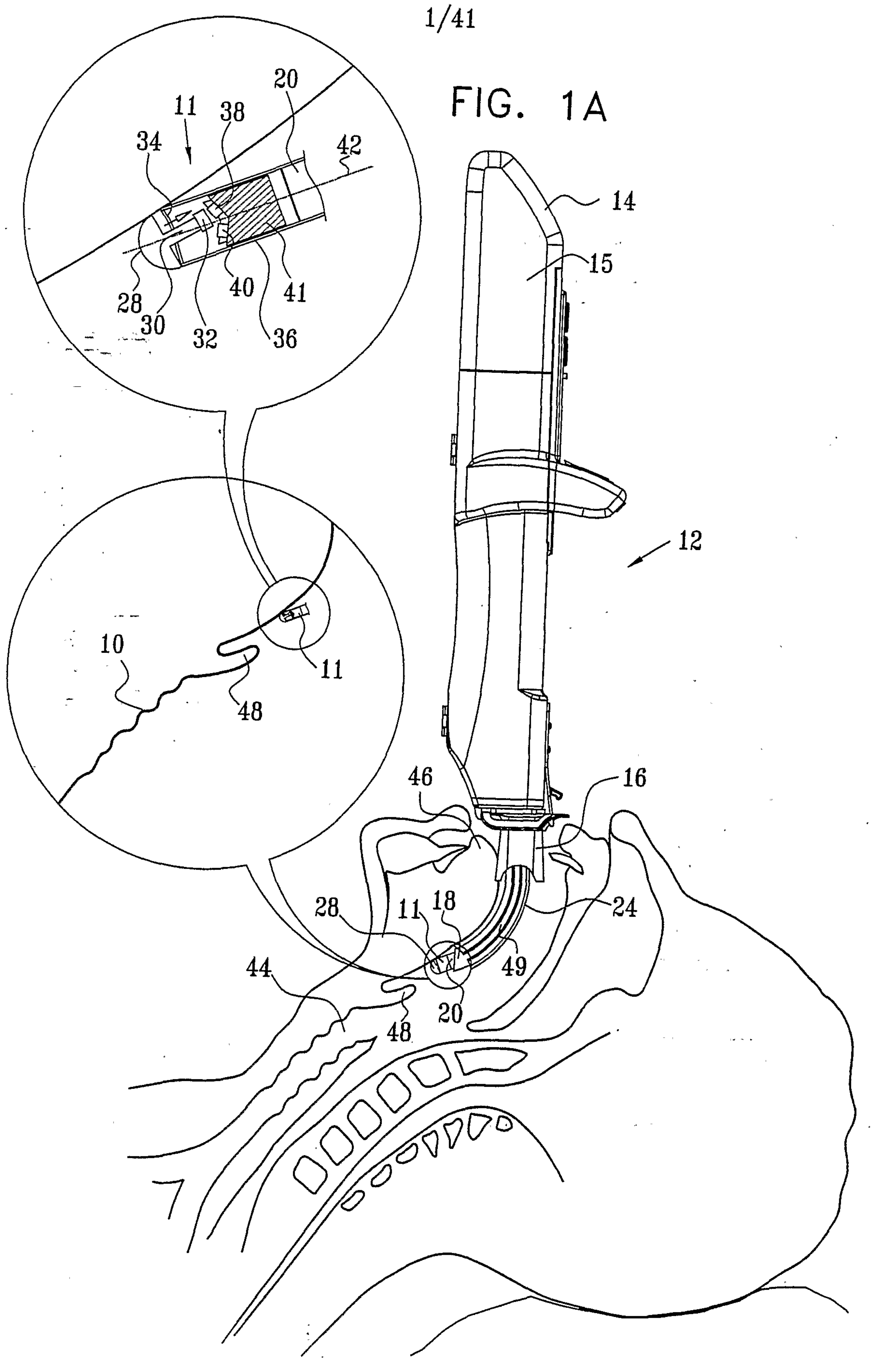
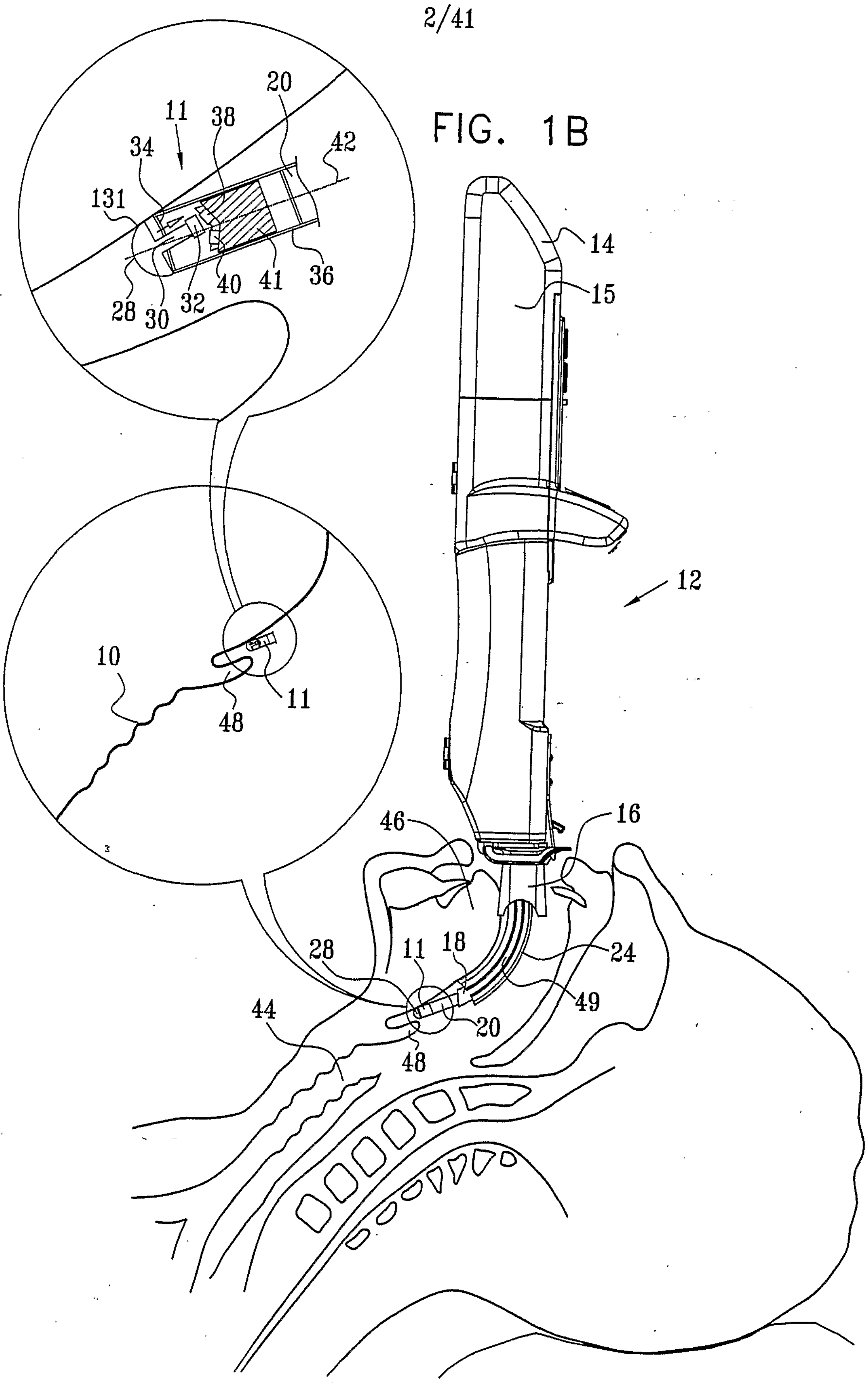


FIG. 1A

20
11
38
34
42
14
15
28
30
32
40
41
36
12
10
11
48
46
16
28
11
18
24
44
49
20
48

FIG. 1B



11
20
38
34
42
131
28
30
32
40
41
36
14
15
12
10
48
11
16
46
28
11
18
24
49
20
44
48

FIG. 1C

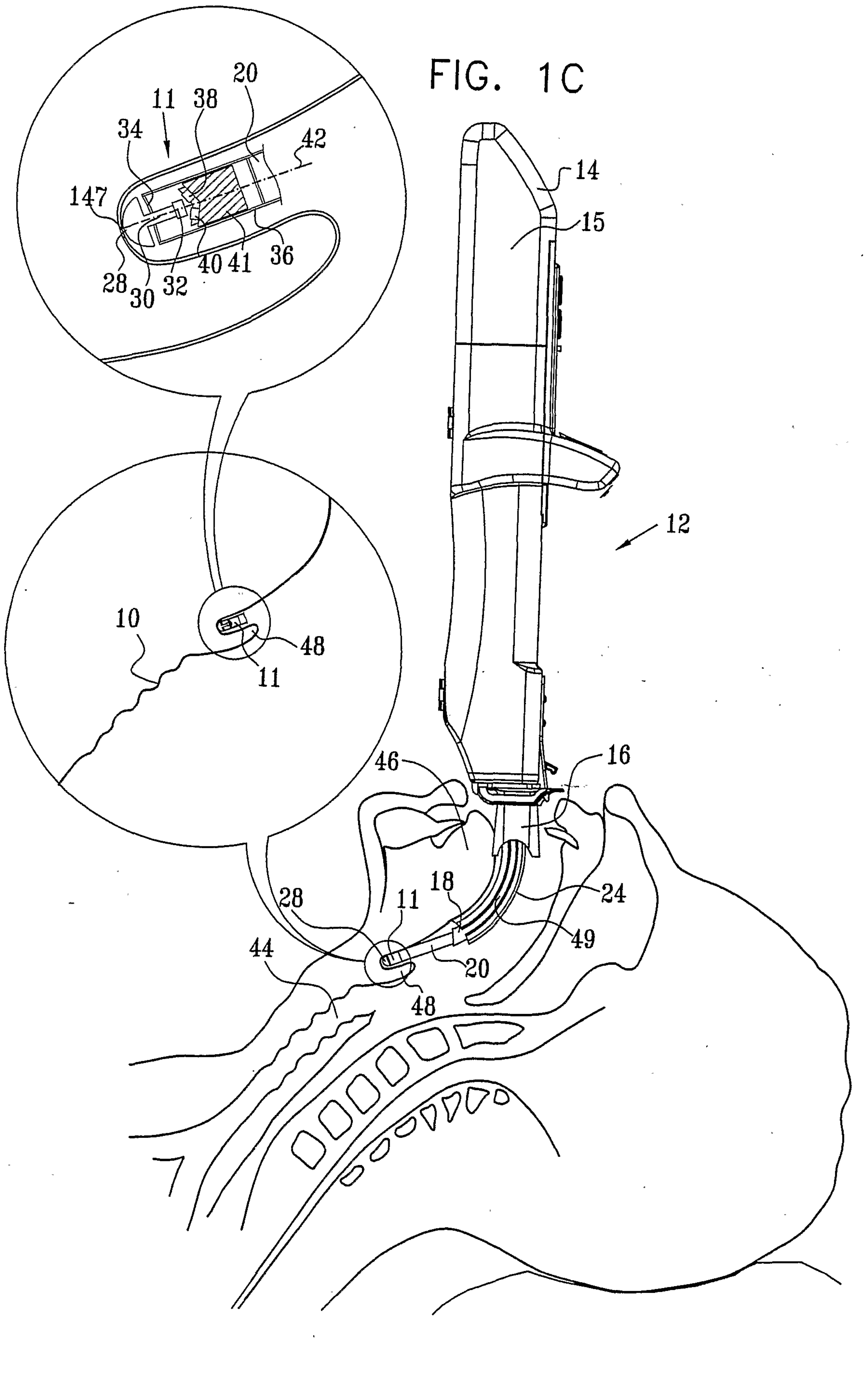

11
38
20
34
42
147
28
30
32
40
41
36
14
15
12
10
48
11
46
16
18
24
28
11
49
44
20
48

FIG. 1D

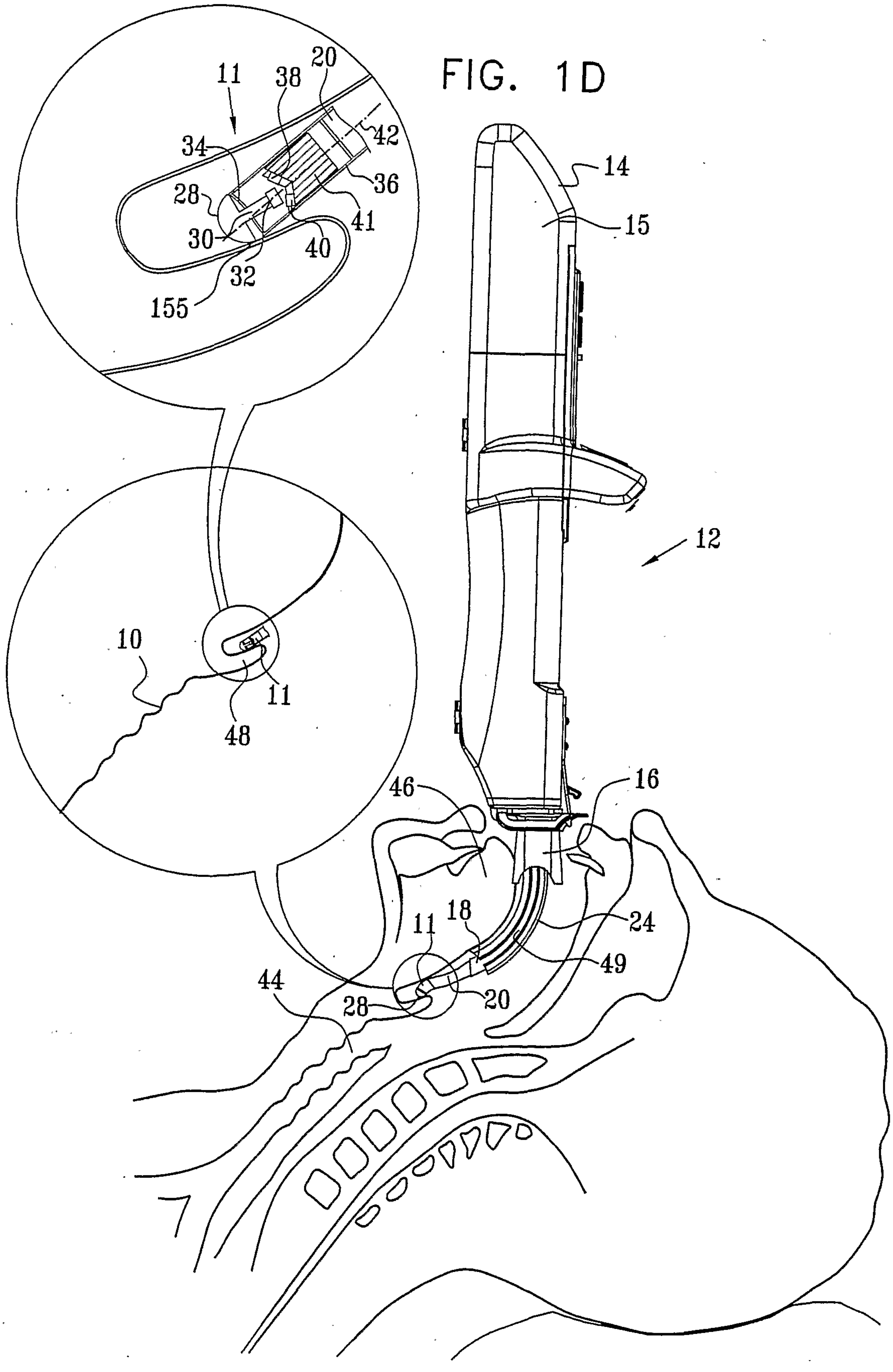

11
38
20
42
34
36
28
41
30
40
32
155
14
15
12
10
11
48
16
46
24
18
11
49
20
44
28

FIG. 1E

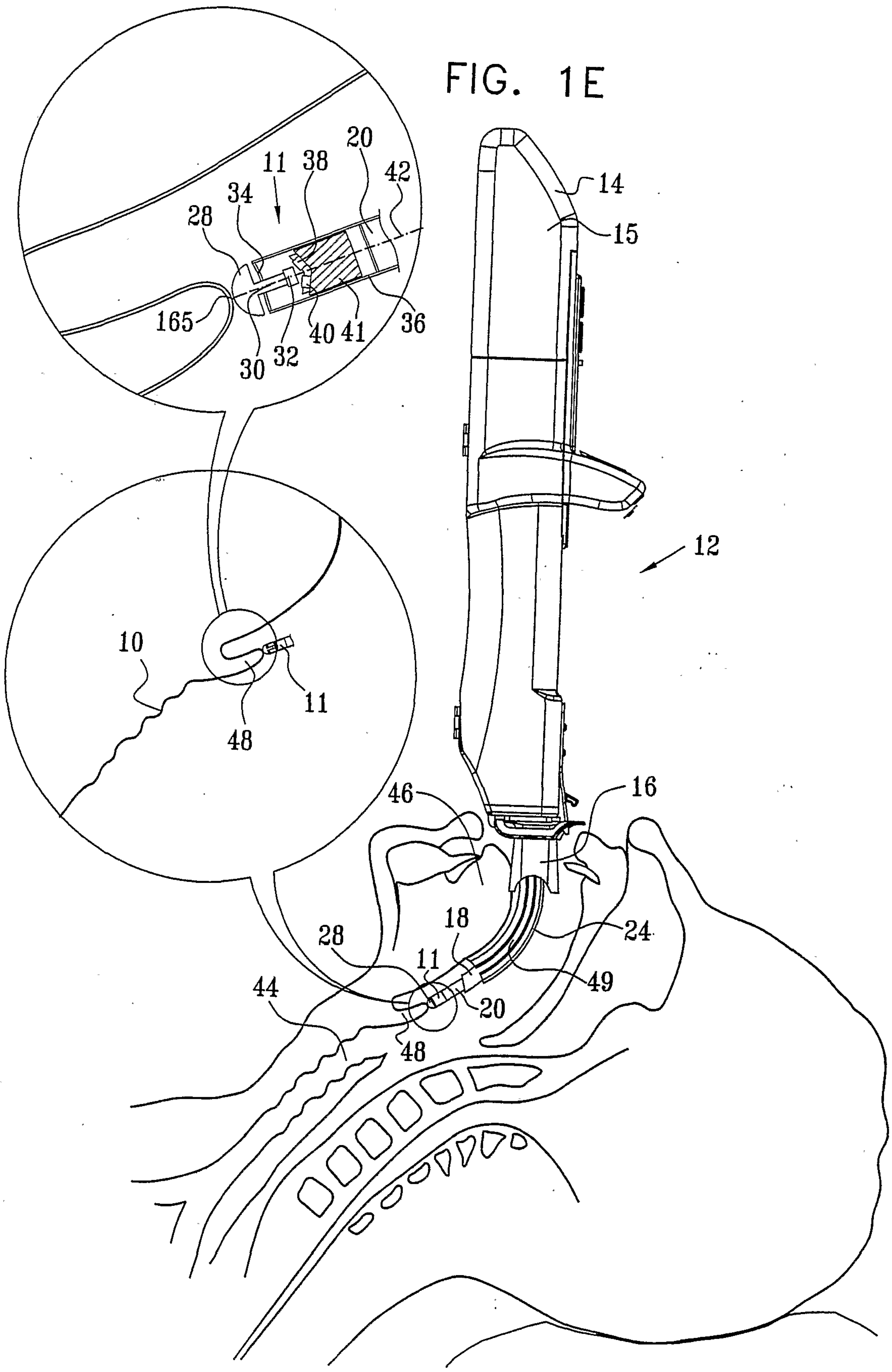

11
38
20
42
34
28
165
30
32
40
41
36
14
15
12
10
11
48
16
46
18
24
28
11
49
20
44
48

FIG. 1F

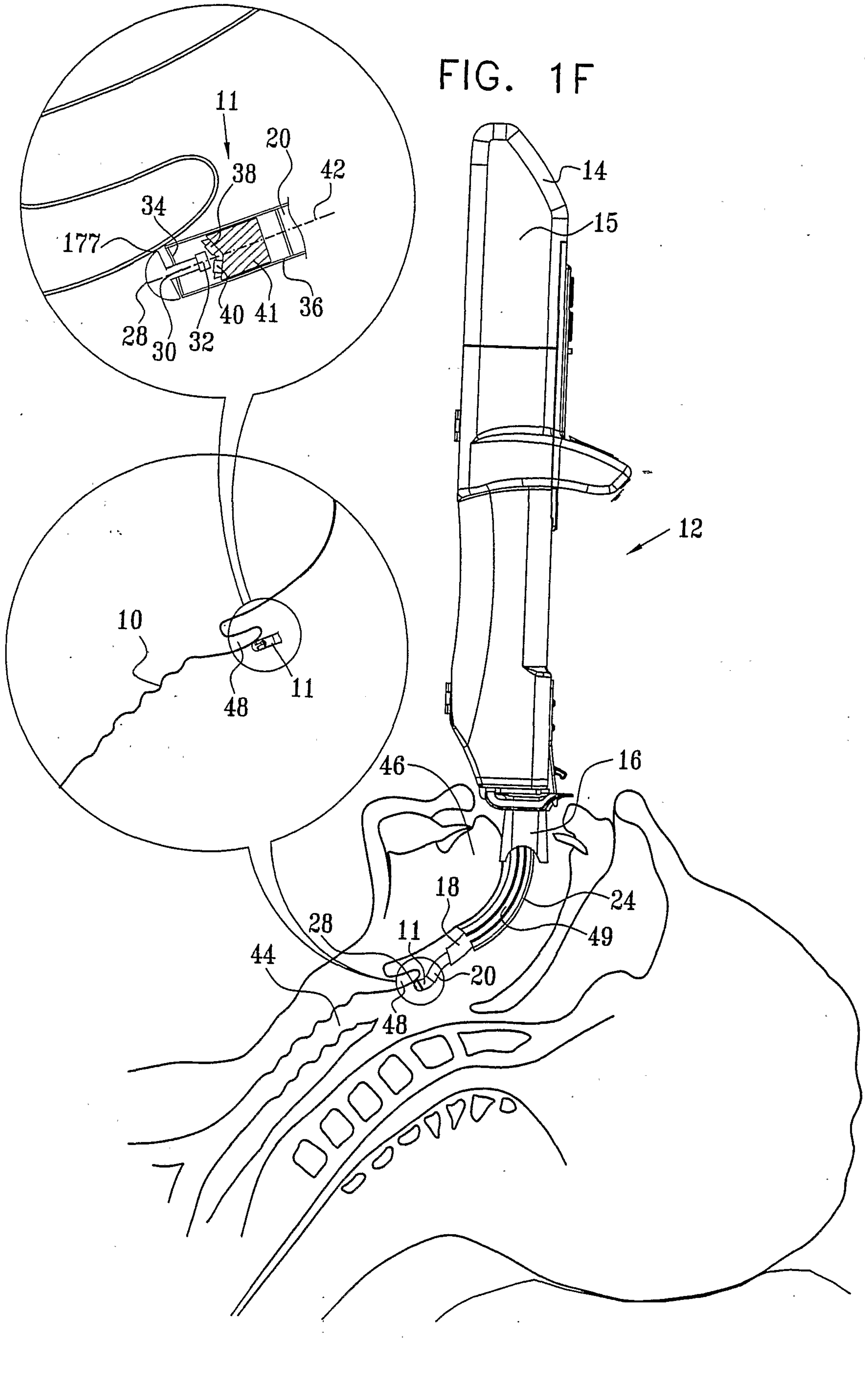

11
20
38
42
34
177
28
30
32
40
41
36
14
15
12
10
48
11
46
16
18
24
49
28
11
20
44
48

FIG. 1G

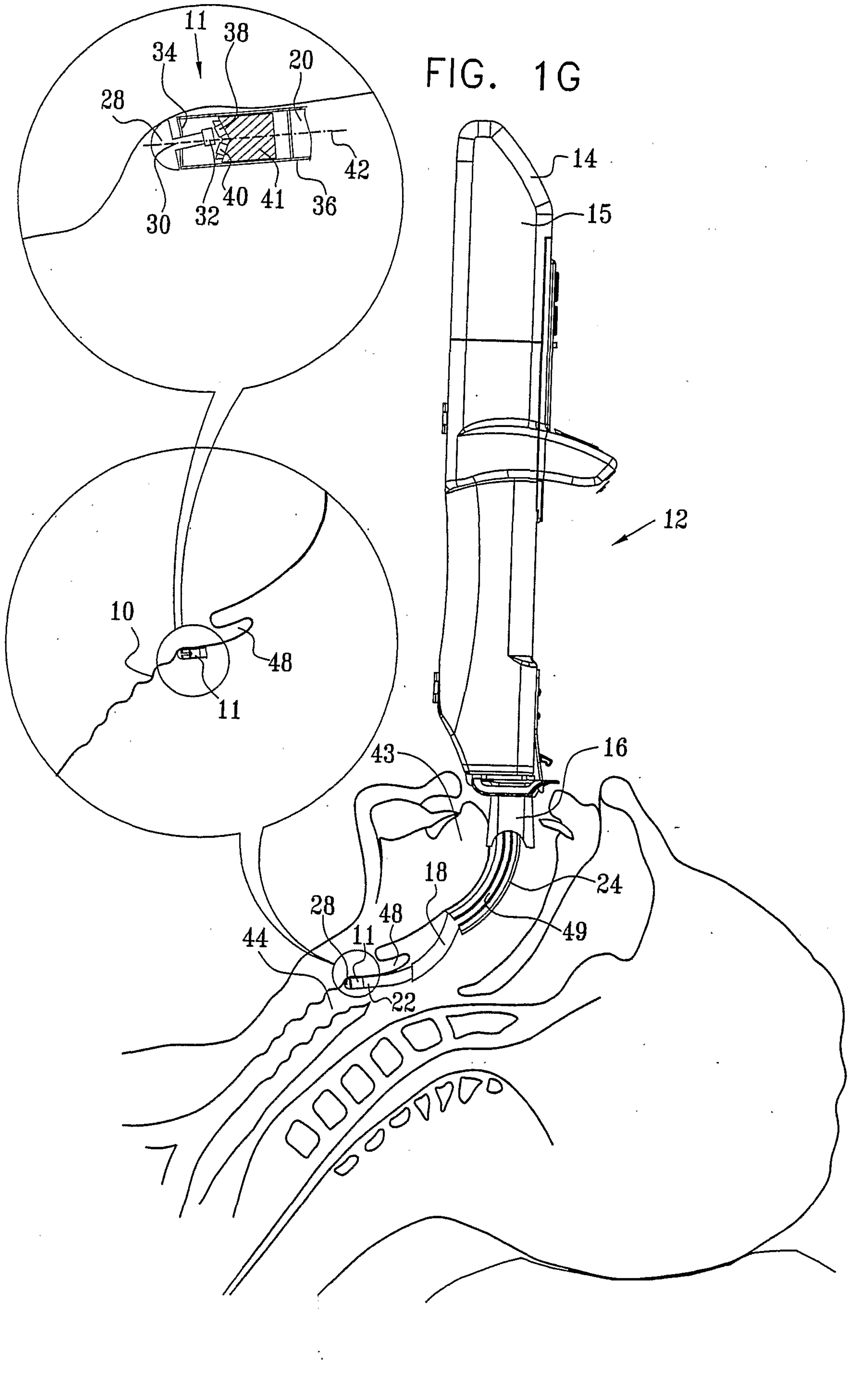

11
38
34
20
28
42
30
32
40
41
36
14
15
12
10
48
11
43
16
24
18
49
28
48
44
11
22

FIG. 1H

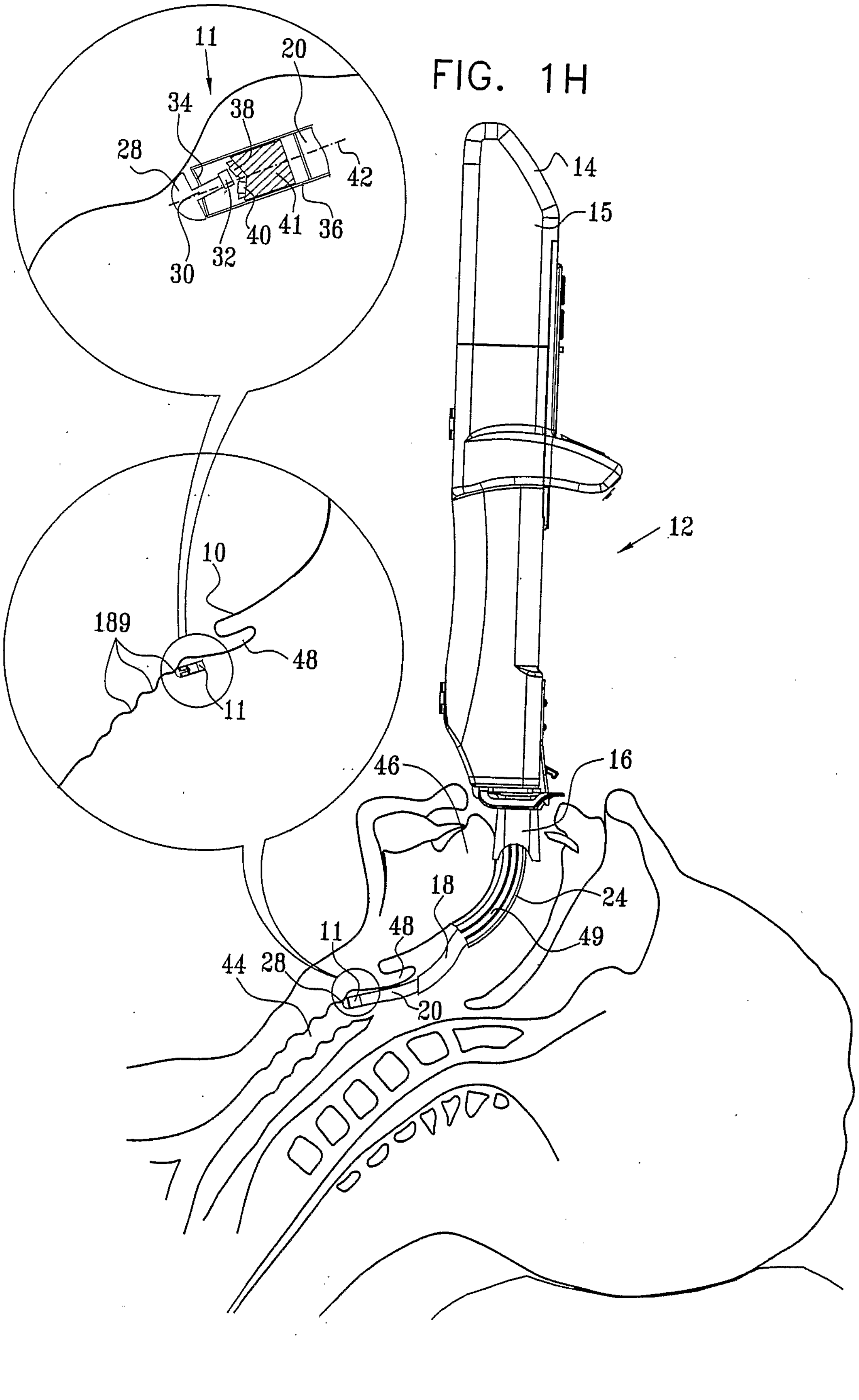

11
20
34
38
28
42
40
41
36
32
30
14
15
12
10
189
48
11
46
16
18
24
49
11
48
44
28
20

FIG. 11

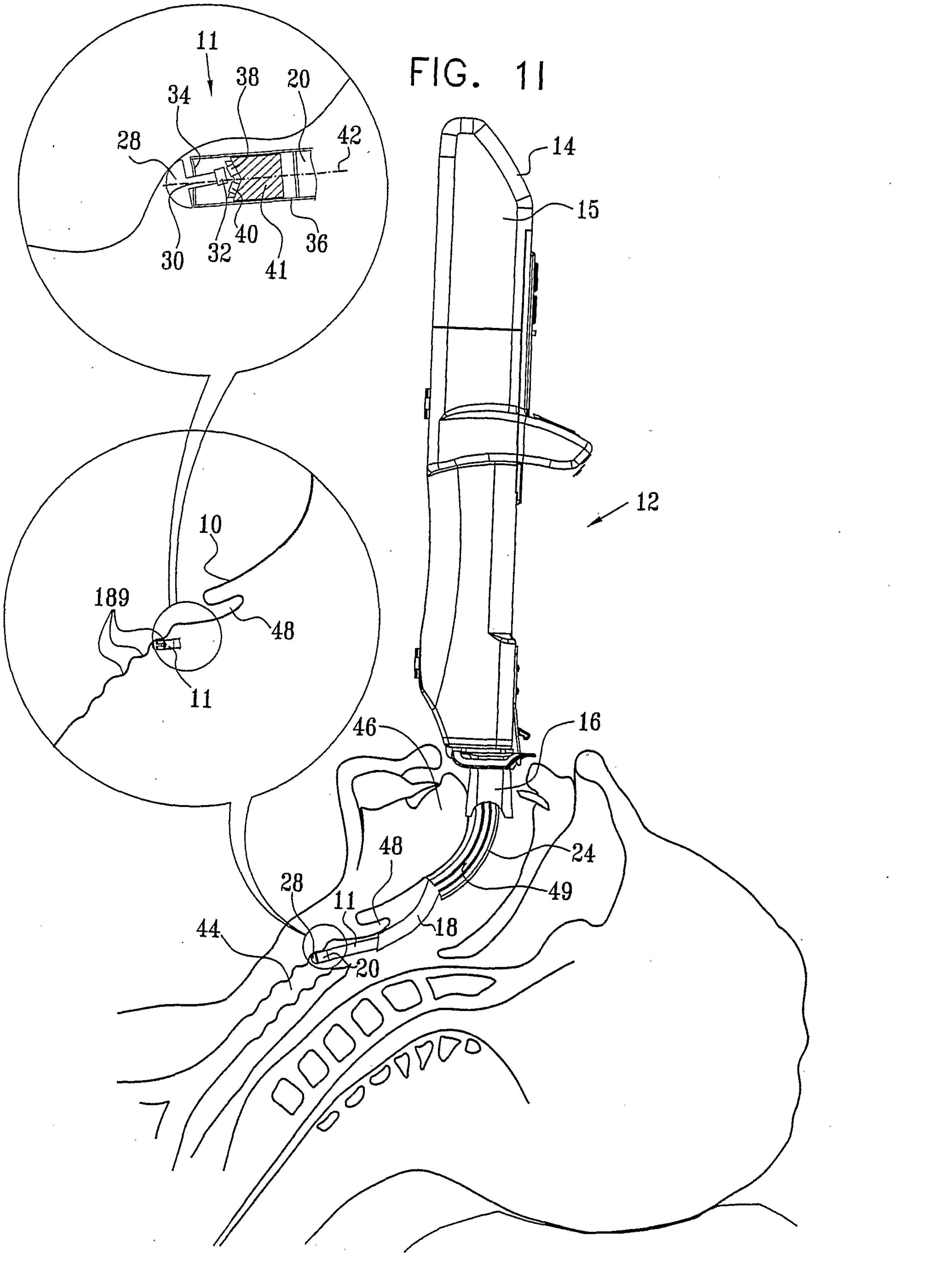

11
34
38
20
28
42
30
32
40
41
36
14
15
12
10
189
48
11
46
16
48
24
28
11
49
44
18
20

FIG. 1J

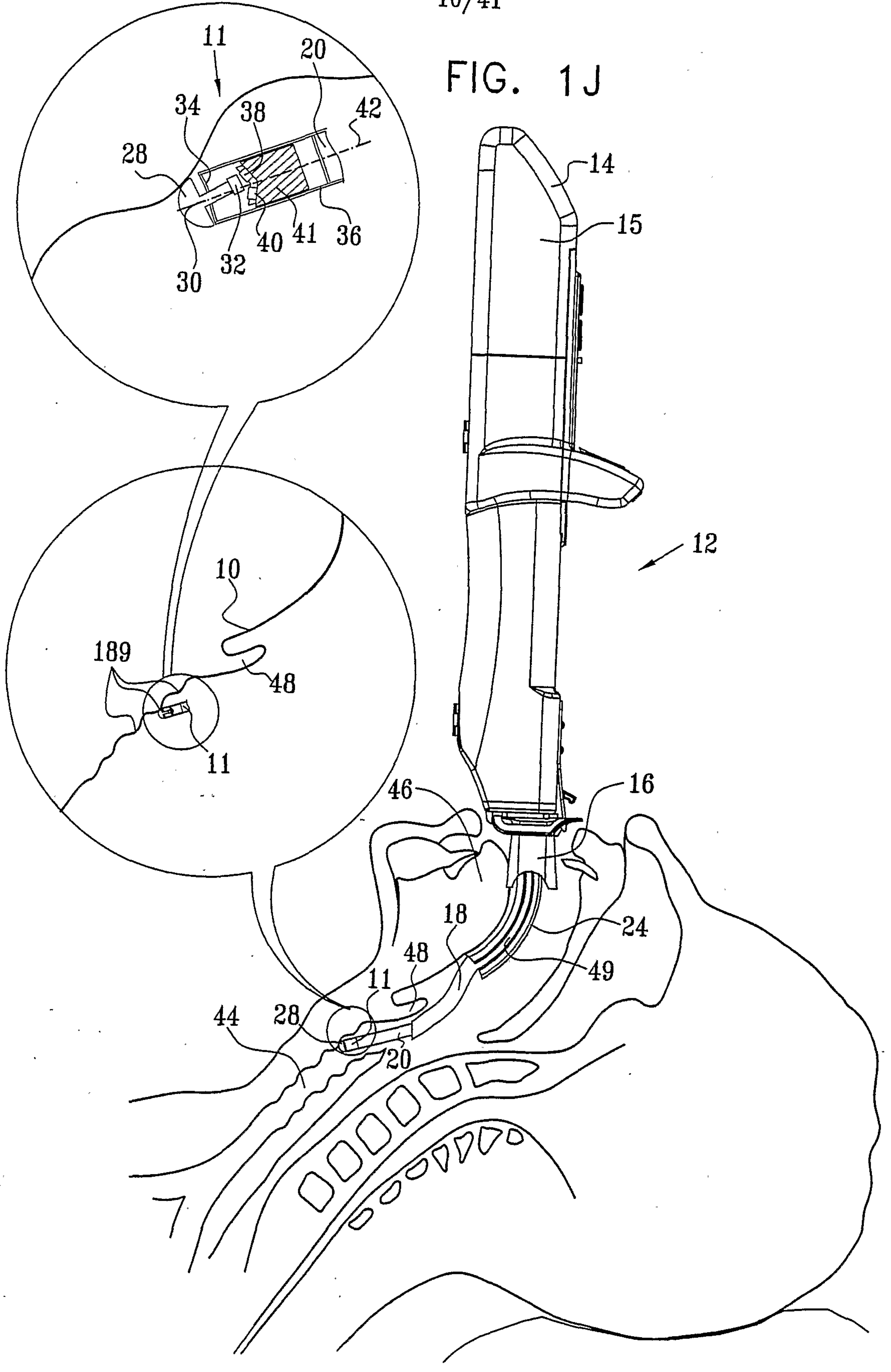
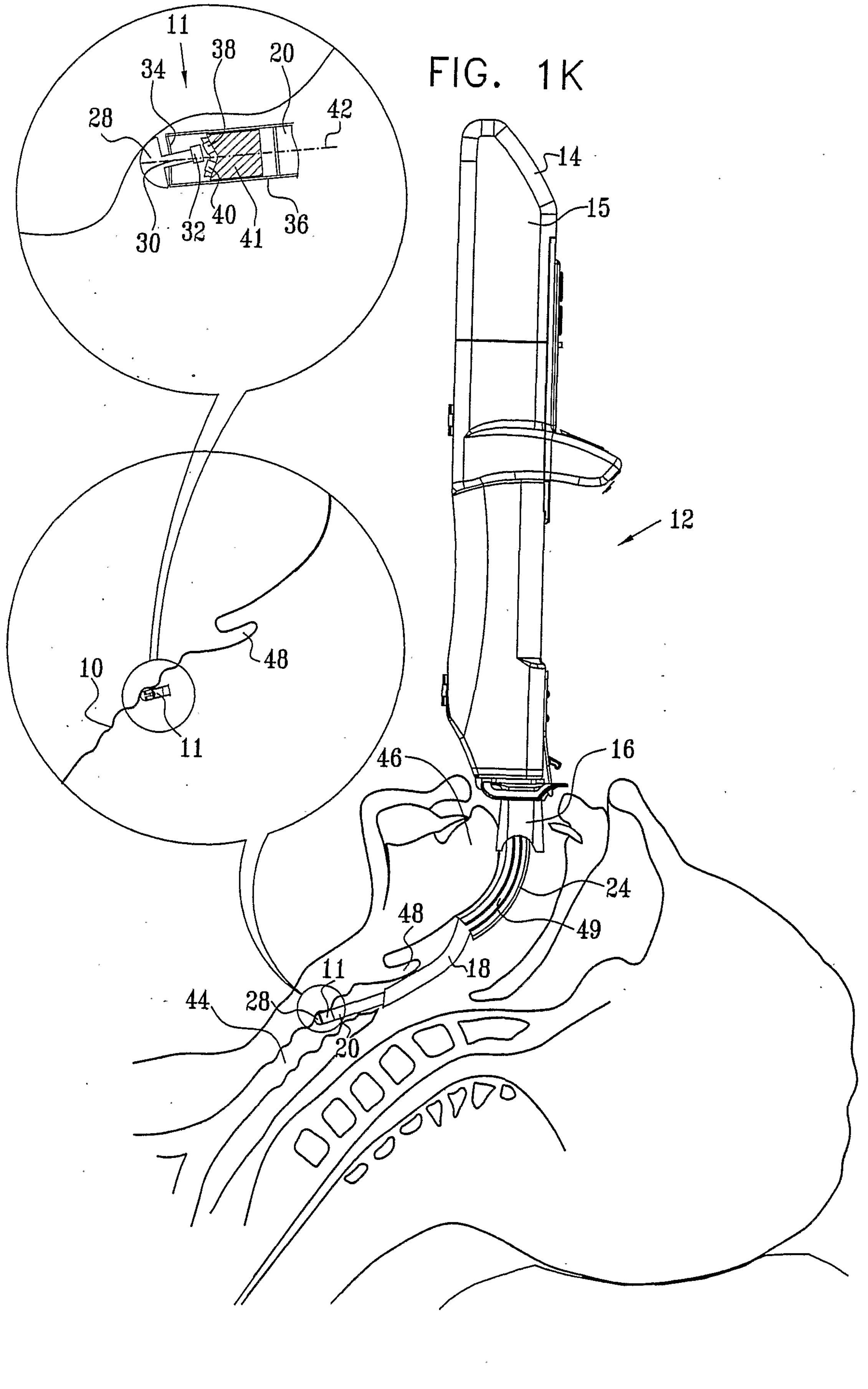

11
20
34
38
42
28
30
32
40
41
36
14
15
12
10
189
48
11
46
16
18
24
48
49
11
44
28
20

FIG. 1K


11
38
20
34
28
42
30
32
40
41
36
14
15
12
48
10
11
46
16
24
49
48
18
11
44
28
20

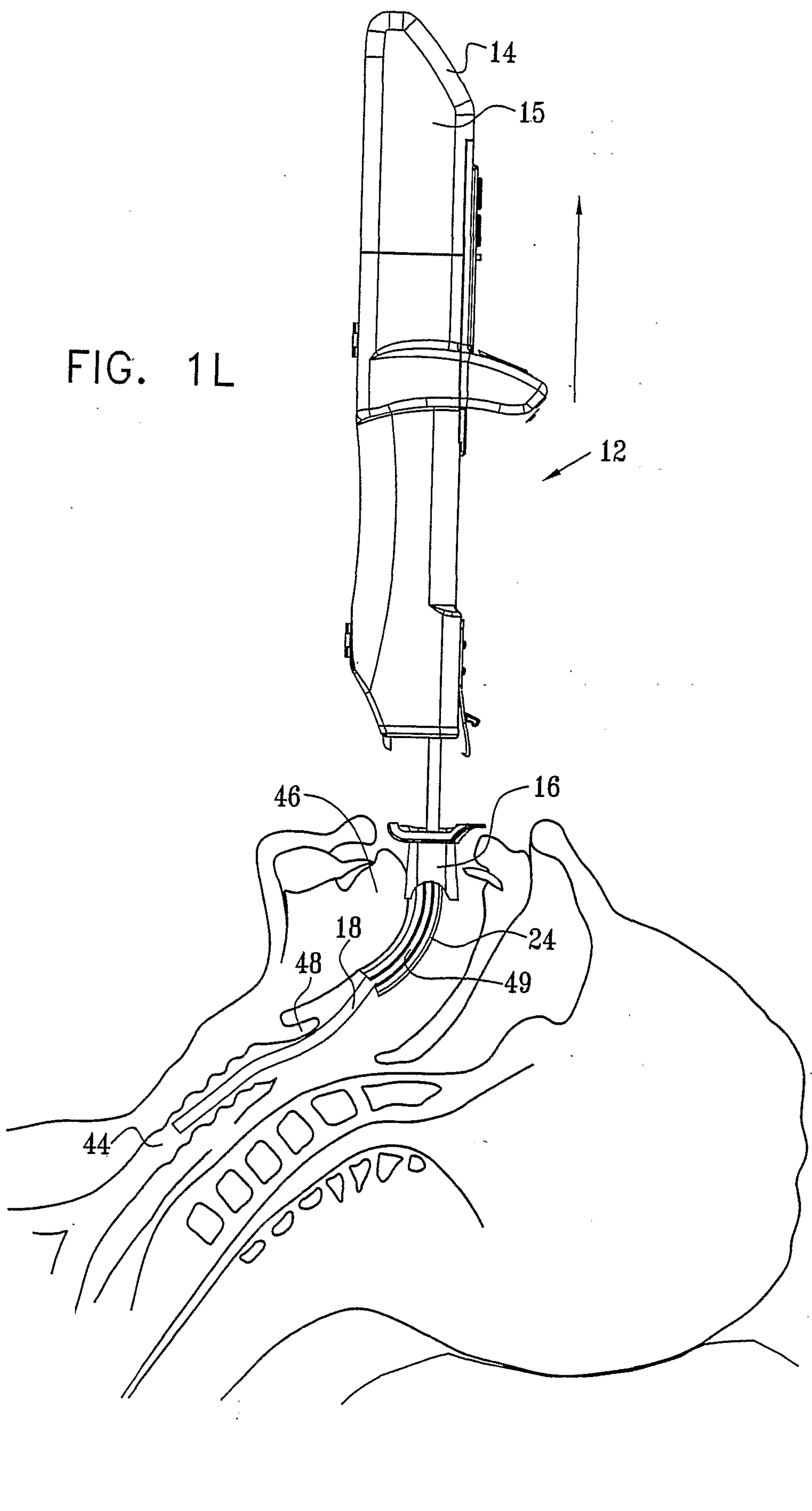
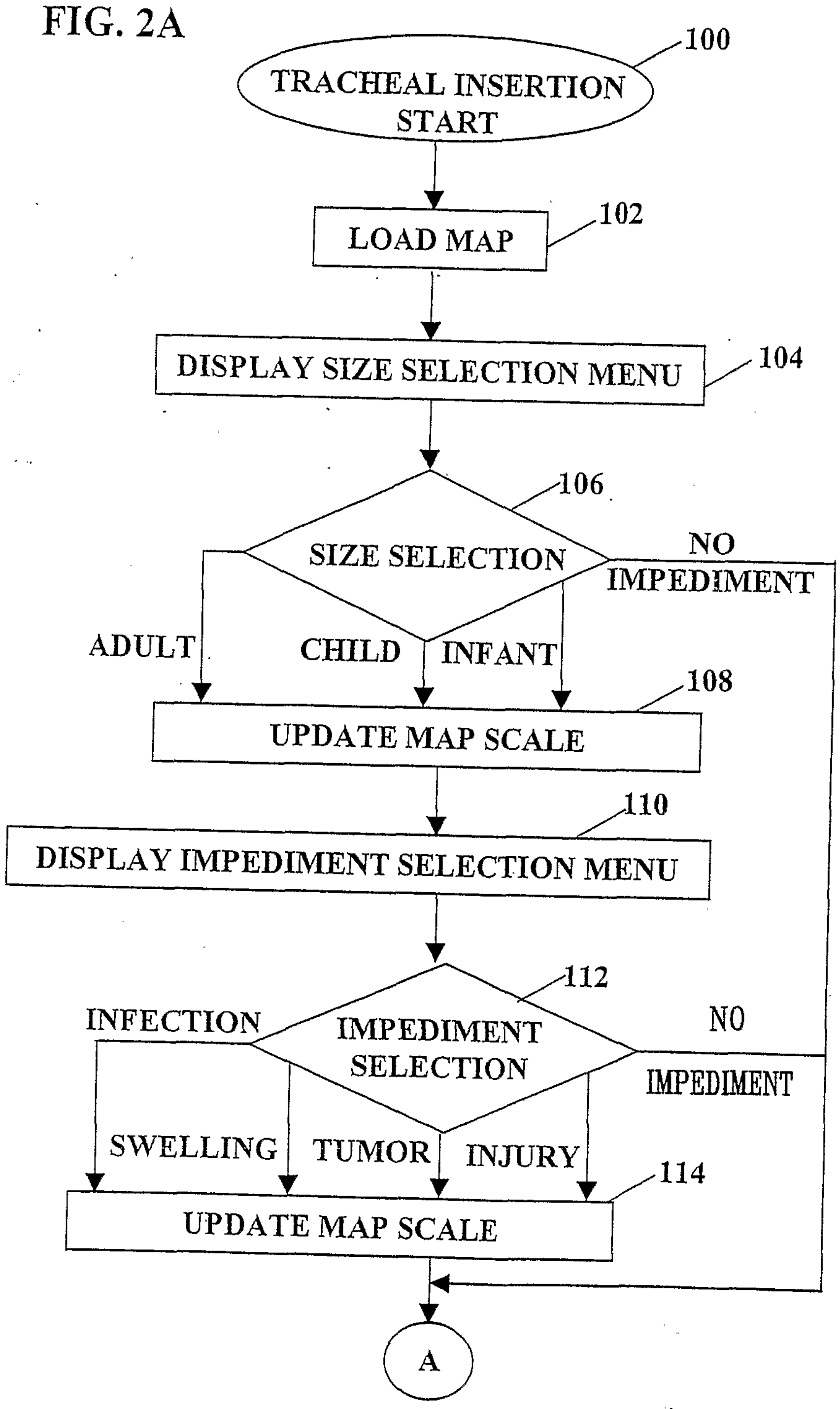


FIG. 1L

FIG. 2A



100
TRACHEAL INSERTION START
102
LOAD MAP
104
DISPLAY SIZE SELECTION MENU
106
SIZE SELECTION
NO IMPEDIMENT
ADULT
CHILD
INFANT
108
UPDATE MAP SCALE
110
DISPLAY IMPEDIMENT SELECTION MENU
112
IMPEDIMENT SELECTION
INFECTION
NO IMPEDIMENT
SWELLING
TUMOR
INJURY
114
UPDATE MAP SCALE
A

FIG. 2B

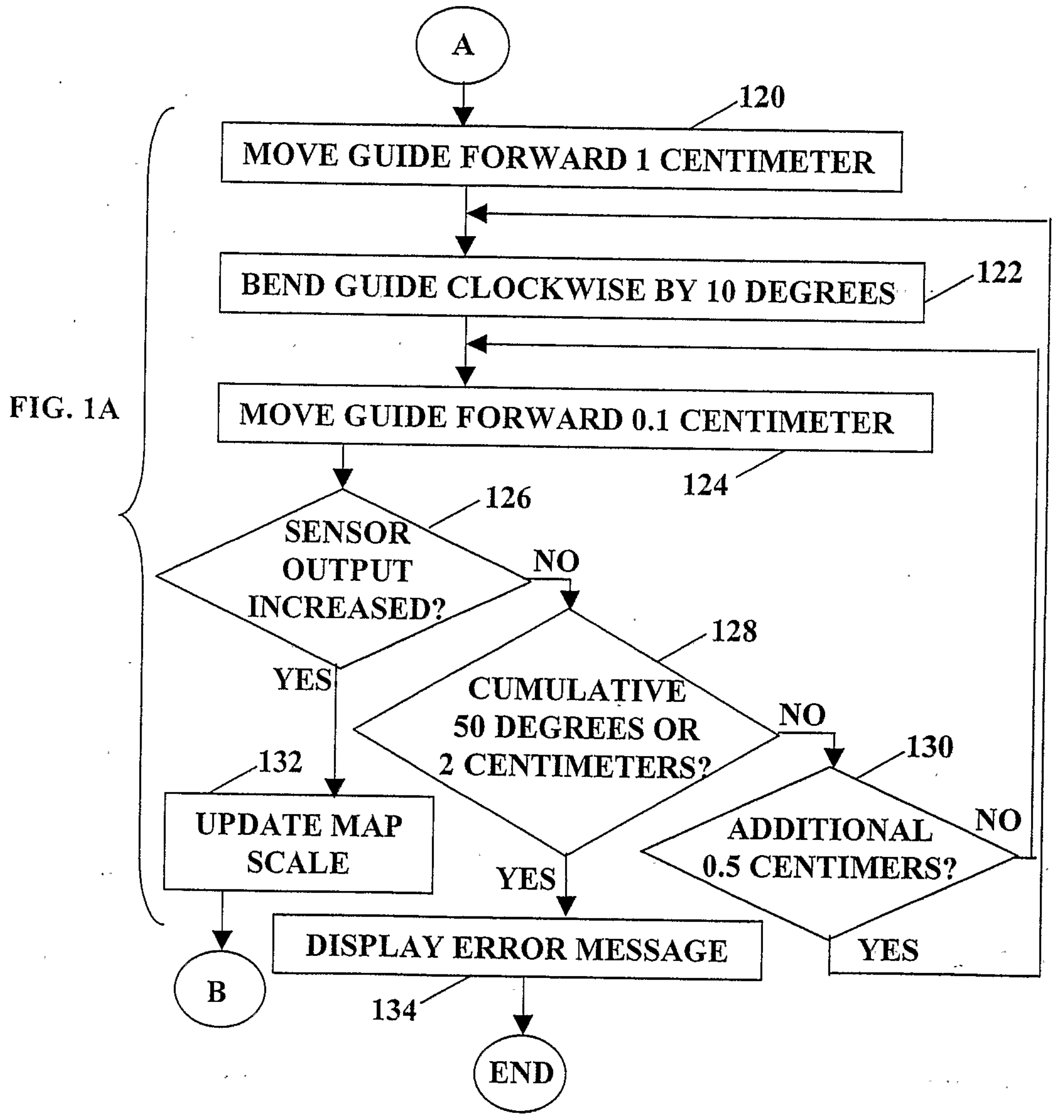

A
120
MOVE GUIDE FORWARD 1 CENTIMETER
BEND GUIDE CLOCKWISE BY 10 DEGREES
122
FIG. 1A
MOVE GUIDE FORWARD 0.1 CENTIMETER
124
126
SENSOR OUTPUT INCREASED?
NO
128
YES
CUMULATIVE 50 DEGREES OR 2 CENTIMETERS?
NO
130
132
UPDATE MAP SCALE
ADDITIONAL 0.5 CENTIMERS?
NO
YES
DISPLAY ERROR MESSAGE
YES
B
134
END

FIG. 2C

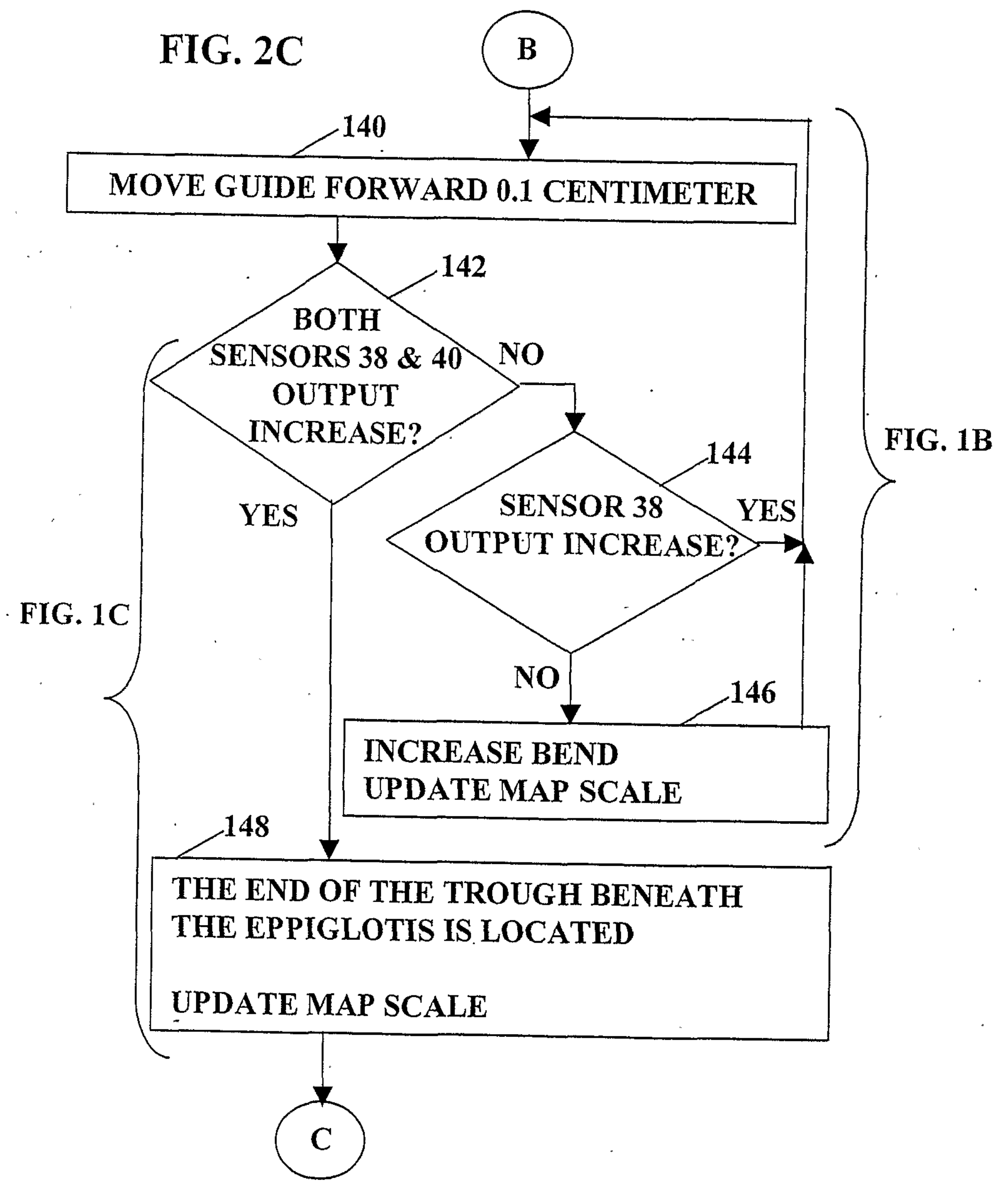

B
140
MOVE GUIDE FORWARD 0.1 CENTIMETER
142
BOTH SENSORS 38 & 40 OUTPUT INCREASE?
NO
YES
144
SENSOR 38 OUTPUT INCREASE?
YES
NO
146
INCREASE BEND
UPDATE MAP SCALE
148
THE END OF THE TROUGH BENEATH THE EPPIGLOTIS IS LOCATED
UPDATE MAP SCALE
C
FIG. 1B
FIG. 1C

FIG. 2D

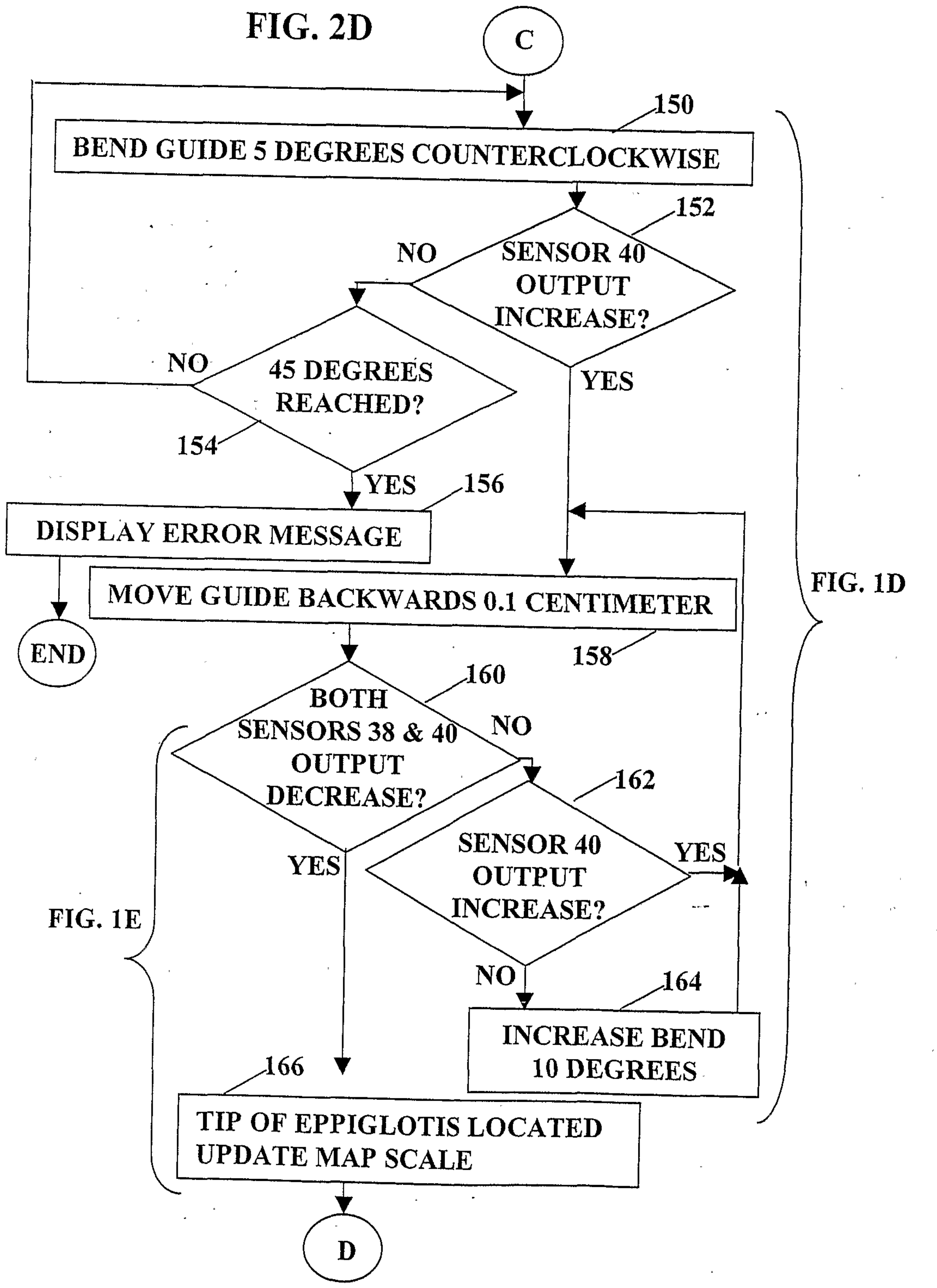

C
BEND GUIDE 5 DEGREES COUNTERCLOCKWISE
150
SENSOR 40 OUTPUT INCREASE?
152
NO
YES
45 DEGREES REACHED?
154
NO
YES
DISPLAY ERROR MESSAGE
156
END
MOVE GUIDE BACKWARDS 0.1 CENTIMETER
158
FIG. 1D
BOTH SENSORS 38 & 40 OUTPUT DECREASE?
160
NO
YES
SENSOR 40 OUTPUT INCREASE?
162
YES
NO
INCREASE BEND 10 DEGREES
164
FIG. 1E
TIP OF EPPIGLOTIS LOCATED UPDATE MAP SCALE
166
D

FIG. 2E

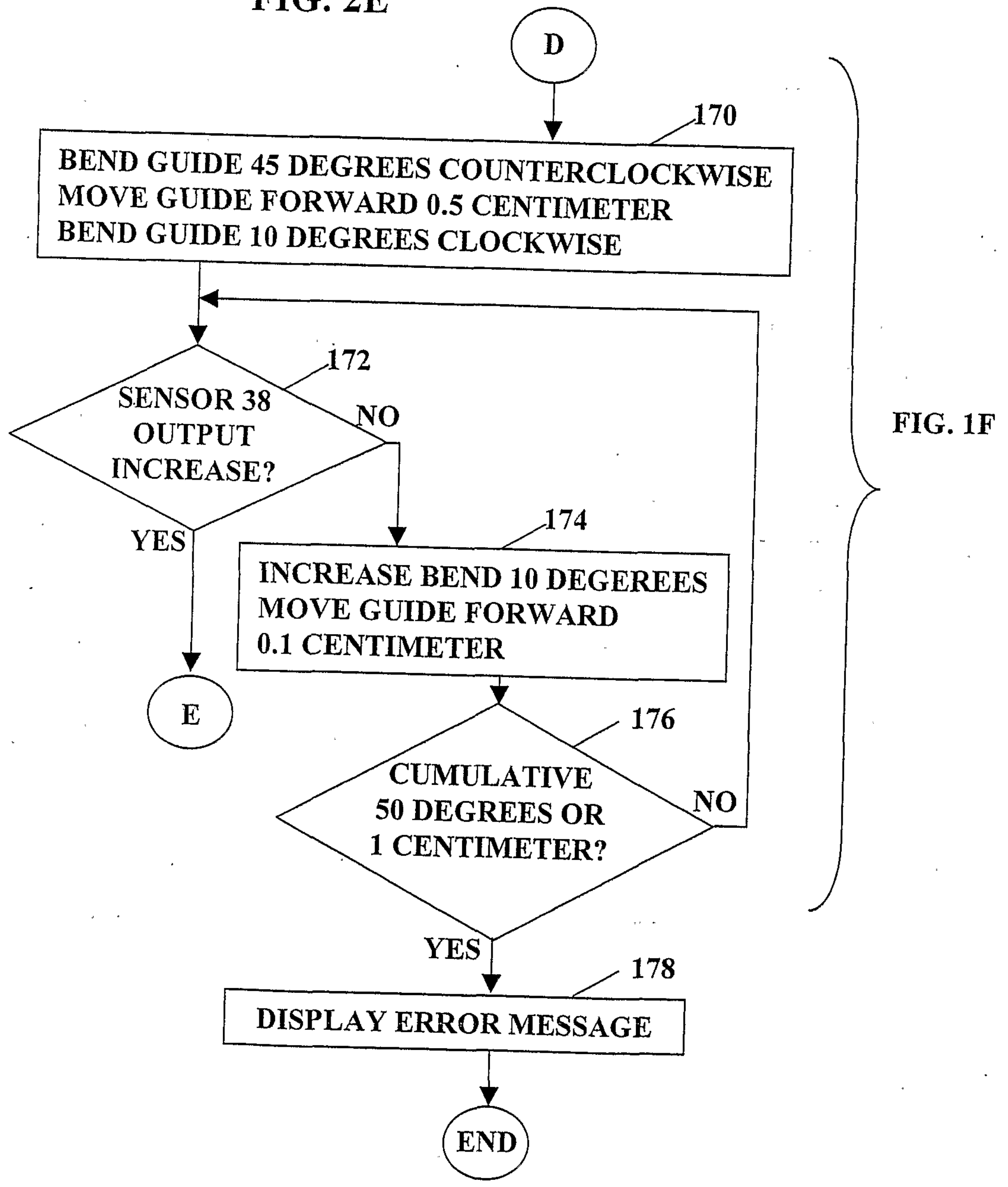
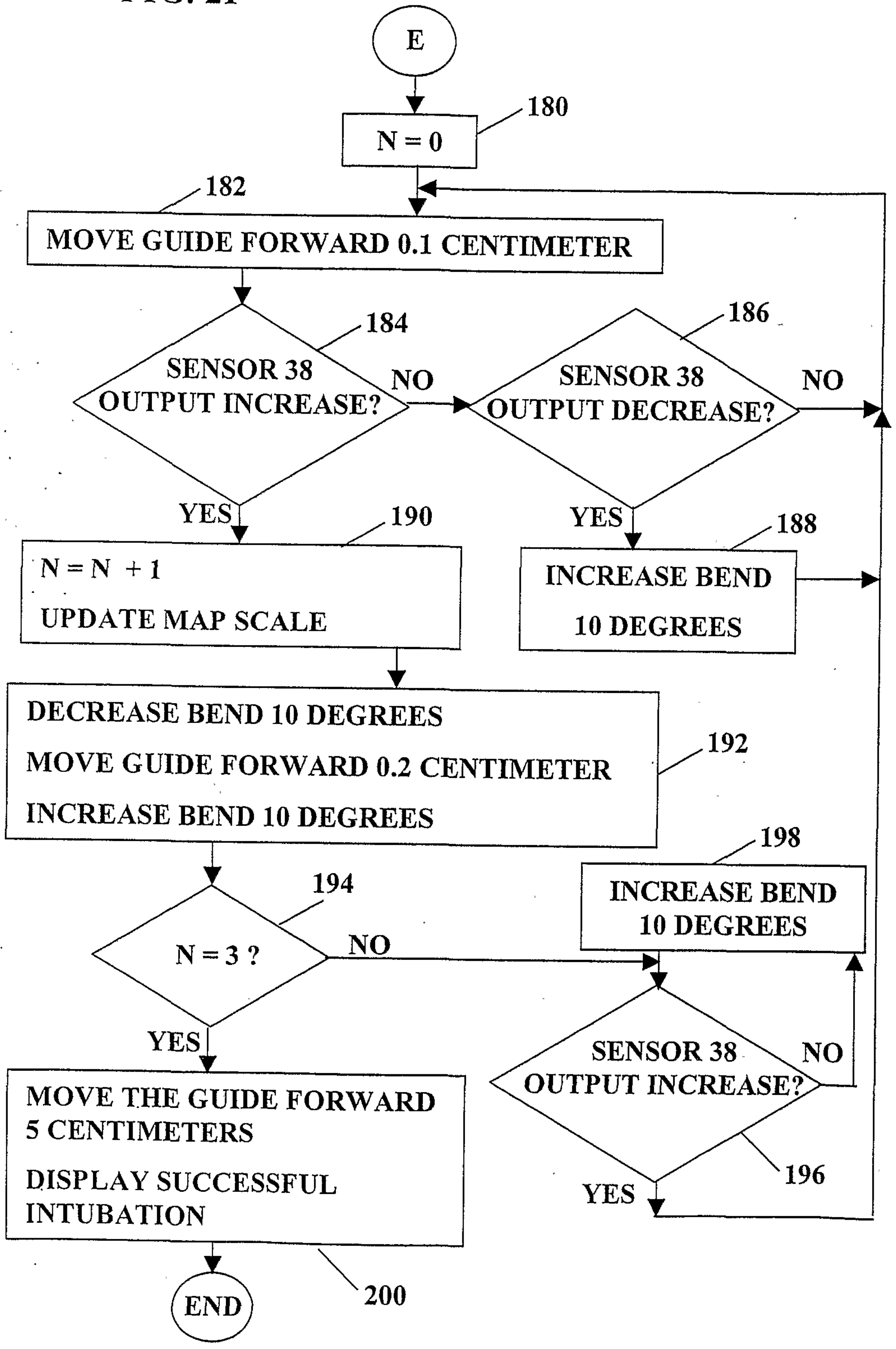

D
170
BEND GUIDE 45 DEGREES COUNTERCLOCKWISE
MOVE GUIDE FORWARD 0.5 CENTIMETER
BEND GUIDE 10 DEGREES CLOCKWISE
172
SENSOR 38 OUTPUT INCREASE?
NO
YES
E
174
INCREASE BEND 10 DEGEREES
MOVE GUIDE FORWARD
0.1 CENTIMETER
176
CUMULATIVE 50 DEGREES OR 1 CENTIMETER?
NO
YES
178
DISPLAY ERROR MESSAGE
END
FIG. 1F

FIG. 2F


E
180
N = 0
182
MOVE GUIDE FORWARD 0.1 CENTIMETER
184
SENSOR 38 OUTPUT INCREASE?
NO
186
SENSOR 38 OUTPUT DECREASE?
NO
YES
190
N = N + 1
UPDATE MAP SCALE
YES
188
INCREASE BEND 10 DEGREES
DECREASE BEND 10 DEGREES
MOVE GUIDE FORWARD 0.2 CENTIMETER
INCREASE BEND 10 DEGREES
192
198
INCREASE BEND 10 DEGREES
194
N = 3 ?
NO
YES
SENSOR 38 OUTPUT INCREASE?
NO
MOVE THE GUIDE FORWARD 5 CENTIMETERS
DISPLAY SUCCESSFUL INTUBATION
196
YES
END
200

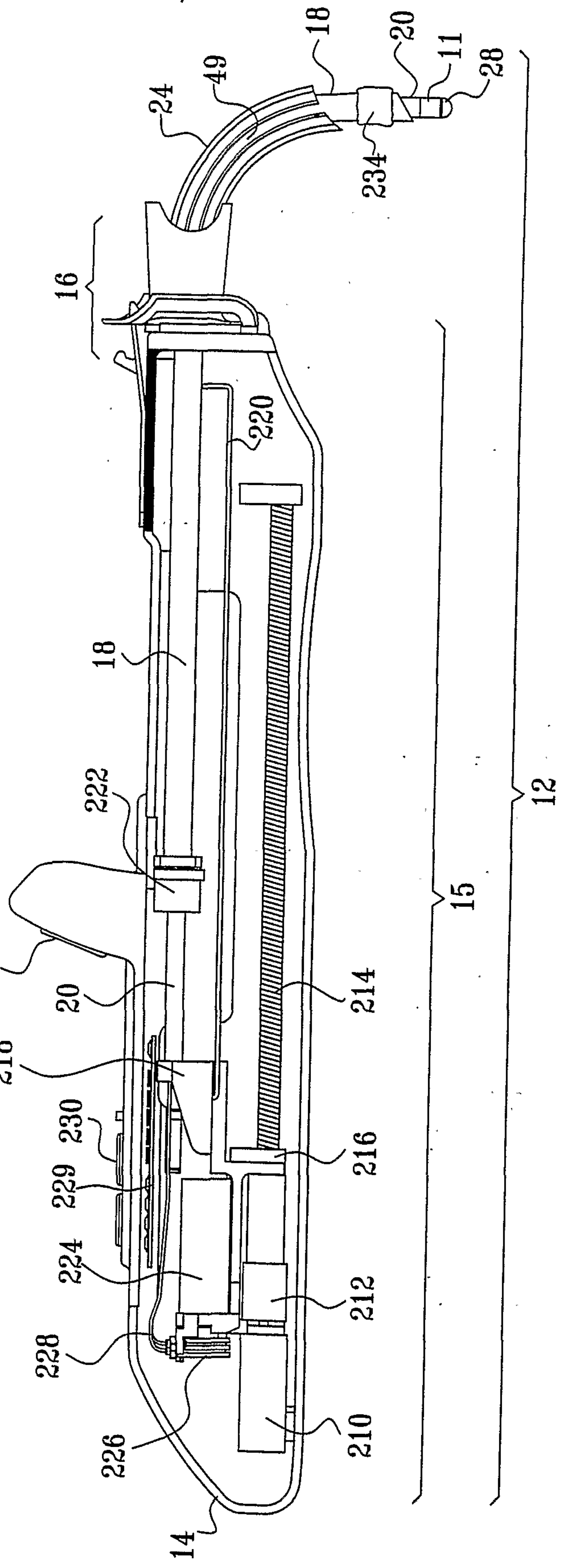

18
20
11
28
49
24
234
16
220
18
222
232
20
218
230
229
224
228
226
14
210
212
216
214
15
12

FIG. 3

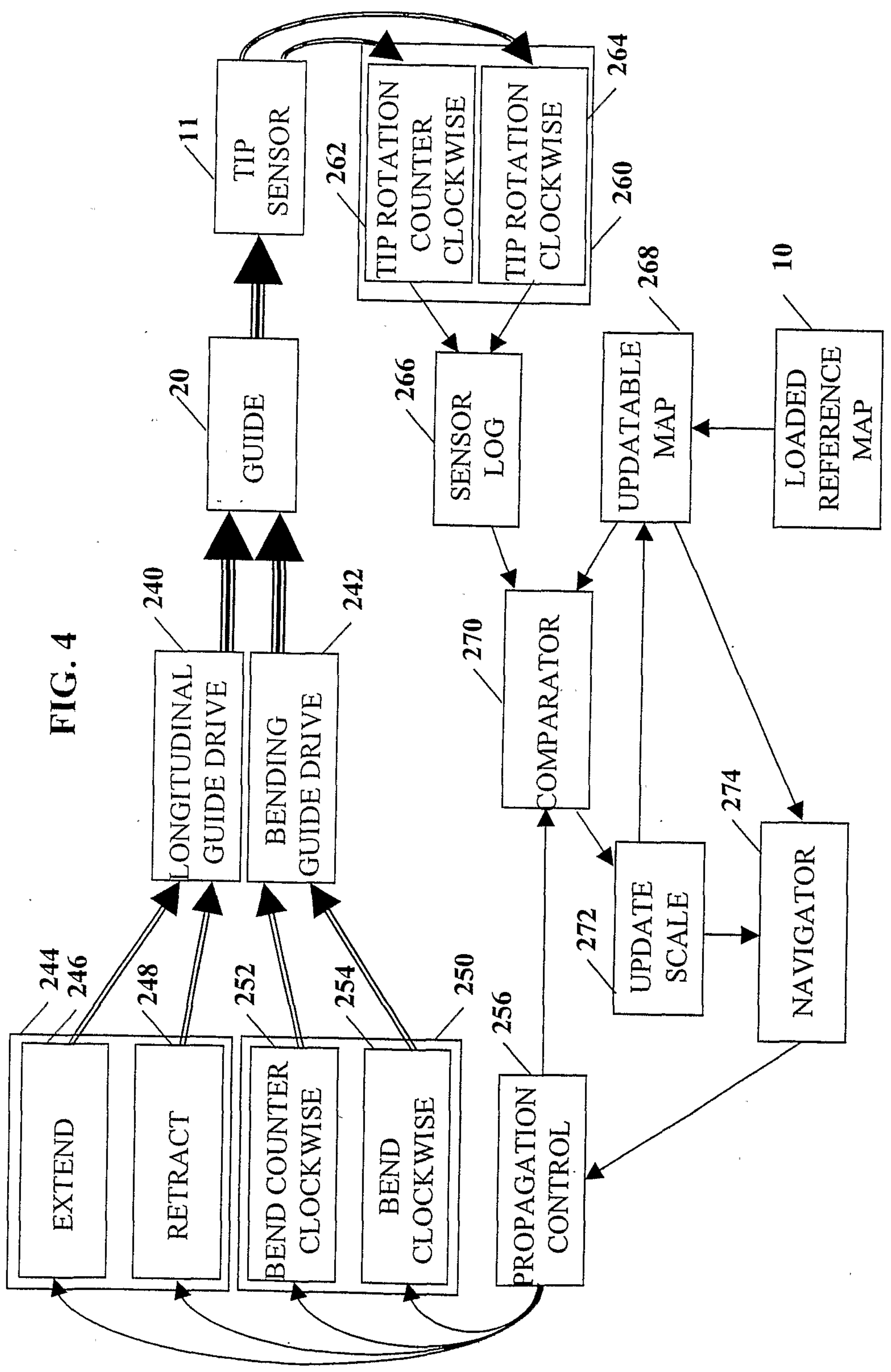
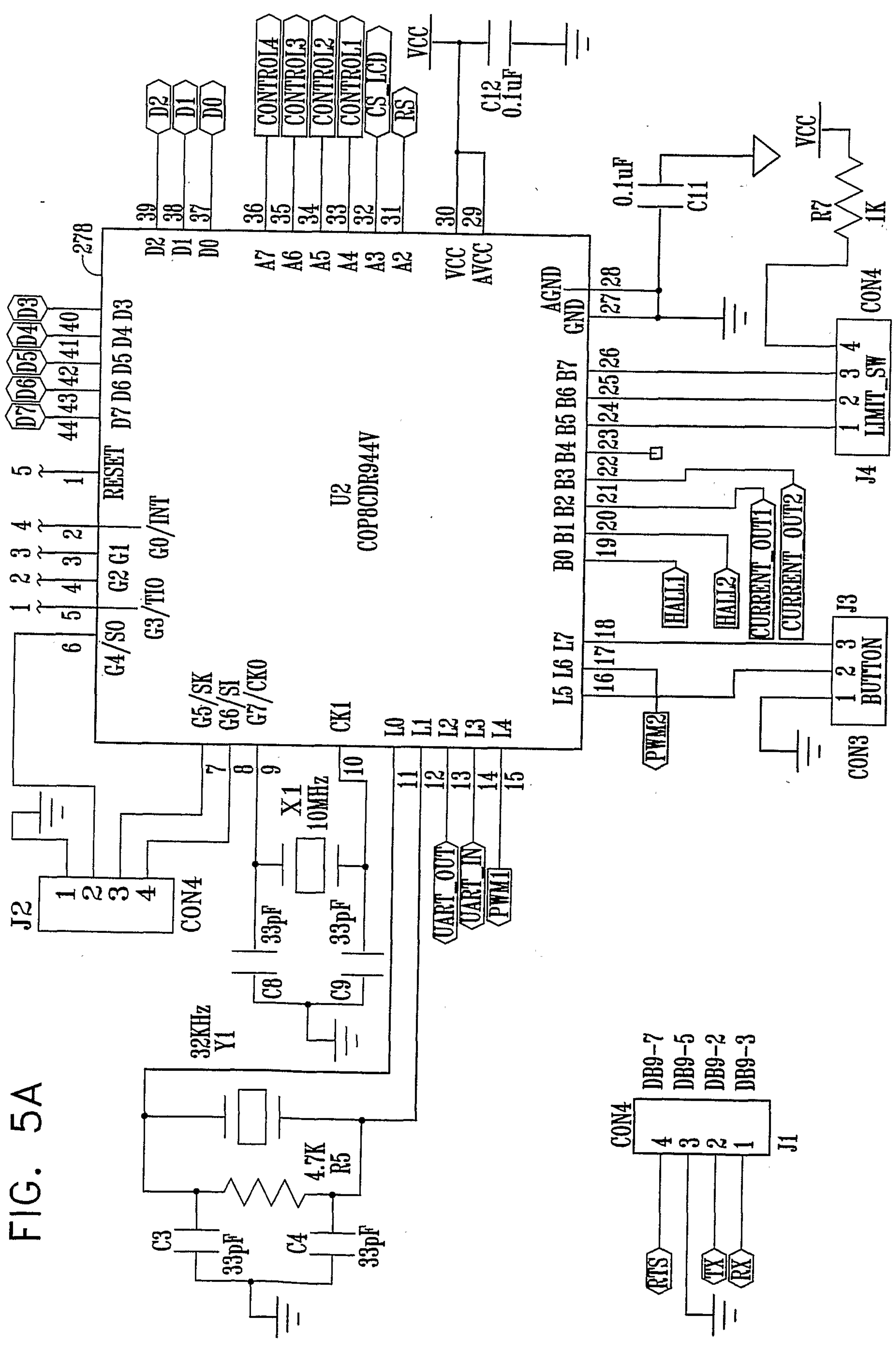

EXTEND
RETRACT
BEND COUNTER CLOCKWISE
BEND CLOCKWISE
PROPAGATION CONTROL
LONGITUDINAL GUIDE DRIVE
BENDING GUIDE DRIVE
GUIDE
TIP SENSOR
TIP ROTATION COUNTER CLOCKWISE
TIP ROTATION CLOCKWISE
SENSOR LOG
UPDATABLE MAP
LOADED REFERENCE MAP
COMPARATOR
UPDATE SCALE
NAVIGATOR
244
246
248
252
254
250
256
240
242
20
11
262
264
260
266
268
10
270
272
274

FIG. 4



278
U2
COP8CDR944V
D2 D1 D0
A7 A6 A5 A4 A3 A2
VCC AVCC
AGND GND
B0 B1 B2 B3 B4 B5 B6 B7
L5 L6 L7
L0 L1 L2 L3 L4
CK1
G5/SK G6/SI G7/CKO
G4/SO G3/TIO G2 G1 G0/INT
RESET
D7 D6 D5 D4 D3
CONTROL4 CONTROL3 CONTROL2 CONTROL1 CS_LCD RS
VCC
C12 0.1uF
C11 0.1uF
VCC
R7 1K
CON4
J4 LIMIT_SW
HALL1 HALL2 CURRENT_OUT1 CURRENT_OUT2
J3 BUTTON
CON3
PWM2
J2 CON4
X1 10MHz
C8 33pF
C9 33pF
UART_OUT UART_IN PWM1
32KHz Y1
4.7K R5
C3 33pF
C4 33pF
CON4 J1
DB9-7 DB9-5 DB9-2 DB9-3
RTS TX RX

FIG. 5A

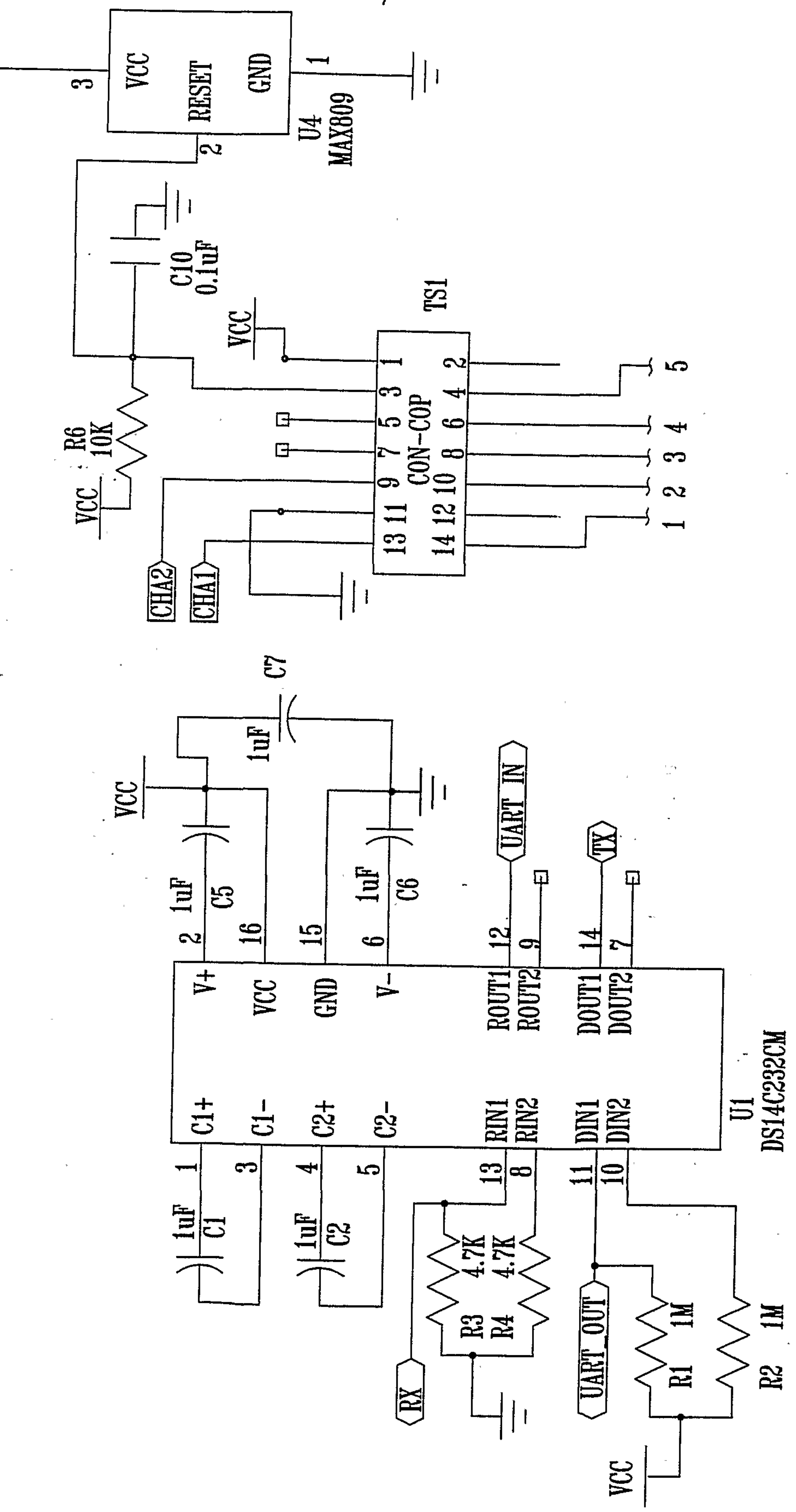

VCC
VCC
RESET
GND
U4
MAX809
C10
0.1uF
TS1
CON-COP
R6
10K
CHA2
CHA1
C7
1uF
VCC
1uF
C5
1uF
C6
UART_IN
TX
V+
VCC
GND
V-
ROUT1
ROUT2
DOUT1
DOUT2
C1+
C1-
C2+
C2-
RIN1
RIN2
DIN1
DIN2
U1
DS14C232CM
1uF
C1
1uF
C2
4.7K
4.7K
R3
R4
RX
UART_OUT
1M
R1
1M
R2
VCC

FIG. 5B

FIG. 5C

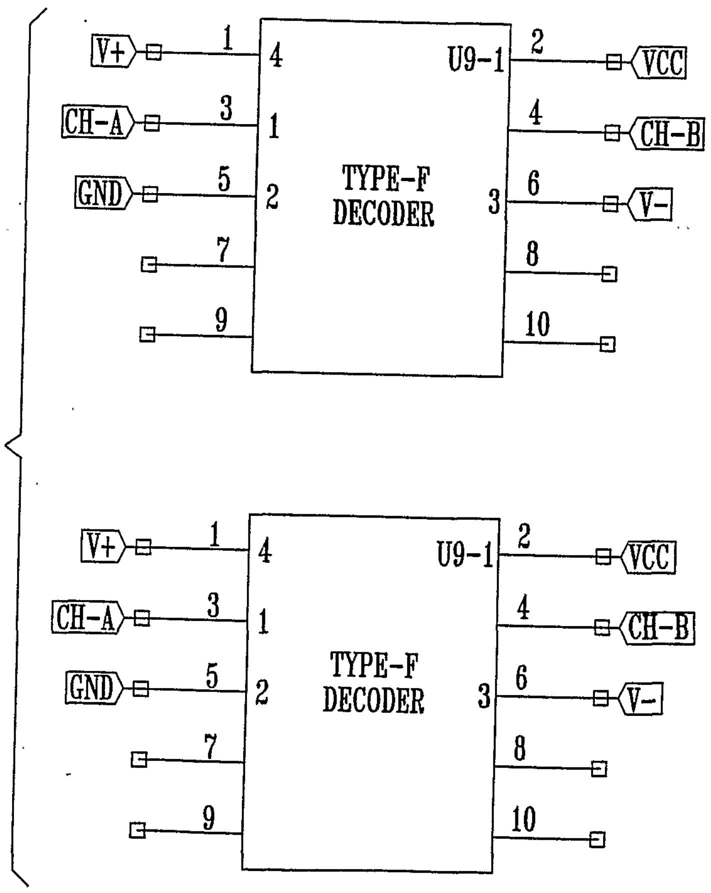
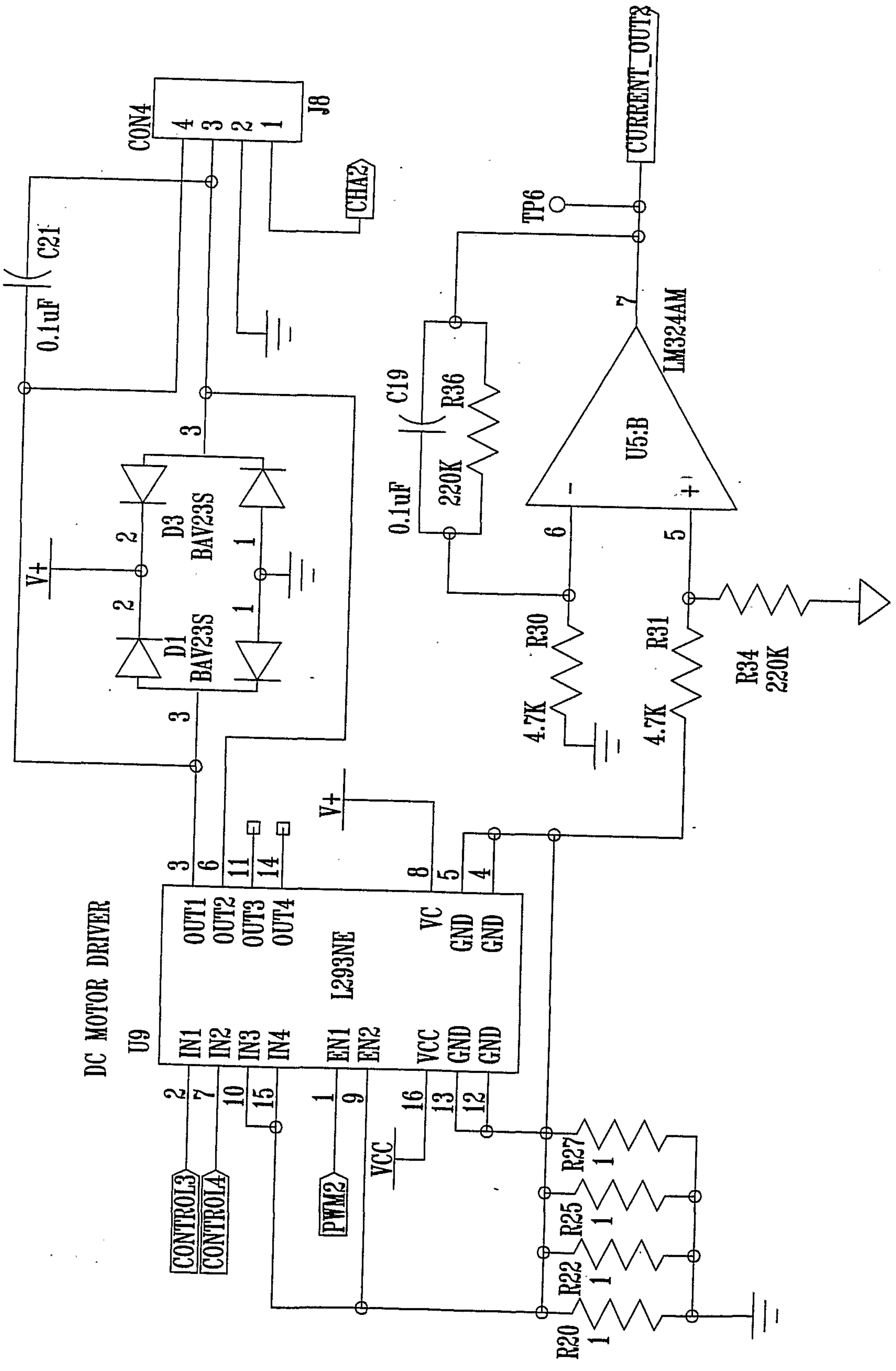
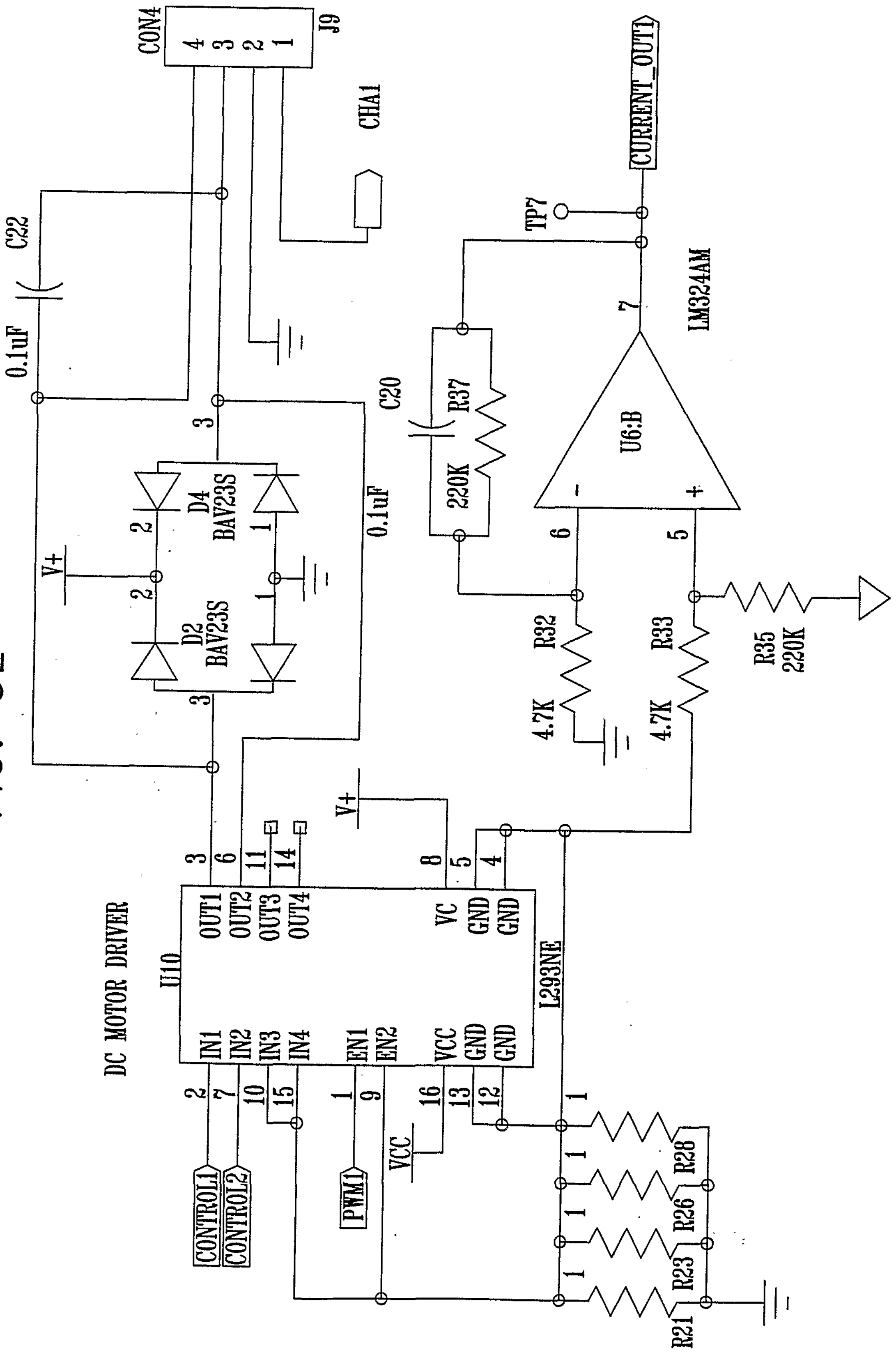

V+
CH-A
GND
1
3
5
7
9
4
1
2
U9-1
TYPE-F
DECODER
3
2
4
6
8
10
VCC
CH-B
V-
V+
CH-A
GND
1
3
5
7
9
4
1
2
U9-1
TYPE-F
DECODER
3
2
4
6
8
10
VCC
CH-B
V-

FIG. 5D


J8
CON4
CHA2
CURRENT_OUT2
TP6
C21
0.1uF
C19
0.1uF
R36
220K
U5:B
LM324AM
D3
BAV23S
D1
BAV23S
V+
R30
4.7K
R31
4.7K
R34
220K
DC MOTOR DRIVER
U9
L293NE
OUT1
OUT2
OUT3
OUT4
VC
GND
IN1
IN2
IN3
IN4
EN1
EN2
VCC
CONTROL3
CONTROL4
PWM2
R20
R22
R25
R27



CON4
J9
4
3
2
1
CHA1
CURRENT_OUT1
C22
0.1uF
TP7
LM324AM
7
C20
R37
220K
0.1uF
U6:B
D4
BAV23S
D2
BAV23S
V+
6
5
R32
4.7K
R33
4.7K
R35
220K
DC MOTOR DRIVER
U10
L293NE
OUT1
OUT2
OUT3
OUT4
VC
GND
IN1
IN2
IN3
IN4
EN1
EN2
VCC
CONTROL1
CONTROL2
PWM1
R21
R23
R26
R28

FIG. 5E

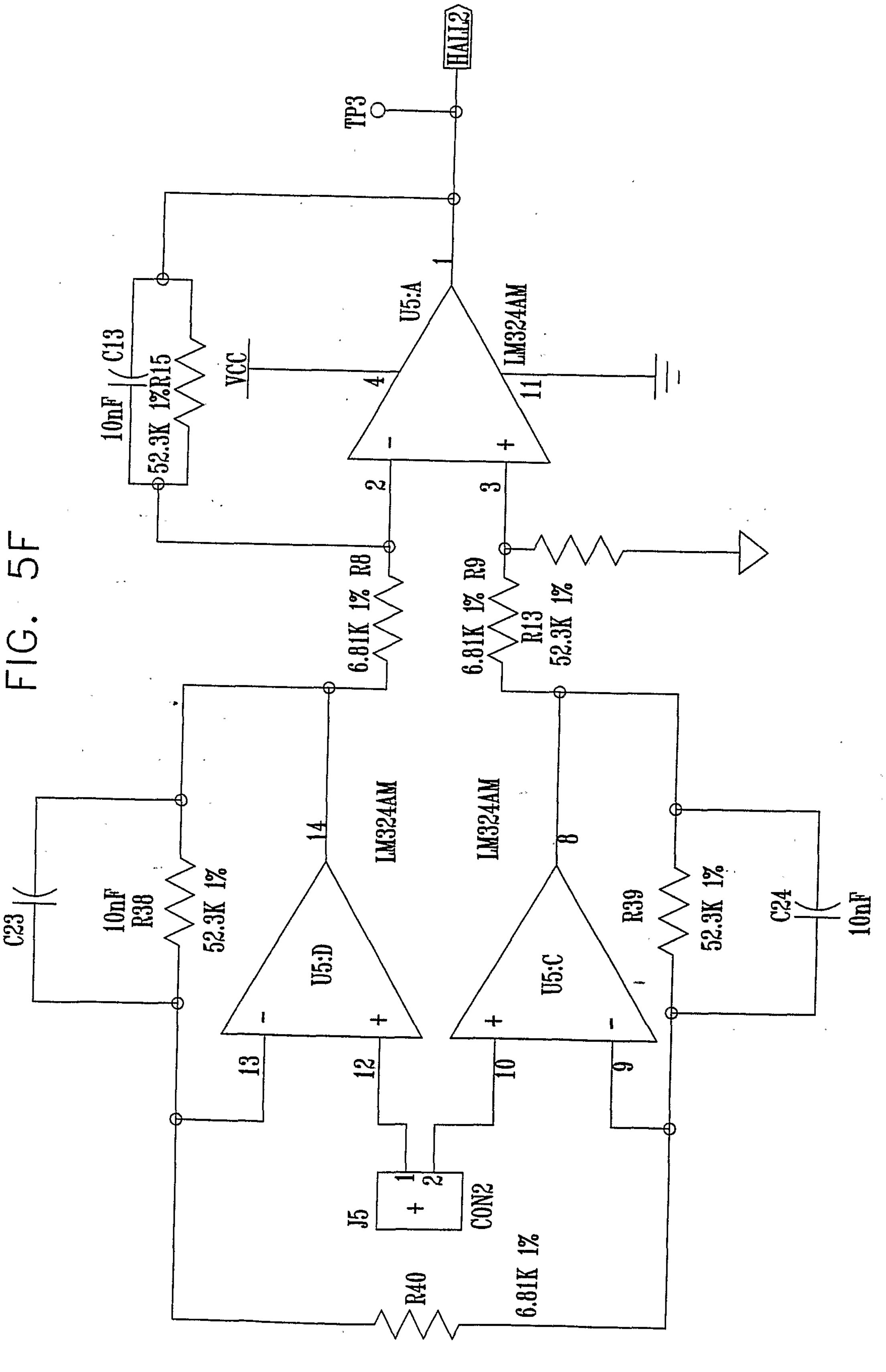

HALL2
TP3
U5:A
LM324AM
VCC
10nF
C13
52.3K 1% R15
6.81K 1% R8
6.81K 1% R9
R13
52.3K 1%
LM324AM
LM324AM
U5:D
U5:C
C23
10nF
R38
52.3K 1%
R39
52.3K 1%
C24
10nF
J5
CON2
R40
6.81K 1%

FIG. 5F

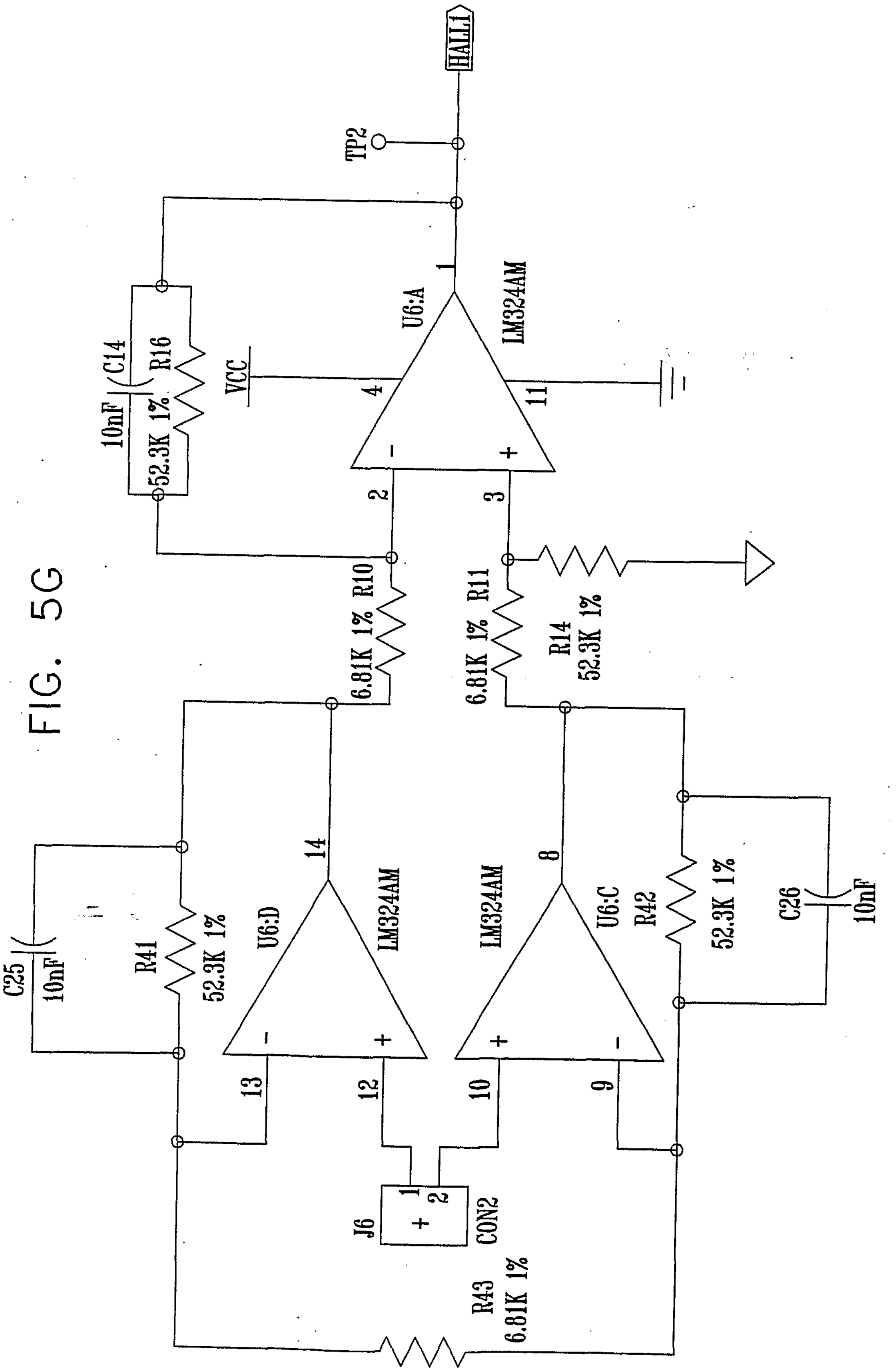

HALL1
TP2
U6:A
LM324AM
VCC
10nF
C14
R16
52.3K 1%
R10
6.81K 1%
R11
6.81K 1%
R14
52.3K 1%
U6:D
LM324AM
U6:C
LM324AM
C25
10nF
R41
52.3K 1%
R42
52.3K 1%
C26
10nF
J6
CON2
R43
6.81K 1%

FIG. 5G

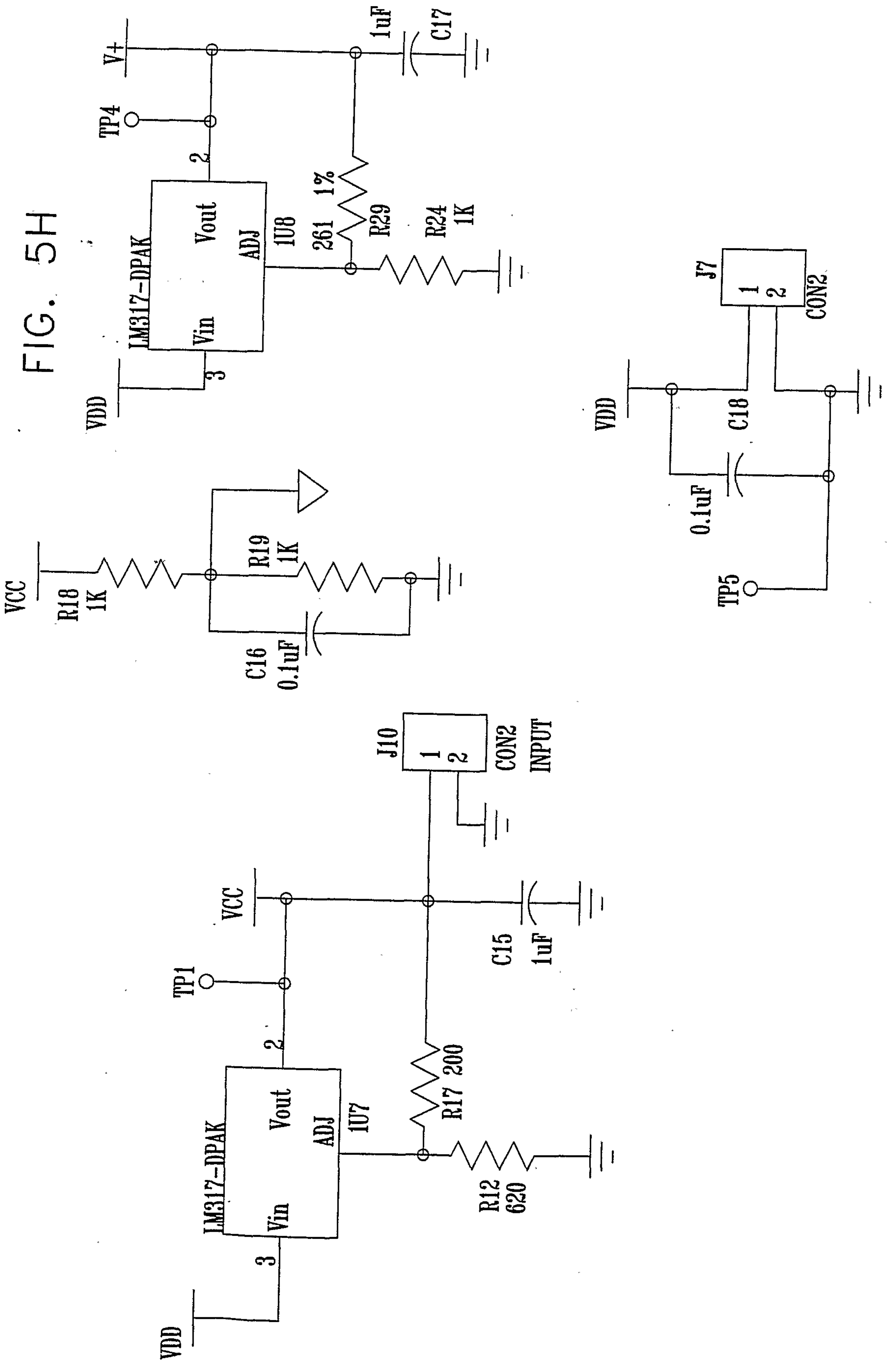

V+
TP4
1uF
C17
2
LM317-DPAK
Vout
ADJ
1U8
Vin
3
VDD
261 1%
R29
R24
1K
J7
1
2
CON2
VDD
C18
0.1uF
TP5
VCC
R18
1K
R19
1K
C16
0.1uF
J10
1
2
CON2
INPUT
VCC
TP1
C15
1uF
2
LM317-DPAK
Vout
ADJ
1U7
Vin
3
VDD
R17 200
R12
620

FIG. 5H

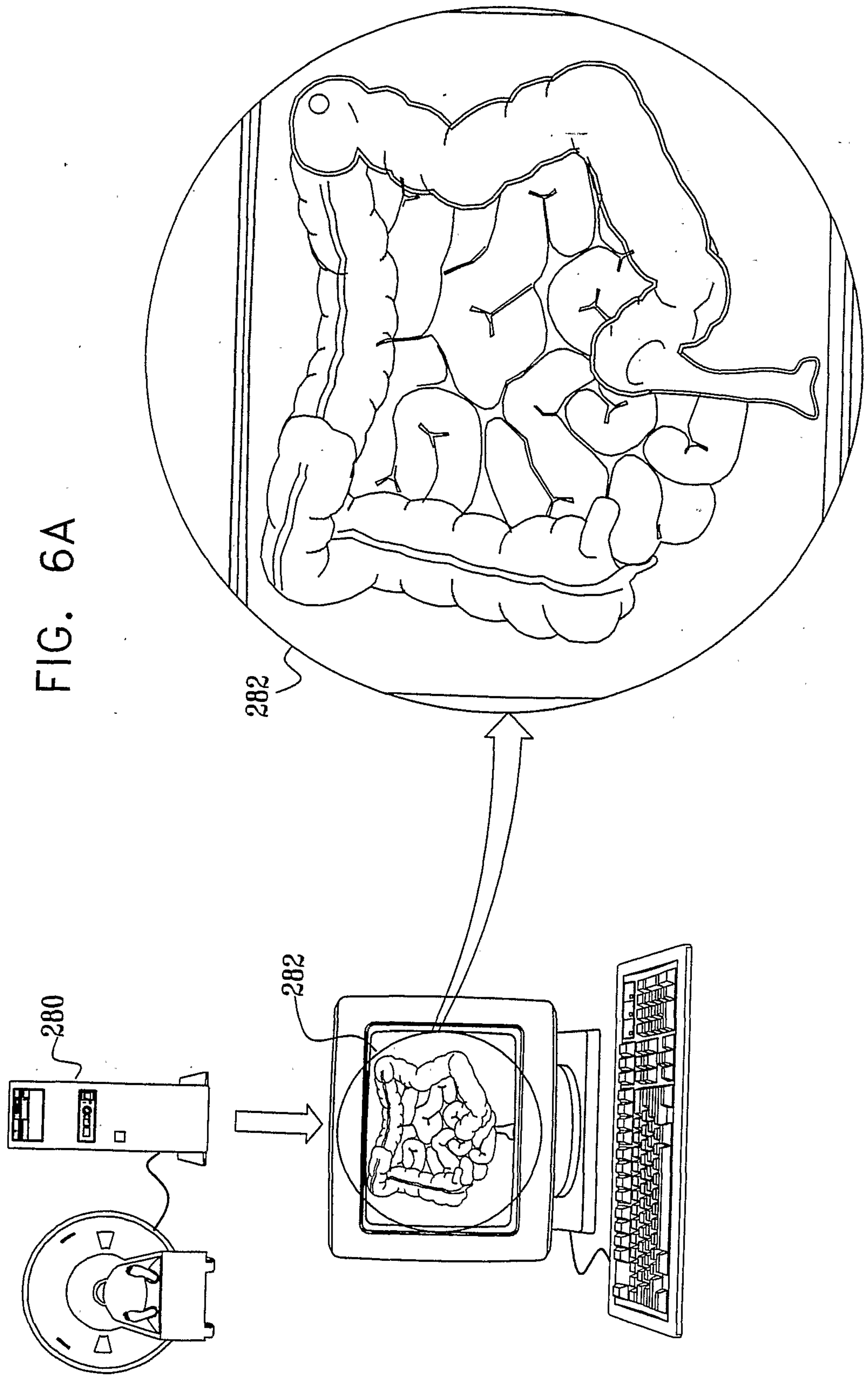


FIG. 6A

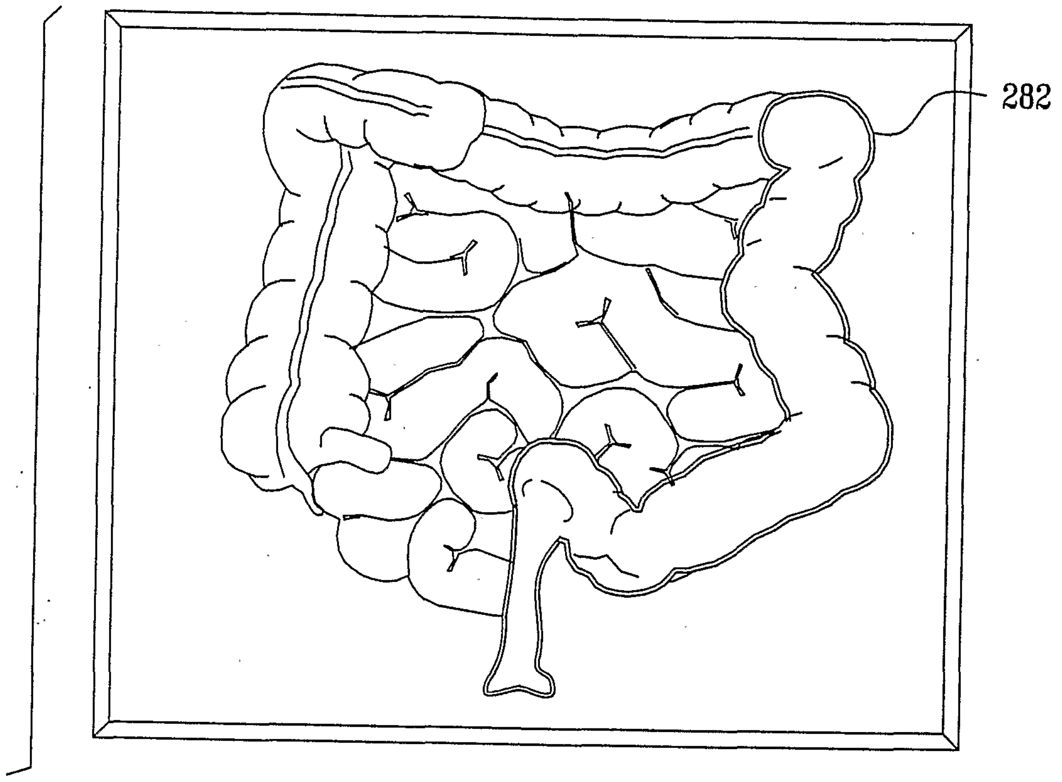
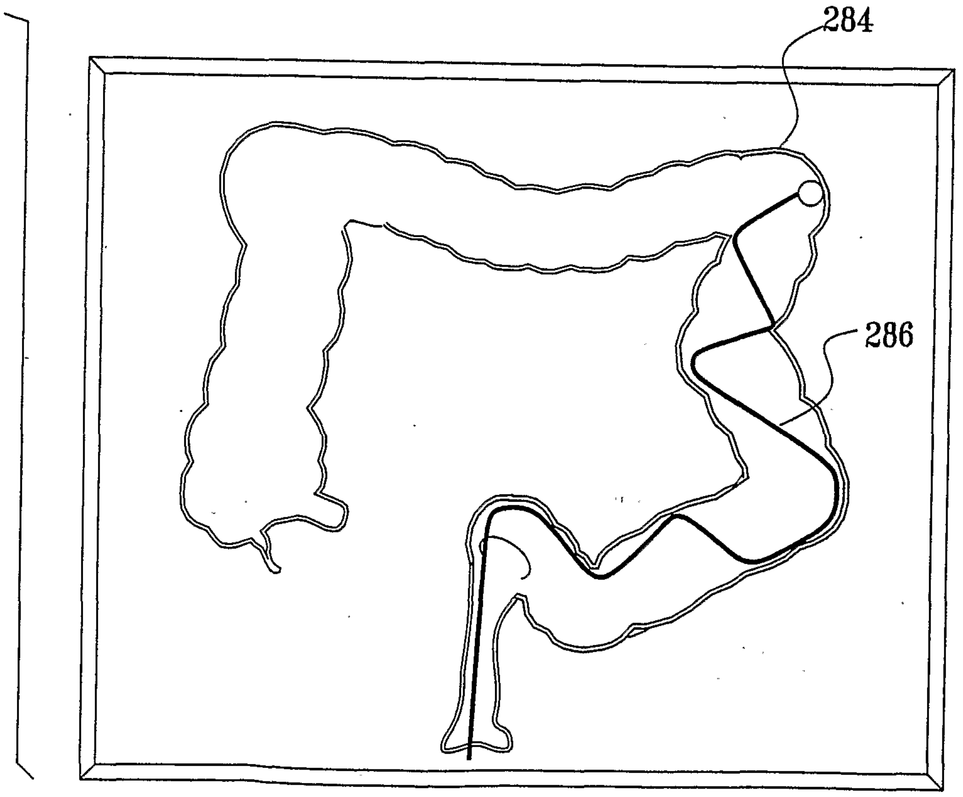


FIG. 6B



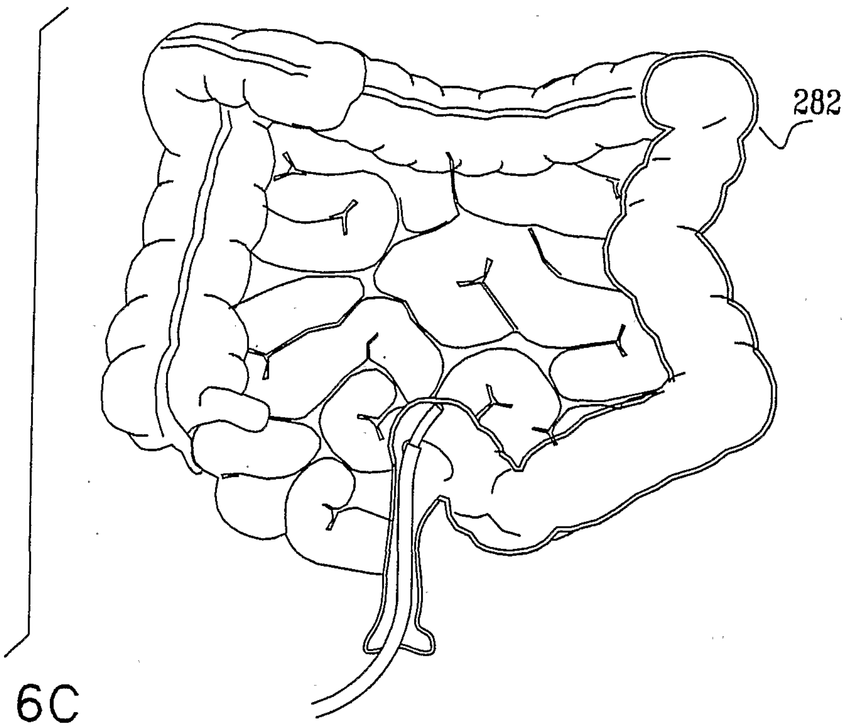
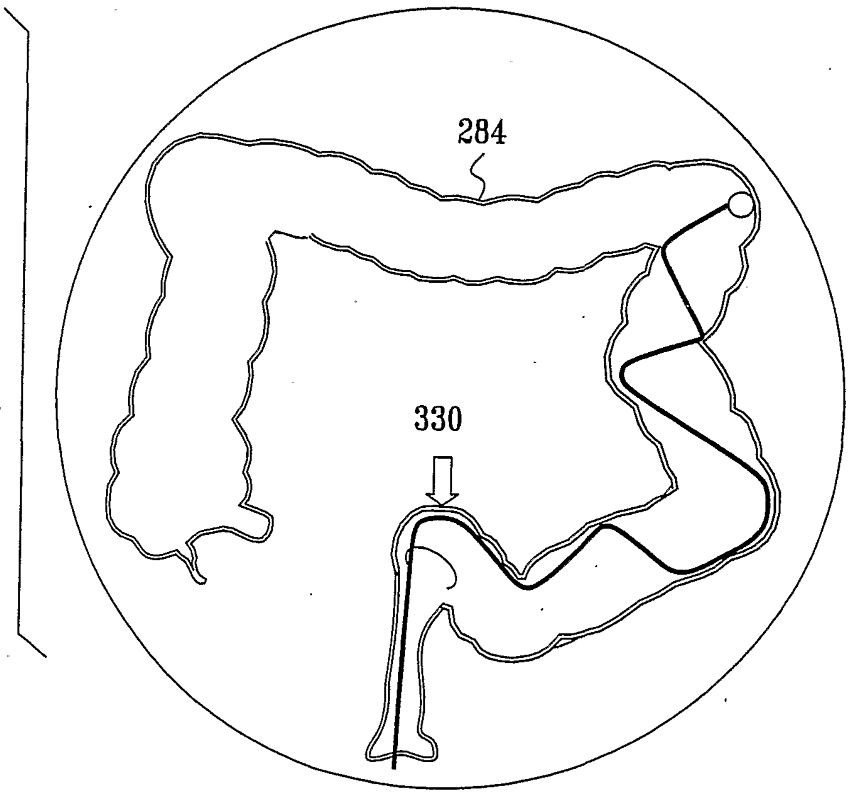


FIG. 6C



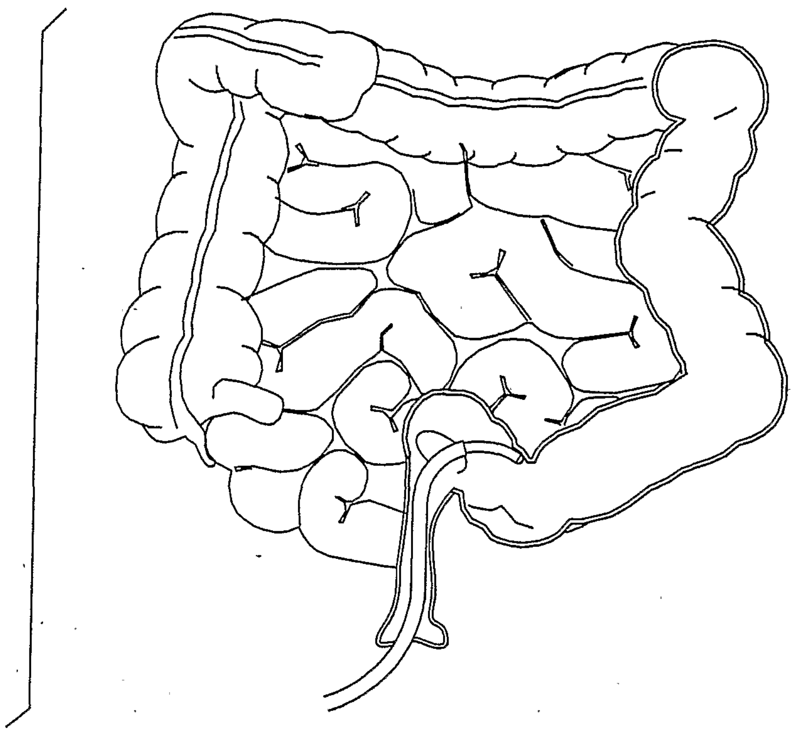
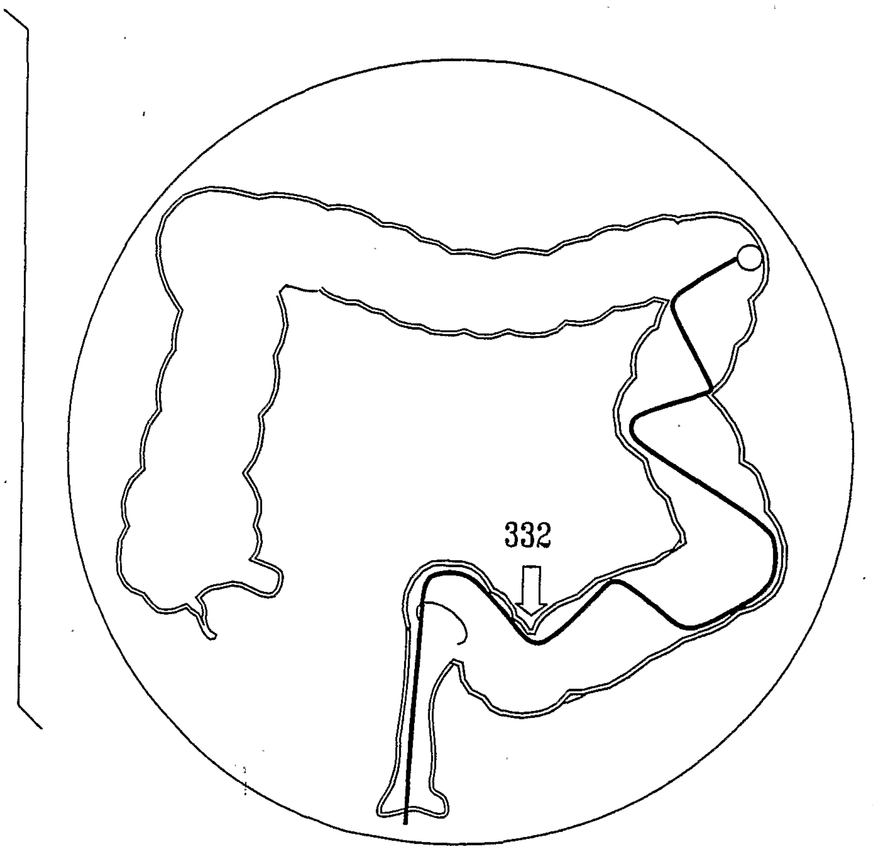


FIG. 6D



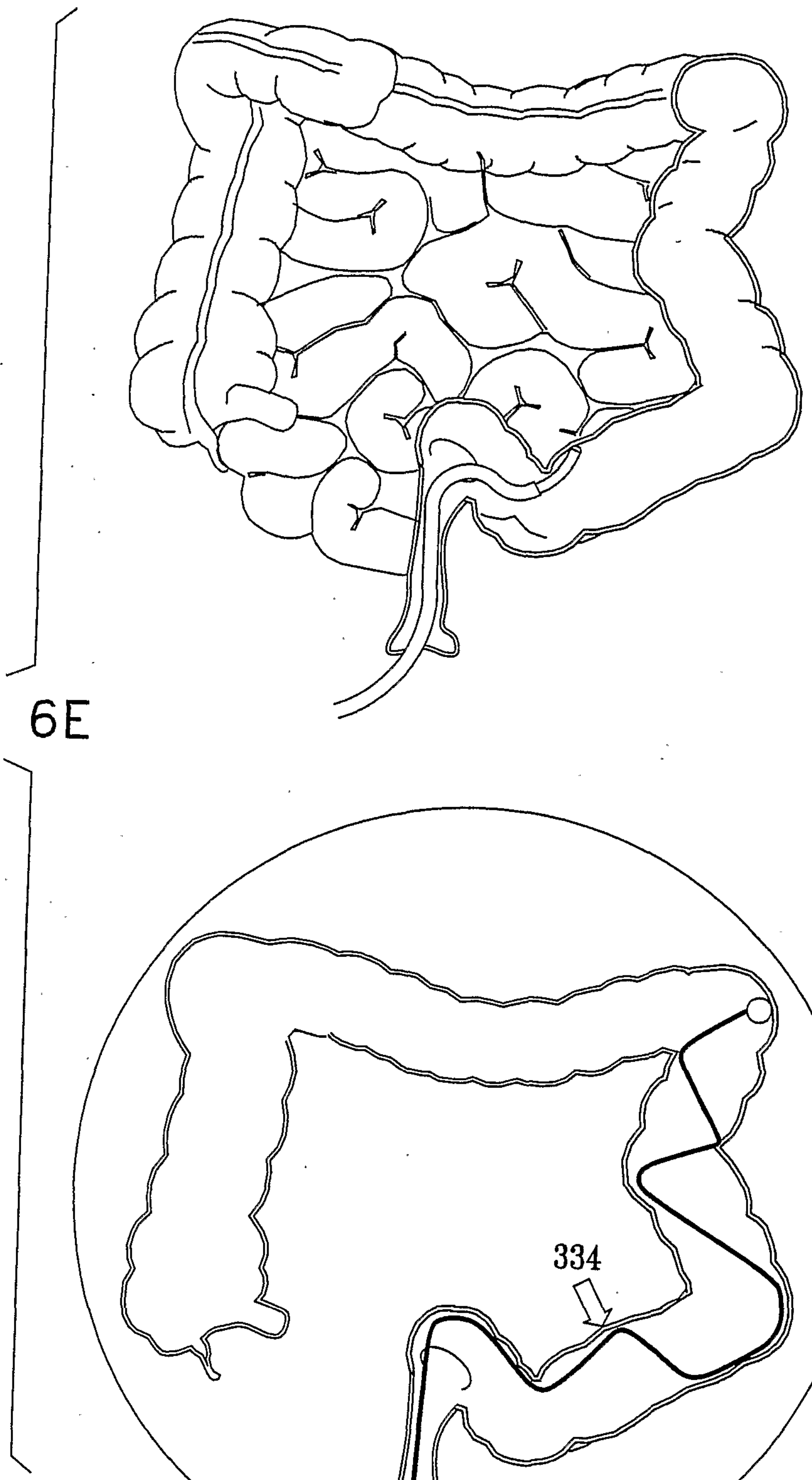


FIG. 6E

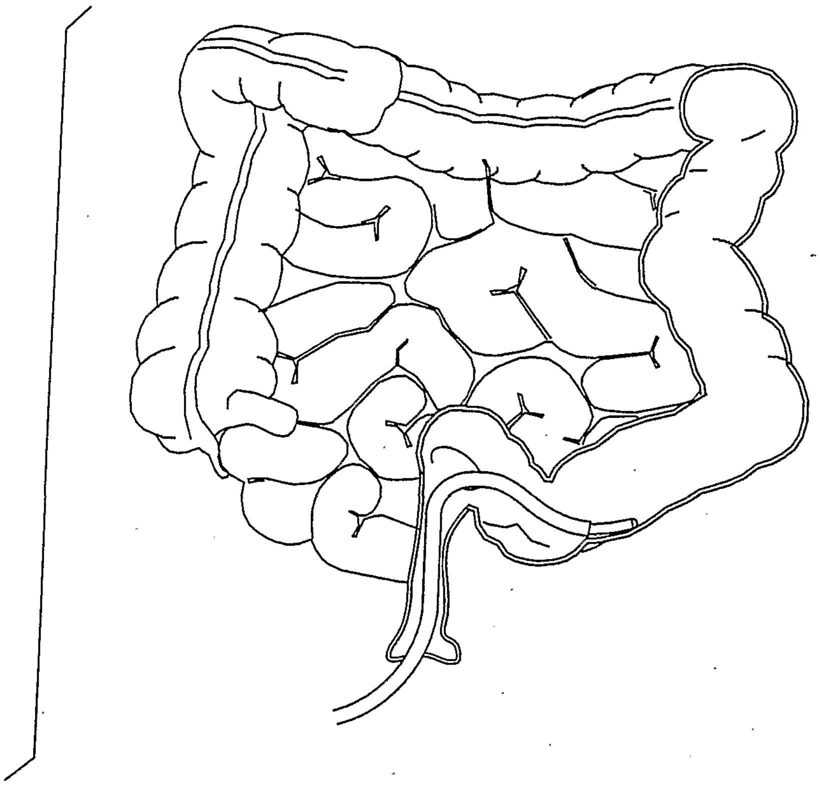
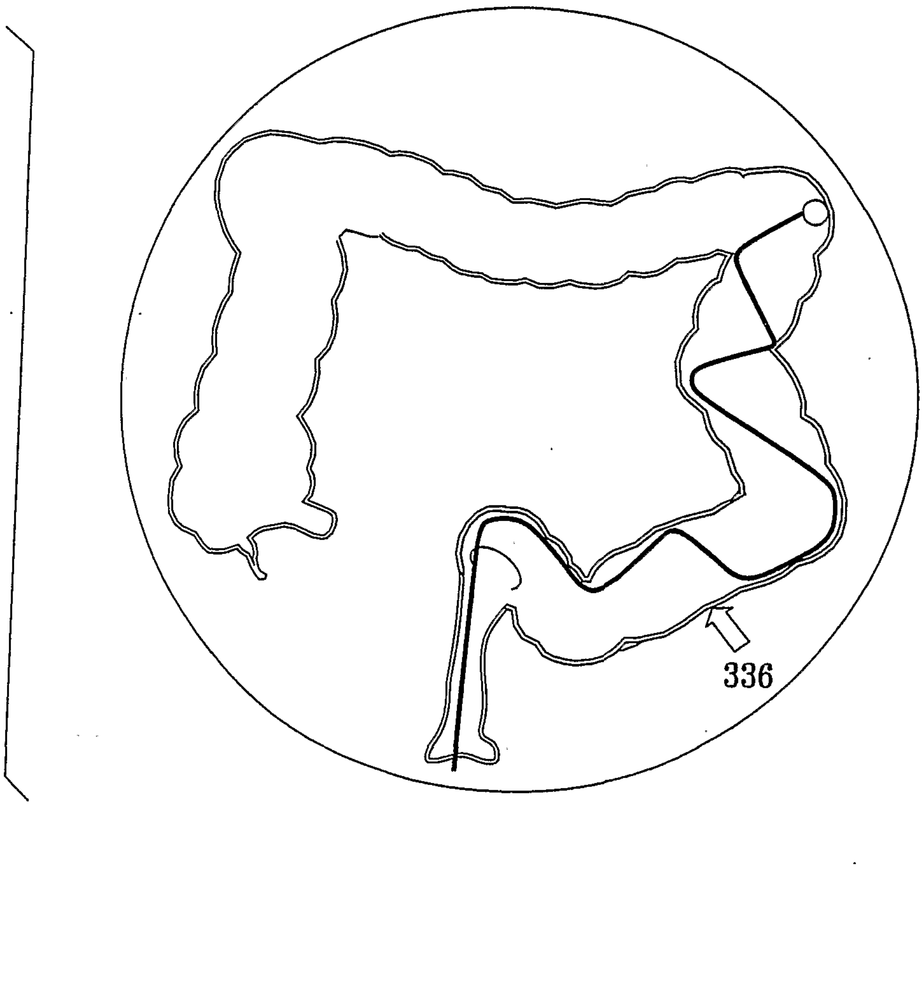


FIG. 6F



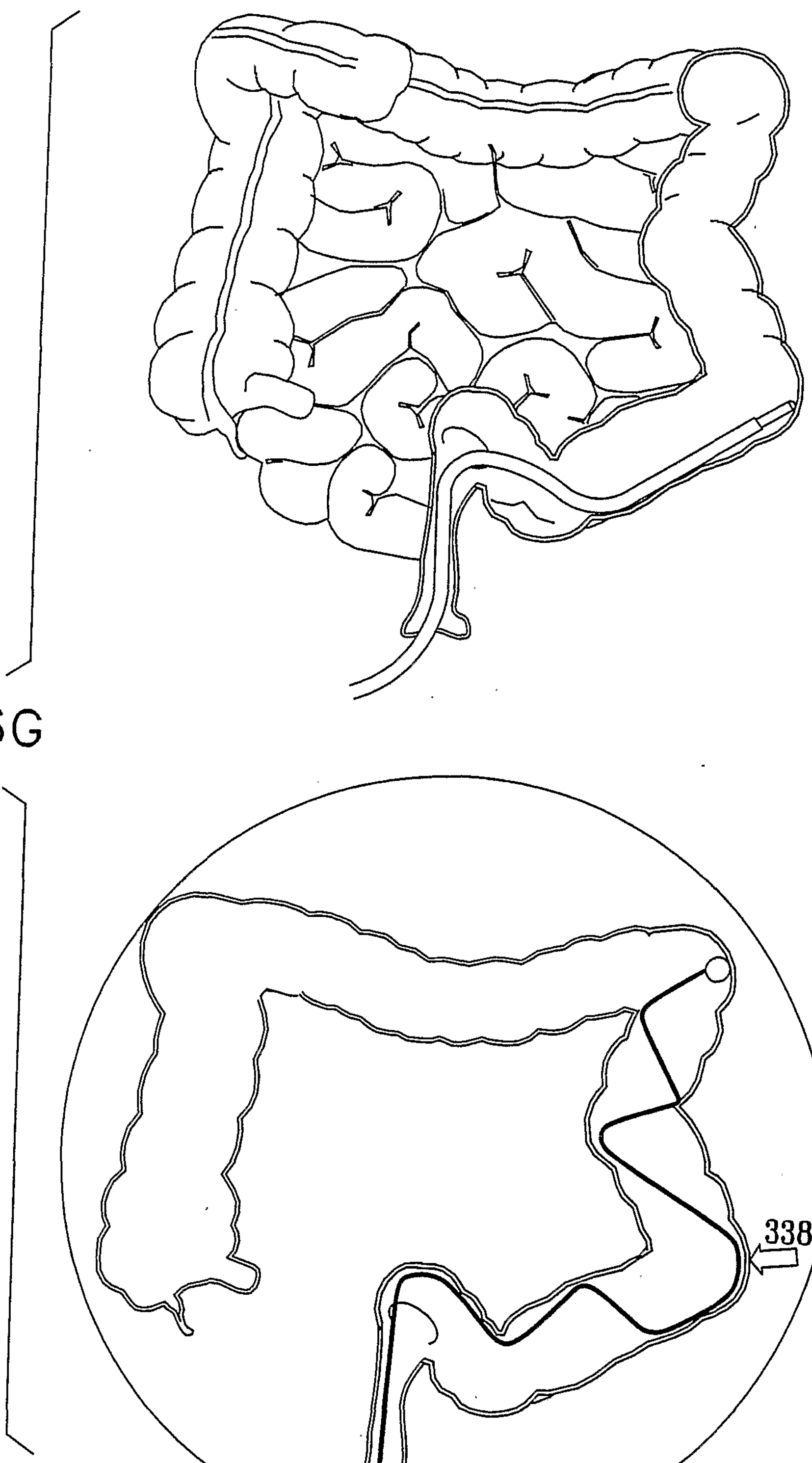


FIG. 6G

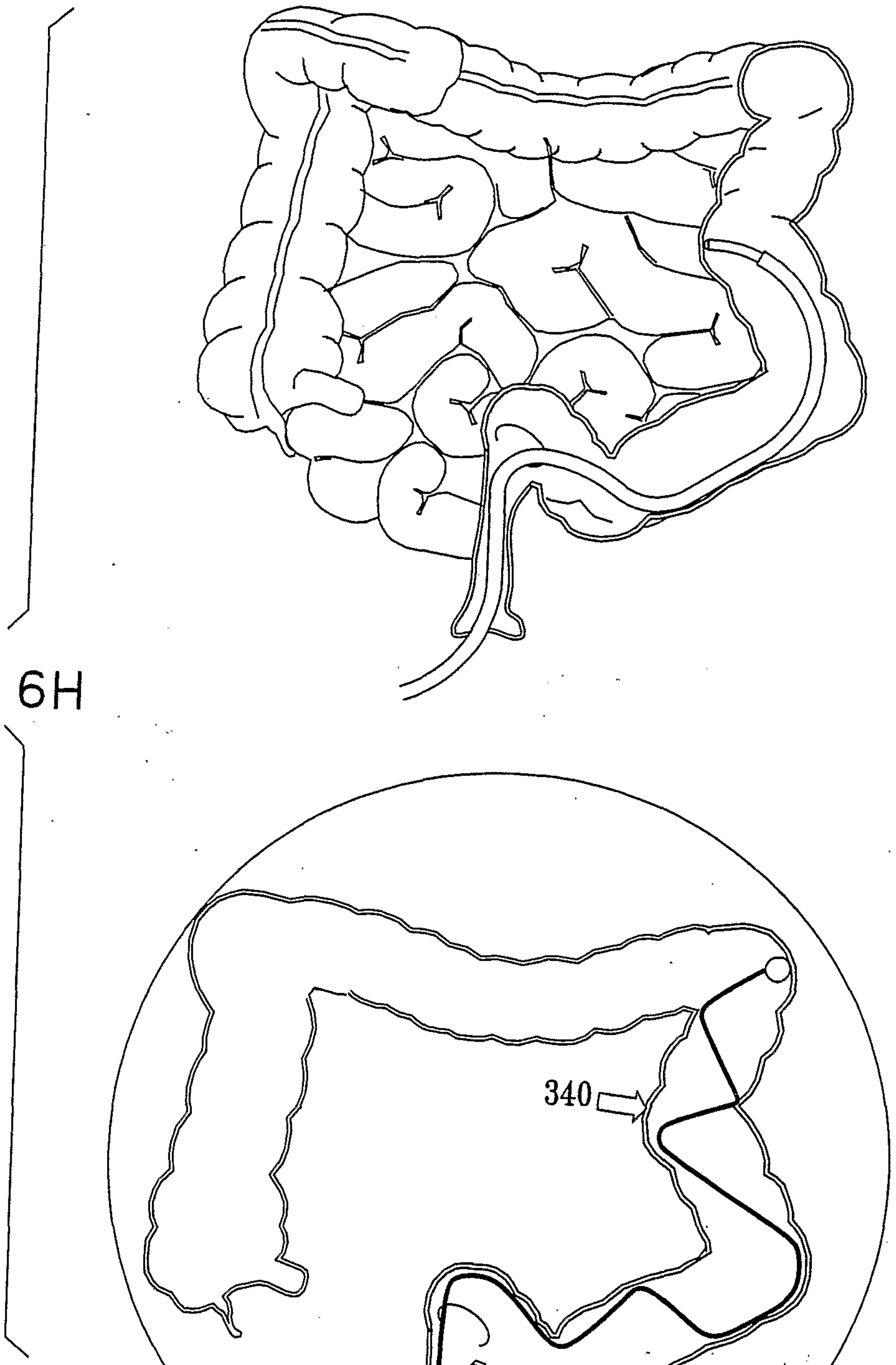


FIG. 6H

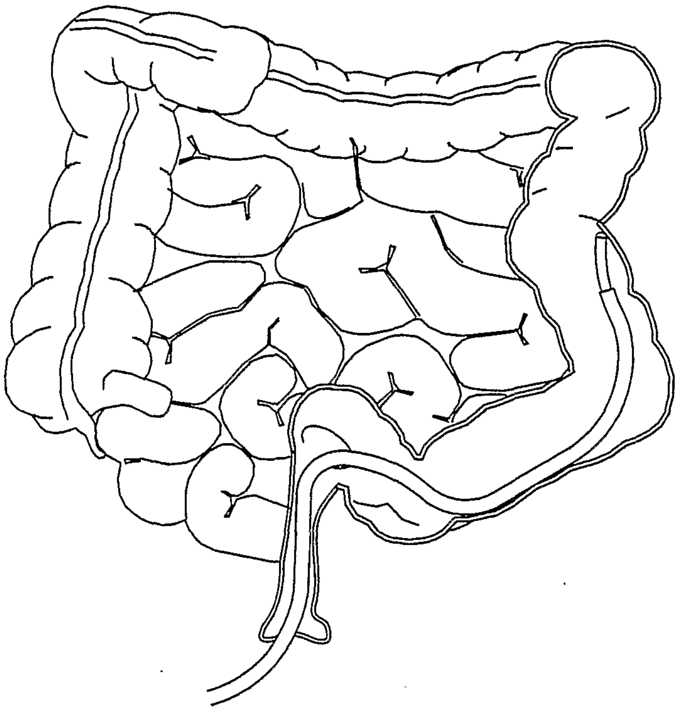
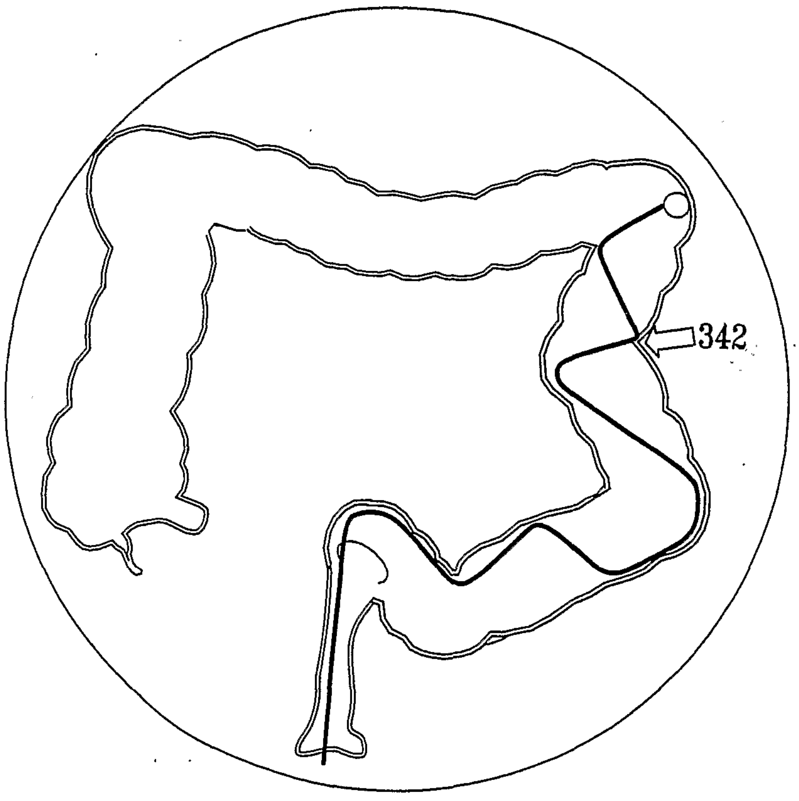


FIG. 61



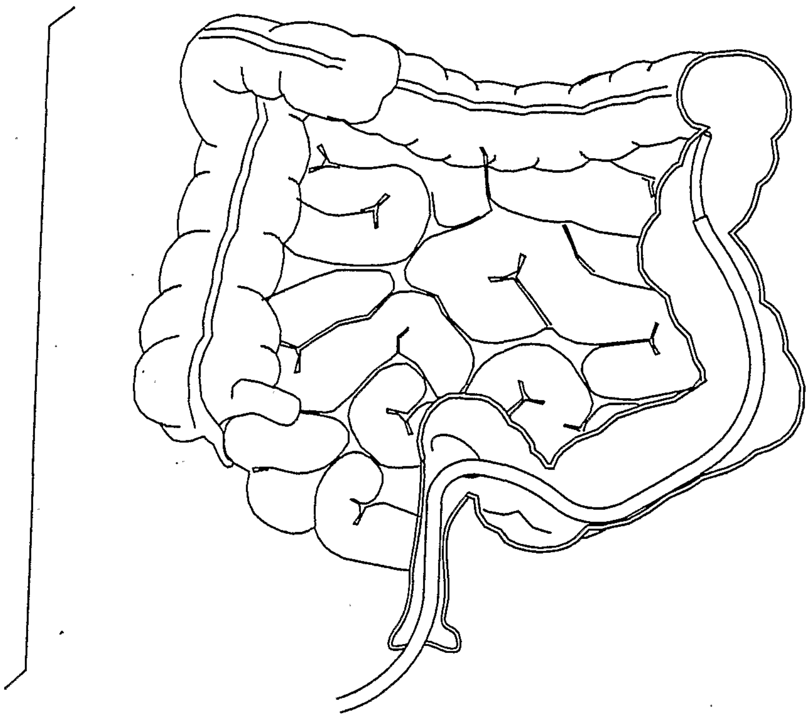
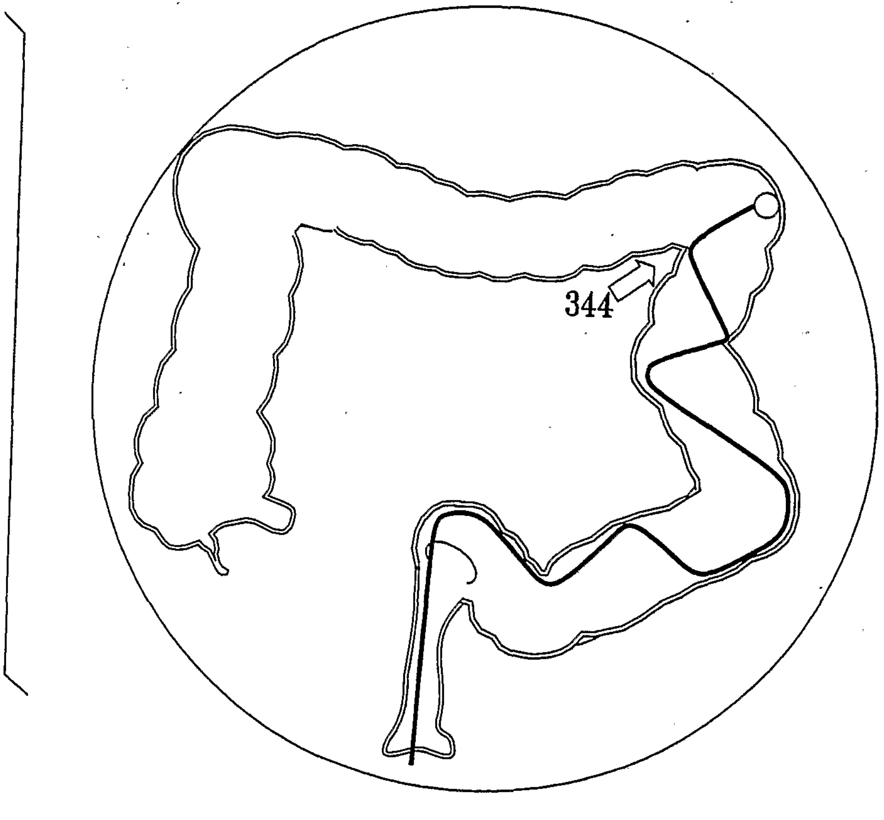


FIG. 6J



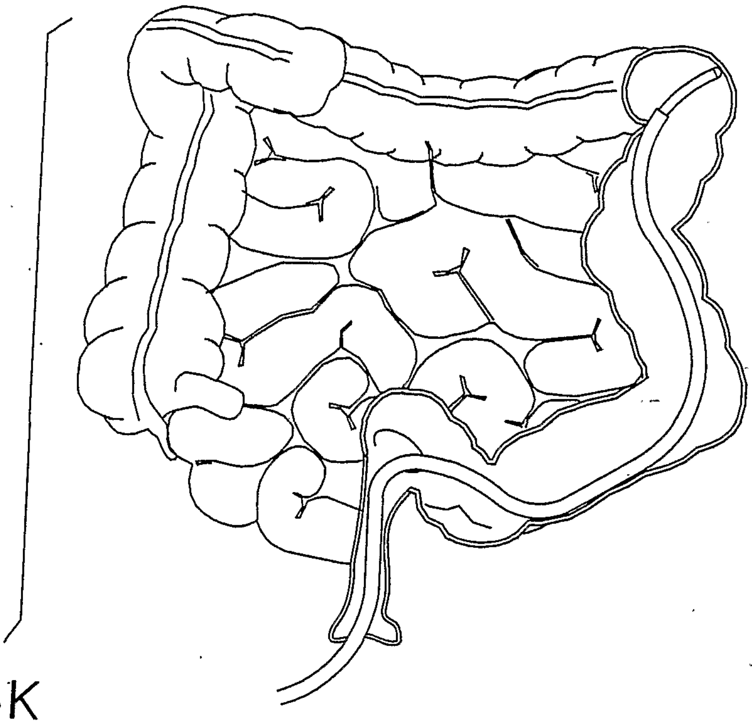


FIG. 6K

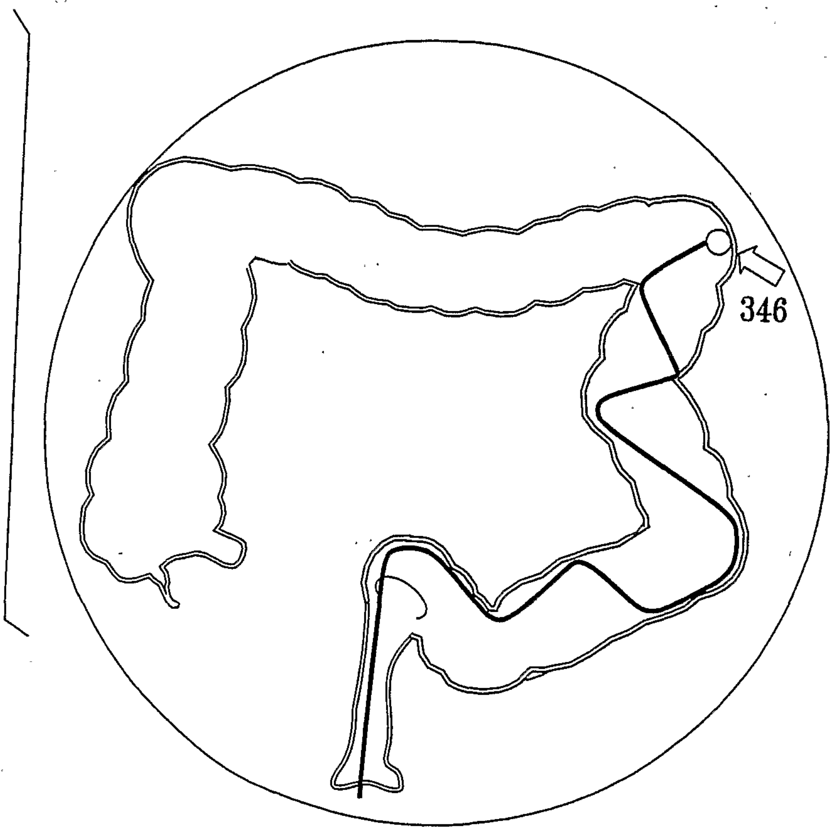


FIG 7

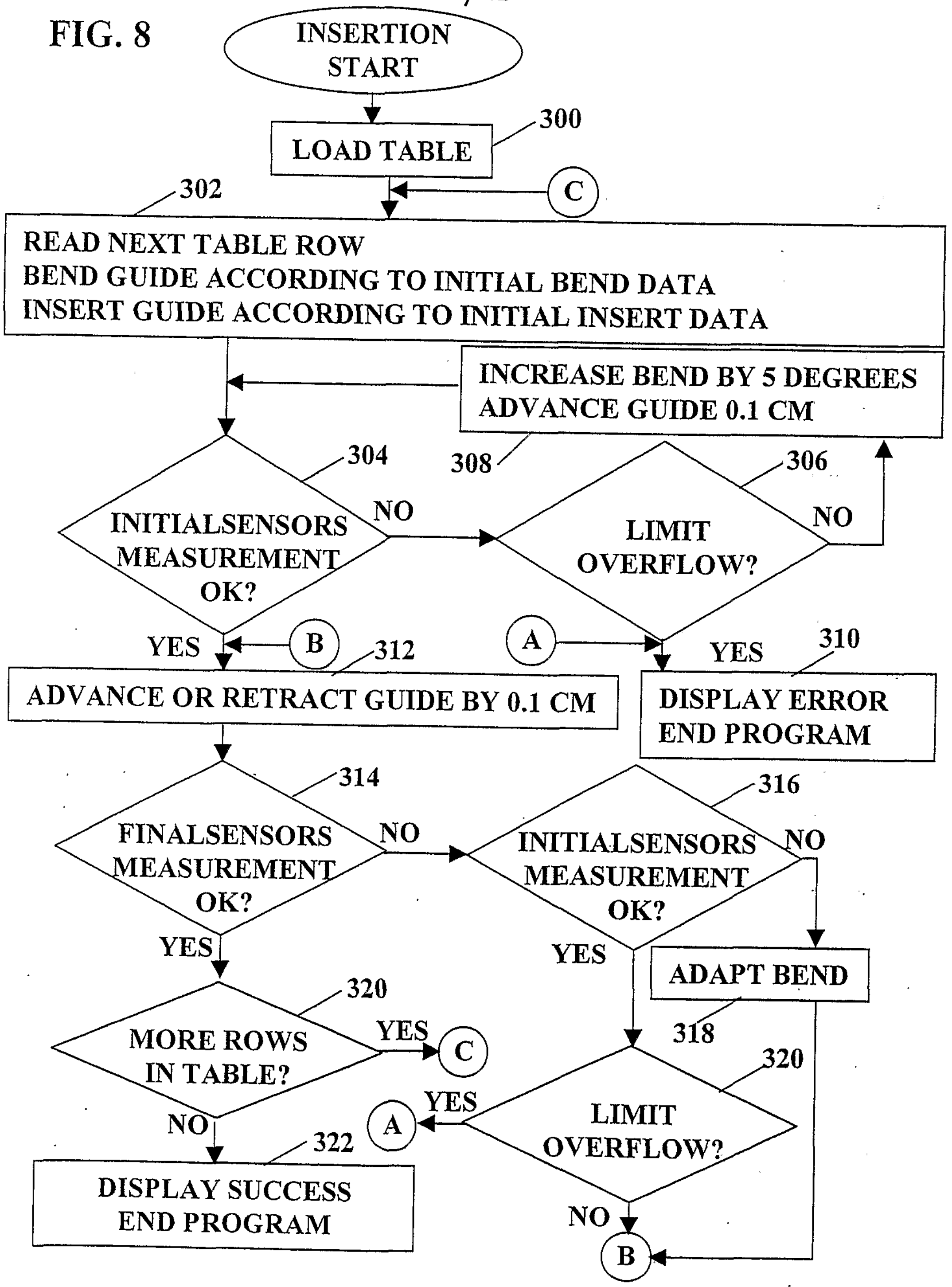
290

294 295 296 297 298

ROW NO.	INITIAL BEND		INITIAL INSERTION	INITIAL SENSOR MEASUREMENTS				INSERT DISTANCE	FINAL SENSOR MEASUREMENTS			
	FRONT	RIGHT		FRONT	BACK	RIGHT	LEFT		FRONT	BACK	RIGHT	LEFT
1	0	-45	0.5	0	0	0	3	5	9	9	9	9
2	0	45	0.1	0	0	0	4	2.5	0	0	0	0
3	0	-110	0.1	0	0	0	2	1	0	0	0	3
4	0	45	1.0	0	0	4	0	6	0	0	7	0
5	0	20	0.5	0	0	4	0	4	3	3	7	7
6	0	-60	1.0	0	0	0	0	3	9	9	9	9
7	0	45	2.5	0	0	0	0	1	0	0	2	0
8	0	0	2.5	0	0	0	0	1	0	0	0	3
9	0	45	2.5	0	0	0	0	1	9	9	9	9

292

FIG. 8


INSERTION START
LOAD TABLE
300
C
302
READ NEXT TABLE ROW
BEND GUIDE ACCORDING TO INITIAL BEND DATA
INSERT GUIDE ACCORDING TO INITIAL INSERT DATA
INCREASE BEND BY 5 DEGREES
ADVANCE GUIDE 0.1 CM
304
308
306
INITIALSENSORS MEASUREMENT OK?
NO
LIMIT OVERFLOW?
NO
YES
B
312
A
YES
310
ADVANCE OR RETRACT GUIDE BY 0.1 CM
DISPLAY ERROR END PROGRAM
314
316
FINALSENSORS MEASUREMENT OK?
NO
INITIALSENSORS MEASUREMENT OK?
NO
YES
YES
ADAPT BEND
320
318
MORE ROWS IN TABLE?
YES
C
320
YES
A
LIMIT OVERFLOW?
NO
322
DISPLAY SUCCESS END PROGRAM
NO
B