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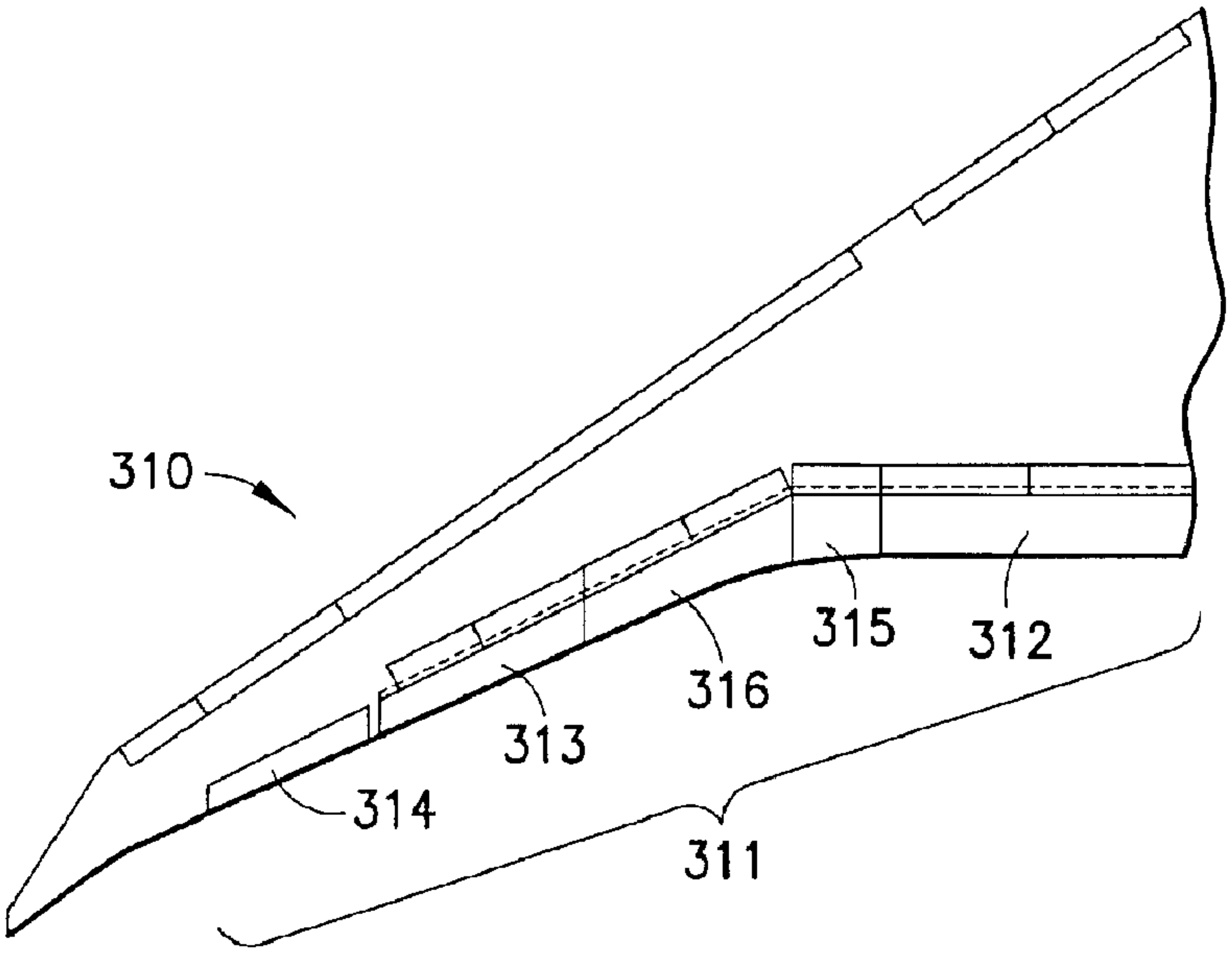
(54) **Titre : AJUSTEMENT DES AILES POUR UNE CAMBRURE VARIABLE SERVANT A OPTIMISER LA CONFIGURATION DE DECOLLAGE OU D'ATTERRISSAGE**

(54) **Title: ADJUSTMENT OF WINGS FOR VARIABLE CAMBER FOR OPTIMUM TAKE-OFF AND LANDING CONFIGURATION**



(57) **Abrégé/Abstract:**

This application is directed to moving flaps differentially to produce better lift/drag characteristics during takeoff and landing of aircraft. A method and apparatus for differentially adjusting a first deployable lift device ("FDLD") and a second deployable lift device

(57) **Abrégé(suite)/Abstract(continued):**
("SDLD") on a wing are described. The FDLD and the SDLD are coupled to a single power drive link. A first desired position for the FDLD and a second desired position for the SDLD are determined. A motor moves the FDLD by a first movement amount determined by subtracting a first position of the FDLD from the first desired position. A second movement amount for the SDLD is determined by subtracting a second position of the SDLD from the second desired position. A differential movement amount is determined by subtracting the first movement amount from the total amount the SDLD will move. Another motor moves the SDLD by the differential movement amount.

ABSTRACT

This application is directed to moving flaps differentially to produce better lift/drag characteristics during takeoff and landing of aircraft. A method and apparatus for differentially adjusting a first deployable lift device ("FDLD") and a second deployable lift device ("SDLD") on a wing are described. The FDLD and the SDLD are coupled to a single power drive link. A first desired position for the FDLD and a second desired position for the SDLD are determined. A motor moves the FDLD by a first movement amount determined by subtracting a first position of the FDLD from the first desired position. A second movement amount for the SDLD is determined by subtracting a second position of the SDLD from the second desired position. A differential movement amount is determined by subtracting the first movement amount from the total amount the SDLD will move. Another motor moves the SDLD by the differential movement amount.

ADJUSTMENT OF WINGS FOR VARIABLE CAMBER FOR OPTIMUM TAKE-OFF AND LANDING CONFIGURATION

Field

This application is directed to systems and methods for moving trailing edge high lift devices on an aircraft wing, and more particularly to moving inboard, outboard and midspan flaps differentially in order to produce better lift/drag characteristics during takeoff and landing of the aircraft.

Background

During takeoff and landing, trailing edge high lift devices, located on the trailing edge of airplane wings, are utilized to provide lift and to reduce stalling speed of the aircraft, at the cost of increased drag. Trailing edge high lift devices include surfaces such as flaps, which can move from a stowed position to a deployed position. The flaps may include inboard flaps, located closer to the fuselage, outboard flaps, located further away from the fuselage, and midspan flaps located between inboard and outboard flaps.

Flap control can be provided automatically by a controller within the aircraft or manually by a pilot moving a flaps lever or other control device to a desired position. Manual flap control is traditionally provided by setting a lever to a certain detent, which causes flaps to move to specific positions. For example, a pilot might set a flap lever to a detent such as “flaps **5**”, which would cause flaps to move by **25**% of their full range of motion. Then, for example, a pilot might set a flap lever to a detent such as “flaps **10**”, which would cause flaps to move by an additional **10**% of their full range of motion.

Presently, due to weight and spatial constraints, during take-off and landing, most aircraft move all flap surfaces on a wing in unison, with the same increment of their full range of motion for each detent. For example, a single power drive unit provides power equally to inboard and outboard flaps (and midspan flaps if they are present), which causes them to move to the same increment of their full range of motion. While this allows for simpler architecture, and requires only a single power drive unit, it is less than optimal. Due to wing shape, flap location, different airflow at different wing locations and other factors, the optimal amount of incremental motion between detent positions for different flap surfaces is not equivalent. Positioning the flaps to the same incremental motions during takeoff and landing therefore produces sub-optimal drag/lift tradeoffs, which leads to decreased efficiency, increased fuel costs, and increased noise behavior due to flight path.

Presently, there are several methods to compensate for these drawbacks. One method is to determine a "trade-off" or "compromise" position for the flap surfaces, which is a position somewhere between the optimal positions for each flap surface. For example, in an aircraft having inboard, midspan and outboard flaps, if the optimal position for outboard flaps is **10**% deflected, while the optimal position for midspan flaps is **13**% deflected and for inboard flaps is **15**% deflected, a "trade-off" position might be **12**% deflection for all flaps. This trade-off provides best drag/lift tradeoffs, given the limitation that the inboard, midspan and outboard flaps are moved to the same increment. However, as the flaps are not in their optimal positions, further advantage could be gained by moving them differentially.

A second method to compensate for this drawback is to have multiple independent power drive units – one for each flap surface or pair of flap surfaces. This produces the benefit that inboard and outboard flaps (and midspan flaps if present) can be optimally positioned, but requires the additional parts and space needed for multiple independent drive trains, which adds weight and complexity to the aircraft.

Other systems exist that have the capability to move various flaps differentially during various phases of flight. However, no such system exists that is designed to move flaps differentially in a manner appropriate for takeoff and landing.

Summary

An aspect of the present invention may provide differential control of flap surface movement utilizing a single drive link to provide improved efficiency over the prior systems during take-off and landing.

The present application may provide systems and methods for enabling better fuel efficiency during landing and take-off by differentially adjusting flap surfaces using a single power drive link. The system might be implemented for a wing having inboard and outboard flaps, or a wing having inboard, outboard and midspan flaps, or with any number of flap surfaces, or may be used to adjust other control surfaces as appropriate.

The disclosed system may have a controller for directing movement of flaps properly during take-off and landing. The controller may produce optimal flap movement during takeoff and landing by properly adjusting flaps based on flap lever position. The system may determine proper motor activation amount during take-off and landing for each flap lever position, based on current flap positions. These determinations may be made using additional information, such as aircraft speed, weight, and altitude.

This differential adjustment may provide the benefit that flaps may be optimally positioned instead of being positioned in a "trade-off" or compromise position during take-off and landing. This may provide benefits such as fuel efficiency. Additionally, the benefits may be obtained without requiring multiple drive links.

In accordance with one aspect of the invention there is provided a method for differentially adjusting a first deployable lift device and a second deployable lift device on an aircraft wing of an aircraft within a takeoff and landing envelope, the first deployable lift device and the second deployable lift device being coupled to a single power drive link. The method involves causing a controller to, within the takeoff and landing envelope: determine a first desired position for the first deployable lift device and a second desired position for the second deployable lift device, based on a desired position signal; activate a first motor of the single power drive link to move the first deployable lift device by a first total movement amount, the first total movement amount being determined by subtracting a first current position of the first deployable lift device from the first desired position; determine a second total movement amount for the second deployable lift device by subtracting a second current position of the second deployable lift device from the second desired position; determine a first differential movement amount by subtracting the first total movement amount from the second total movement amount; and activate a second motor to move the second deployable lift device by the first differential movement amount.

The first desired position and the second desired position may be further determined based on weight, altitude and airspeed of the aircraft.

The method may involve causing the controller to engage a first differential brake prior to activating the first motor, disengage the first differential brake after moving the first deployable lift device is complete, and activate the second motor.

The method may involve causing the controller to determine the second current position by adding the first current position to a first differential position.

The method may involve causing the controller to determine a third total movement amount for a third deployable lift device by subtracting a third current position of the third deployable lift device from a third desired position for the third deployable lift device, determine a second differential movement amount for the third deployable lift device by subtracting the second total movement amount from the third total movement amount, and activate a third motor to move the third deployable lift device by the second differential movement amount.

The method may involve causing the controller to determine the third current position by adding the second current position to a second differential position.

The method may involve causing the controller to engage a second differential brake prior to activating the second motor, disengage the second differential brake after moving the second deployable lift device is complete, and activate the third motor.

The method may involve causing the controller to determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

In accordance with another aspect of the invention there is provided an aircraft wing system for differentially adjusting a first deployable lift device and a second deployable lift device on an aircraft wing of an aircraft within a takeoff and landing envelope. The system includes a first deployable lift device and a second deployable lift device, the first deployable lift device and the second deployable lift device being coupled to a single power drive link. The system also includes a high horsepower motor providing power to the power drive link, and a first low horsepower motor, the first low horsepower motor having a lower horsepower than the high horsepower motor. The system further includes a first differential configured to receive power from the drive link and the first low horsepower motor, and to provide power to the second deployable lift device. The system also includes a controller programmed to, within the takeoff and landing envelope: determine a first desired position for the first deployable lift device and a second desired position for the second deployable lift device, based on a desired position signal; activate the high horsepower motor to move the first deployable lift device by a first total movement amount, the first total movement amount being determined by subtracting a first current position of the first deployable lift device from the first desired position; determine a second total movement amount for the second deployable lift device by subtracting a second current position of the second deployable lift device from the second desired position; determine a first differential movement amount by subtracting the first total movement amount from the second total movement amount; and activate the first low horsepower motor to move the second deployable lift device by the first differential movement amount.

The controller may be programmed to determine the first desired position and the second desired position based on weight, altitude and airspeed of the aircraft.

The controller may be further programmed to engage a first differential brake prior to activating the high horsepower motor, disengage the first differential brake after moving the first deployable lift device is complete, and activate the first low horsepower motor.

The controller may be further programmed to determine a second current position by adding the first current position to a first differential position.

The system may include a third deployable lift device, and the controller may be further programmed to determine a third total movement amount for the third deployable lift device by subtracting a third current position of the third deployable lift device from a third desired position, determine a second differential movement amount for the third deployable lift device by subtracting the second total movement amount from the third total movement amount, and activate a second low horsepower motor to move the third deployable lift device by the second differential movement amount, the second low horsepower motor having a lower horsepower than the high horsepower motor.

The controller may be further programmed to determine the third current position by adding the second current position to a second differential position.

The controller may be further programmed to engage a second differential brake prior to activating the first low horsepower motor, disengage the second differential brake and engage the first differential brake after moving the second deployable lift device is complete, and activate the second low horsepower motor.

The controller may be further programmed to determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

In accordance with another aspect of the invention there is provided an aircraft employing an aircraft wing system for differentially adjusting a first deployable lift device and a second deployable lift device within a takeoff and landing envelope. The aircraft includes an aircraft body and a wing having a first deployable lift device and a second deployable lift device, the first deployable lift device and the second deployable lift device being coupled to a single power drive link. The aircraft also includes a high horsepower motor providing power to the power drive link, and a first low horsepower motor, the first low horsepower motor having a lower horsepower than the high horsepower motor. The aircraft further includes a first differential configured to receive power from the drive link and the first low horsepower motor, and to provide power to the second deployable lift device. The aircraft also includes a controller programmed to, within the takeoff and landing envelope: determine a first desired position for the first deployable lift device and a second desired position for the second deployable lift device, based on a desired position signal; activate the high horsepower motor to move the first deployable lift device by a first total movement amount, the first total movement amount being determined by subtracting a first current position of the first deployable lift device from the first desired position; determine a second total movement amount for the second deployable lift device by subtracting a second current position of the second deployable lift device from the second desired position; determine a first differential movement amount by subtracting the first total movement amount from the second total movement amount; and activate the first low horsepower motor to move the second deployable lift device by the first differential movement amount.

The controller may be programmed to determine the first desired position and the second desired position based on weight, altitude and airspeed of the aircraft.

The controller may be further programmed to engage a first differential brake prior to activating the high horsepower motor, disengage the first differential brake after moving the first deployable lift device is complete, and activate the first low horsepower motor.

The controller may be further programmed to determine a second current position by adding the first current position to a first differential position.

The aircraft may include a third deployable lift device, and the controller may be further programmed to determine a third total movement amount for the third deployable lift device by subtracting a third current position of the third deployable lift device from a third desired position, determine a second differential movement amount for the third deployable lift device by subtracting the second total movement amount from the third total movement amount, and activate a second low horsepower motor to move the third deployable lift device by the second differential movement amount, the second low horsepower motor having a lower horsepower than the high horsepower motor.

The controller may be further programmed to determine the third current position by adding the second current position to a second differential position.

The controller may be further programmed to determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

The features, functions, and advantages that have been discussed can be achieved independently in various embodiments disclosed herein, or may be combined in yet other embodiments, further details of which can be seen with reference to the following description and drawings. Other features and advantages of the embodiments disclosed herein will be explained in the following detailed description with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a graph showing a typical airplane flight operating within maximum altitude and speed boundaries and the target flight operating envelope for differential control of flaps in accordance with embodiments of the system disclosed herein.

FIG. **2** is an illustration showing an overall view of typical airplane controllable camber surfaces on wing and empennage.

FIG. **3** is an illustration showing a detailed view of wing controllable camber surfaces, including inboard and outboard flaps.

FIG. **4** is an illustration showing a detailed view of wing controllable camber surfaces, including inboard, outboard and midspan flaps.

FIG. **5** is an illustration depicting an embodiment of a control system operatively connected to and controlling inboard and outboard flap positions during take-off and landing.

FIG. **6** is an illustration depicting an embodiment of a control system operatively connected to and controlling inboard, outboard and midspan flap positions during take-off and landing.

FIG. **7** is an illustration of steps for activating motors, brakes and other parts within primary and differential control devices, in order to achieve differential motion of inboard flaps with respect to outboard flaps.

FIG. **8** is an illustration of steps for activating motors, brakes and other parts within primary and differential control devices, in order to achieve differential motion of inboard flaps and midspan flaps with respect to outboard flaps.

FIG. **9** is a block diagram depicting a control law for determining movement amount for controlling inboard and outboard flaps based on a flap lever position during take-off and landing.

FIG. **10** is a block diagram depicting a control law for determining movement amount for controlling inboard, outboard and midspan flaps based on a flap lever position during take-off and landing.

Reference will hereinafter be made to the drawings in which similar elements in different drawings bear the same reference numerals.

DETAILED DESCRIPTION

In the following detailed description, certain preferred embodiments are described as illustrations in a specific application environment in order to provide a thorough understanding of the present disclosure. Those methods, procedures, components, or functions which are commonly known to persons of ordinary skill in the field of the disclosure are not described in detail so as not to unnecessarily obscure a concise description of the present disclosure. Certain specific embodiments or examples are given for purposes of illustration only, and it will be recognized by one skilled in the art that the teachings of this disclosure may be practiced in other analogous applications or environments and/or with other analogous or equivalent variations of the illustrative embodiments.

Some portions of the detailed description which follows are presented in terms of procedures, steps, logic blocks, processing, and other symbolic representations of operations within a computer memory. These descriptions and representations are the means used by those skilled in the art to most effectively convey the substance of their work to others skilled in the art. A procedure, computer executed step, logic block, process, etc., is here, and generally, conceived to be a self-consistent sequence of steps or instructions leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a computer system.

Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present disclosure, discussions utilizing terms such as "processing" or "computing" or "translating" or "calculating" or "determining" or "displaying" or "recognizing" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

A basic implementation of the teachings disclosed herein will now be described to show an exemplary embodiment of a system for differential adjustment of flap surfaces during take-off and landing. The example embodiment is implemented as an add-on control module to the system described in US Patents Nos. **7,726,610**, entitled “Systems and Methods for Providing Differential Motion to Wing High Lift Device,” and **7,494,094**, entitled “Aircraft Wing Systems for Providing Differential Motion to Deployable Lift Devices”. These patents describe systems implemented on aircraft having inboard and outboard flaps. Implementations of the teachings of the present disclosure will also be described with respect to systems for differentially controlling more than two flap surfaces, for example, an aircraft having inboard, outboard and midspan flaps.

Referring to FIG **1**, an exemplary embodiment is intended to operate within the flight envelope defined by the boundary parameters shown. The maximum altitude boundary of the flight envelope is the maximum altitude at which flaps would be deployed to increase lift for take-off and landing (ALTmax). The minimum altitude boundary is the altitude of the lowest airport the airplane is designed to operate from. The maximum speed boundaries within which the system operates is the maximum speed at which flaps would be deployed for takeoff or landing (SPEEDmax). The minimum speed boundary is zero knots.

Referring to FIG **2**, an overall view of a typical commercial airliner shows its controllable camber surfaces including wing **110**, wing trailing-edge devices **111**, wing leading-edge devices **116**, horizontal tail **106** and tail elevators **105**. This exemplary embodiment is operative to adjust trailing devices **111** to provide optimal settings in the take-off and landing flight envelope.

Referring to FIG **3**, a detailed view shows typical wing camber surfaces including wing **110**, wing trailing-edge devices **111**, and wing leading-edge devices **116**. In particular, the wing trailing-edge devices **111** include inboard trailing-edge flap **212**, inboard roll-control flap device **215**, outboard trailing-edge flap **213**, outboard roll-control flap device **214**, and spoilers **222**. Camber characteristics of the flap devices **212** and **213** and can be adjusted appropriately during take-off and landing to provide optimal efficiency.

Referring to FIG. **4**, a detailed view shows an alternate wing **310** embodiment showing alternate wing trailing edge devices **311**. The wing trailing-edge devices **311** include outboard trailing-edge flap **313**, midspan trailing-edge flap **316** and inboard trailing-edge flap **312**, as well as inboard roll-control flap device **315** and outboard roll-control flap device **314**. The camber characteristics of the flap devices **312**, **313** and **316** can be adjusted appropriately during take-off and landing to provide optimal efficiency.

Referring to FIG. **5**, a control system **420** configured to implement the control law of the present application, for moving inboard and outboard flaps differentially within the take-off and landing flight envelope is shown and described. The control system **420** may be implemented, for example, to control a wing as depicted in FIG. **3**.

Controller **423** may be an electronic or other type of control device containing memory and a microprocessor, for accepting input, processing the input, and providing output commands in response to the inputs, for controlling the motors and other devices which will adjust flap position. Controller **423** is operatively coupled to a central control device **430** and two differential control devices **440**. Controller **423** receives automatic inputs **425** and operator inputs **424**. Operator inputs can include a flap lever position reading **462**, determined from flap lever **460**. Automatic inputs can include left differential position **464**, right differential position **466** and inboard flap position **468**. Left differential position **464** and right differential position **466** are absolute values – that is, they represent an absolute amount that differential motors **455** have moved from a "zero" position. Devices that can measure such "absolute" positions include rotary sensors, such as a rotary variable differential transformer, a resolver, or an optical encoder. Automatic inputs may also include airplane weight **467**, airplane altitude **469** and airspeed **471**. During take-off and landing, controller **423** will determine optimal movements for inboard flaps **212** and outboard flaps **213** and direct the central control device **430** and differential control devices **440** appropriately.

Central control device **430** has primary motor **451** and alternate motor **452**, each of which power a drive link **453**. Central control device **430** also has primary brake **431** and alternate brake **432** which selectively inhibit the motion of the primary motor **451** and alternate motor **452**, respectively. Power provided to the drive link **453** may also be transferred through differential **441** to the outboard flaps **213**.

Differential control devices **440** are provided which provide differential control for outboard flaps **213**. Differential control device **440** preferably has a differential motor **455**, differential brake **442**, a differential **441**, and range limiter **443**. Range limiter **443** might be a physical device, or may be implemented in programmed instructions in controller **423** or in another control device.

The differential motor **455** provides power to the differential **441** to create differential motion between the inboard and outboard flaps. The differential **441** can receive power from both differential motor **455** and drive link **453**, and can distribute power to inboard flap **212**, outboard flap **213**, or both. Accordingly, differential **441** can include a planetary gear device or other suitable mechanical differential, or similar hydraulic or electrical device, depending on the nature of the drive link **453**. A range limiter **443** prevents differential motion of the outboard flaps **213** relative to the inboard flaps **212** past certain fixed bounds. As stated above, this range limiting function may be implemented entirely or partially within the programming of controller **423** or other programmable control device, and need not be implemented as a separate physical structure.

When the differential brake **442** is engaged, it prevents differential motion of the outboard flaps **213** with respect to inboard flaps **212** such that the differential control device **440** acts as a pass through gearbox with a fixed gear ratio. In this situation, inboard flaps **212** and outboard flaps **213** travel by the same amount.

When the differential brake **442** is not engaged, differential motor **455** can be utilized to move outboard flaps **213** differentially relative to inboard flaps **212**. If primary motor **451** is providing power to drive link **453** in one direction and differential motor **455** is providing power in the same direction, then the outboard flap **213** will travel in the same direction, but farther than inboard flaps **212**. If, on the other hand, primary motor **451** is providing power to drive link **453** in one direction and differential motor **455** is providing power in the opposite direction, then the outboard flap **213** will travel in the same direction, but not as far as the inboard flap **212**.

An outboard brake **444** can be used to prevent motion of the outboard section of the drive link **453**, and therefore prevent motion of the outboard flaps **213** while the inboard flaps **212** are in motion. If outboard brake **444** is engaged while differential brake is disengaged and the differential motor is engaged, differential motor **455** will move inboard flaps **212** while outboard flaps **213** remain stationary. While outboard brake **444** is shown in a physically separate location, outboard brake **444** may be included within differential control device **440**.

To save weight and space, the differential motor **455** may be a lower horsepower motor than the primary **451** and/or alternate motor **452**. As an example, the primary motor **451** may be a high horsepower hydraulic motor, having a horsepower of **40**Hp while the differential motor **455** may be a much lower horsepower electric motor of **3** Hp. It should be recognized that other types of motors may be used, and that the types described are merely exemplary. The goal of using motors having different horsepower amounts is to reduce space occupied and weight of structures on the wing.

Referring to FIG. **6**, a control system **600** configured to implement the control law of the present application, for moving inboard, outboard and midspan flaps differentially within the take-off and landing flight envelope is shown and described. The control system **600** may be implemented, for example, to control a wing as depicted in FIG. **4**.

Controller **623** may be an electronic or other type of control device containing memory and a microprocessor, for accepting input, processing the input, and providing output commands in response to the inputs, for controlling the motors and other devices which will adjust flap position.

Controller **623** is operatively coupled to a central control device **630**, midspan differential control devices **640** and outboard differential control devices **650**. Controller **623** receives automatic inputs **625** and operator inputs **624**. Operator inputs **625** can include a flap lever position reading **662**, determined from flap lever **660**. Automatic inputs can include left outboard differential position **676**, right outboard differential position **680**, left midspan differential position **677**, right midspan differential position **679** and inboard flap position **678**. As with the embodiment described with respect to FIG. **5**, the differential positions **676**, **677**, **679**, **680** represent absolute movement of the midspan and outboard differential motors **644**, **655** from an initial "zero" position. Devices that can measure such "absolute" positions include rotary sensors, such as a rotary variable differential transformer, a resolver, or an optical encoder. Automatic inputs may also include airplane weight **667**, airplane altitude **669** and airspeed **671**. During take-off and landing, controller **623** will determine optimal movements for inboard flaps **312**, outboard flaps **313** and midspan flaps **316** and direct the central control device **630**, outboard differential control devices **640** and midspan differential control devices **650** appropriately.

Central control device **630** has primary motor **653** and alternate motor **654**, each of which power a drive link **645**. Central control device **630** also has primary brake **631** and alternate brake **632** which selectively inhibit the motion of the primary motor **633** and alternate motor **634**, respectively. Power provided to the drive link **645** may also be transferred to midspan flaps **316** and outboard flaps **313**.

Midspan differential control devices **650** are provided which provide differential control for midspan flaps **316** relative to inboard flaps **312**. Midspan differential control device **650** preferably has a midspan differential motor **655**, midspan differential brake **652**, midspan differential **651**, and midspan range limiter **653**. Midspan range limiter **653** might be a physical device, or may be implemented in programmed instructions in controller **623** or in another control device.

Midspan differential motor **655** provides power to the midspan differential **651** to create differential motion between the inboard flaps **312** and the midspan flaps **316**. This differential motion may be transferred to outboard flaps **313** depending on the state of outboard control device **640**. This will be described in further detail below, with respect to FIG. **10**. Midspan differential **651** can receive power from both midspan differential motor **655** and drive link **645**, and can distribute power to inboard flap **312**, outboard flap **313**, midspan flaps **316**, or any combination thereof. Accordingly, midspan differential **651** can include a planetary gear device or other suitable mechanical differential, or similar hydraulic or electrical device, depending on the nature of the drive link **653**. Midspan range limiter **653** prevents differential motion of the midspan flaps **316** relative to the inboard flaps **312** and/or outboard flaps **313** past certain fixed bounds. As stated above, this range limiting function may be implemented entirely or partially within the programming of controller **623** or other programmable control device, and need not be implemented as a separate physical structure.

When the midspan differential brake **652** is engaged, it prevents differential motion of the midspan flaps **316** with respect to inboard flaps **312** such that the midspan differential control device **650** acts as a pass through gearbox with a fixed gear ratio. In this situation, midspan flaps **316** and inboard flaps **312** travel by the same amount. Engagement of midspan differential brake **652** does not necessitate that outboard flaps **313** travel by the same amount as midspan flaps **316** or inboard flaps **312**.

When the midspan differential brake **652** is not engaged, midspan differential motor **655** can be utilized to move midspan flaps **316** and inboard flaps **312** differentially. If primary motor **633** is providing power to drive link **645** in one direction and midspan differential motor **655** is providing power in the same direction, then the midspan flap **316** will travel in the same direction, but farther than inboard flaps **312**. If, on the other hand, primary motor **633** is providing power to drive link **645** in one direction and midspan differential motor **655** is providing power in the opposite direction, then the midspan flap **316** will travel in the same direction, but not as far as the inboard flap **312**.

Outboard differential control devices **640** are provided which provide differential control for outboard flaps **313**. Outboard differential control device **640** preferably has an outboard differential motor **644**, outboard differential brake **642**, outboard differential **641**, and outboard range limiter **643**. Outboard range limiter **643** might be a physical device, or may be implemented in programmed instructions in controller **623** or in another control device

Outboard differential motor **644** provides power to the outboard differential **641** to create differential motion between the midspan flap **316** and outboard flaps **313**. The outboard differential **641** can receive power from both outboard differential motor **644** and drive link **645**, and can distribute power to midspan differential **641**, outboard flap **313** or both. Accordingly, outboard differential **641** can include a planetary gear device or other suitable mechanical differential, or similar hydraulic or electrical device, depending on the nature of the drive link **645**. An outboard range limiter **643** prevents differential motion of the outboard flaps **313** relative to the midspan flaps **316** past certain fixed bounds. As stated above, this range limiting function may be implemented entirely or partially within the programming of controller **623** or other programmable control device, and need not be implemented as a separate physical structure. Because midspan differential **651** can provide power to outboard flaps **313**, motion of outboard flaps **313** will be dependent on the interaction between midspan differential control device **650** and primary control device **630**, as described above.

When the outboard differential brake **642** is engaged, it prevents differential motion of the outboard flaps **313** with respect to midspan flaps **316** such that the outboard differential control device **640** acts as a pass through gearbox with a fixed gear ratio. In this situation, midspan flaps **316** and outboard flaps **313** travel by the same amount.

When the outboard differential brake **642** is not engaged, outboard differential motor **644** can be utilized to move outboard flaps **313** differentially. Outboard flaps **313** can receive power both from midspan differential **651** and from outboard differential motor **644**.

If drive link **645** is providing power in one direction and outboard differential motor **644** is providing power in the same direction, then the outboard flap **313** will travel in the same direction, but farther than midspan flaps **316**. If, on the other hand, midspan differential **651** is providing power in one direction and outboard differential motor **644** is providing power in the opposite direction, then the outboard flap **313** will travel in the same direction, but not as far as the midspan flap **316**.

An outboard brake **646** can be used to prevent motion of the outboard section of the drive link **645**, and therefore prevent motion of the outboard flaps **313** while the inboard flaps **312** and/or midspan flaps **316** are in motion. If outboard brake **646** is engaged while outboard differential brake **642** is disengaged and the outboard differential motor **644** is engaged, outboard differential motor **644** can provide power to midspan flap **316** and/or inboard flap **312** while outboard flap **313** remains stationary. While outboard brake **646** is shown in a physically separate location, outboard brake **646** may be included within outboard differential control device **640**.

Differential motion is thus provided by the combination of central control device **630**, outboard differential control devices **640** and midspan differential control devices **650**.

To save weight and space, the midspan differential motor **655** and/or outboard differential motor **644** may be a lower horsepower motor than the primary **633** and/or alternate motor **634**. As an example, the primary motor **633** may be a high horsepower hydraulic motor, having a horsepower of **40**Hp while the midspan differential motor **655** and/or outboard differential motor **644** may be a much lower horsepower electric motor of **3** Hp. It should be recognized that other types of motors may be used, and that the types described are merely exemplary. The goal of using motors having different horsepower amounts is to reduce space occupied and weight of structures on the wing.

Referring to FIG. **7**, an illustration of the steps performed for controlling outboard and inboard flaps differentially is shown. These steps may be implemented, for example, on a wing and control system as depicted in FIGS. **3** and **5**, respectively. The different parts are activated to bring inboard flaps **212** and outboard flaps **213** to their optimal positions. To move inboard flaps **212** and outboard flaps **213** differentially, differential motor **455** may be activated. It should be understood that differential control devices **440** on each wing may be controlled separately, to move left and right outboard flap surfaces to different positions.

In step **702**, a flap lever position changes, and provides a signal **462** to controller **423** indicating that a change in flap position is desired. Although shown originating at a flap lever **460**, it should be understood that flap lever signal **462** may come from other structures or devices, such as other physical devices used to manually command flaps, or from an automatic system which can automatically command flap position (for example, from "flap load relief" system which automatically readjusts flaps if pilot accelerates to an airspeed greater than the flap is designed for).

In step **704**, new desired (or "ideal") flap positions for inboard and outboard flaps are determined from a lookup table. The lookup table accepts flap lever position signal (or "desired position signal") **462** as input, and may also accept airplane weight, airplane altitude and/or airspeed to more precisely determine ideal flap positions. Other variables that can assist in determining optimal flap surface positions may be used as inputs to the lookup table—the lookup table serves the purpose of providing ideal flap surface positions, given flap lever position during takeoff and landing. Other methods of determining ideal flap positions may also be used.

In step **706**, the current positions of left outboard differential motor, right outboard differential motor, and primary motor are determined. A gauge or other device for determining these positions may be used.

In step **708**, a move increment for each motor is determined. This will be described in further detail with regard to figure **9**.

In step **710**, all motors are commanded to zero speed. In step **712**, primary brake, left differential brake, right differential brake and outboard brake are released, in order to allow primary motor to power drive link **453**, and to allow outboard flaps **213** to move with respect to inboard flaps **212**.

In step **714**, left outboard motor, right outboard motor, and primary motors are commanded to move by the amount determined in step **708**. In step **716**, primary brake, left differential brake, right differential brake and outboard brake are re-engaged, preventing motion of all flap surfaces.

Referring to FIG. **8**, an illustration of the steps performed by a control law for controlling outboard, midspan and inboard flaps differentially is shown. These steps may be implemented on a wing and control system, for example, as depicted in FIGS. **4** and **6**, respectively. The different parts are activated to bring inboard flaps **312**, midspan flaps **316** and outboard flaps **313** to their optimal positions. To move inboard flaps **312**, midspan flaps **316** and outboard flaps **313** differentially, differential motors **655**, **644** may be activated.

In step **802**, a flap lever position changes, and provides a signal **662** to controller **623**, indicating that a change in flap position is desired. Although shown originating at a flap lever **660**, it should be understood that flap lever signal **662** may come from other structures or devices, such as other physical devices used to manually command flaps, or from an automatic system which can automatically command flap position.

In step **804**, new desired (or "ideal") flap positions for inboard, midspan and outboard flaps are determined from a lookup table. The lookup table accepts flap lever position signal (or "desired position signal") **662** as input, and may also accept airplane weight, airplane altitude and/or airspeed to more precisely determine ideal flap positions. Other variables that can assist in determining optimal flap surface positions may be used as inputs to the lookup table—the lookup table serves the purpose of providing ideal flap surface positions, given flap lever position during takeoff and landing. Other methods of determining ideal flap positions may also be used.

In step **806**, the current positions of left outboard differential motor, right outboard differential motor, left midspan motor, right midspan motor and primary motor are determined. A gauge or other device for determining these positions may be used.

In step **808**, a move increment for each motor is determined. This will be described in further detail with regard to figure **10**.

In step **810**, all motors are commanded to zero speed. In step **812**, primary brake, left outboard differential brake, right outboard differential brake, left midspan differential brake, right midspan differential brake and outboard brake are released, in order to allow primary motor to power drive link, and to allow outboard flaps, midspan flaps and inboard flaps to move with respect to each other.

In step **814**, left outboard differential motor, right outboard differential motor, left midspan differential motor, right midspan differential motor, and primary motors are commanded to move by the amount determined in step **808**. In step **816**, primary brake, left outboard differential brake, right outboard differential brake, left midspan differential brake, right midspan differential brake and outboard brake are re-engaged, preventing motion of all flap surfaces.

Referring now to FIGS. **9** and **10**, control laws for determining displacement amounts for outboard and inboard flaps, and midspan flaps if present, are disclosed. The control laws described herein are designed to be implemented as computer instructions carried out by controller **423** or controller **623**. Generally speaking, the control laws determine an amount of displacement that each of a primary motor, midspan motor, and/or outboard motor should provide to outboard, midspan, and inboard flaps.

These control laws are designed to provide an appropriate amount of movement to each motor, taking into account the fact that activation of each of the motors may move more than one flap. As an example, depending on the configuration of differential control devices, primary motor may cause inboard and outboard flaps to move, and may cause midspan flaps to move by a certain amount as well. More information relating to motion provided by each motor to each flap is described in more detail below, with respect to FIGS. **9** and **10**.

It should be noted that while the control law contemplates that inputs will be inboard flap position and midspan and outboard differential position, other inputs to the control law could be provided. For example, instead of calculating the current outboard position **516**, **1008** or current midspan position **1004**, those positions could be measured and provided to the control law directly.

Referring to FIG. **9**, a functional block diagram depicting control logic for determining displacement amounts for inboard flaps **212** and outboard flaps **213** is shown. This functional block diagram may be used for wing, control system, and method depicted in FIGS. **3**, **5** and **7**, respectively. Inputs to the block diagram include a flap lever position **462**, a current differential position **464**, **466**, and a current inboard flap position **468**.

The current flap lever position **462** is provided to a lookup table **508**, which outputs an ideal outboard position **510** and ideal inboard flap position **512**. Optionally, airplane weight **467**, airplane altitude **469**, and/or airspeed **471** may also be provided to the lookup table **508**, which will provide appropriate outputs.

Current inboard flap position **468** is subtracted from current right differential position **464** at **514** to determine current right outboard flap position **516**. The current right outboard flap position **516** is subtracted from ideal right outboard position **510** from the lookup table **508** at **518** to determine the total amount the right outboard flap will move **520**.

Current inboard flap position **468** is subtracted from ideal inboard flap position **512** at **522** to determine a total amount inboard flap will move **524**. This amount **524** will be commanded to primary motor **451** at **526**.

The total amount inboard flap will move **524** will be subtracted from the total amount right outboard flap will move **520** at **528**. The output is commanded to the right differential motor at **530**.

If differential motor **455** is activated while primary motor **451** is activated, power will be provided to the outboard flaps **213** by both motors. Therefore, if it is desirable to move outboard flaps **213** by a displacement amount which is greater than the displacement amount of inboard flaps **212**, differential motor **455** may be activated in the same direction as, and during activation of primary motor **451**.

If it is desirable to move the outboard flaps **213** by a displacement amount which is less than the displacement amount of inboard flaps **212**, differential motor **455** may be activated in the opposite direction as, but still during the activation of, the primary motor **451**.

Finally, if it is desirable to move outboard flaps **213** by a displacement amount which is the same as the displacement amount of inboard flaps **212**, differential motor **455** need not be activated. Instead, differential brake **442** may be set in order to prevent differential motion of outboard flaps **213** with respect to inboard flaps **212**. In this case, only primary motor **451** will be required to be activated, and it will be used to move both inboard flaps **212** and outboard flaps **213** by the same amount.

The procedures shown and described for determining the commanded amount for movement of right outboard differential motor and movement of right midspan differential motor are also used to determine commanded movement for left outboard differential motor **529** with current left outboard differential position **466** and ideal left outboard position **510** serving as inputs.

It should be noted that motors **455** and **451** need not be activated simultaneously in order to provide differential motion to inboard, midspan and outboard flaps. Differential brakes **442** may be set to allow any or all surfaces to move together. Subsequently, differential motor **455** may be activated to provide differential motion to flaps **213**.

Referring to FIG. **10**, a functional block diagram depicting control logic for determining displacement amounts for inboard flaps **312**, midspan flaps **316** and outboard flaps **313** is shown. This functional block diagram may be used for wing, control system, and method depicted in FIGS. **4**, **6** and **8**, respectively.

Inputs to the block diagram include a flap lever position **662**, current outboard differential position **680**, **676**, current midspan differential position **677**, **679**, and a current inboard flap position **678** As stated above, "differential position" represents an absolute measurement of the motion of the corresponding differential motor, from a zero position.

Current inboard flap position is added to current right midspan differential position at **1002**, which results in current right midspan position **1004**. Current right midspan position is added to current right outboard differential position at **1006**, to provide current right outboard position **1008**. Current right outboard position **1008** is subtracted from ideal right outboard position **1010** from the lookup table **1001** at **1012** to determine total amount right outboard flap will move **1014**.

Current right midspan position **1004** is subtracted from ideal right midspan position from lookup table **1001** at **1018** to produce the total amount right midspan flap will move **1020**.

Current inboard flap position **678** is subtracted from ideal inboard flap position **1022** at **1024** to determine the total amount inboard flap will move **1026**. The amount inboard flap will move **1026** will be commanded to primary motor **633** at **483**.

Total amount inboard flap will move **1026** will be subtracted from total amount right midspan flap will move **1020** at **1028**. The result will be commanded to right midspan differential motor at **484**.

Total amount right midspan flap will move **1020** will be subtracted from total amount right outboard flap will move **1014** at **1030** and the result will be commanded to right outboard differential motor at **485**.

If midspan differential motor **655** is activated while primary motor **633** is activated, power will be provided to the midspan flaps **316** by both motors. Therefore, if it is desirable to move midspan flaps **316** by a displacement amount which is greater than the displacement amount of inboard flaps **312**, midspan differential motor **655** may be activated in the same direction as, and during activation of primary motor **633**.

If it is desirable to move the midspan flaps **316** by a displacement amount which is less than the displacement amount of inboard flaps **312**, midspan differential motor **655** may be activated in the opposite direction as, but still during the activation of, the primary motor **633**.

Finally, if it is desirable to move midspan flaps **316** by a displacement amount which is the same as the displacement amount of inboard flaps **312**, midspan differential motor **655** need not be activated. Instead, midspan differential brake **652** may be set in order to prevent differential motion of midspan flaps **316** with respect to inboard flaps **312**. In this case, only primary motor **633** will be required to be activated, and it will be used to move both inboard flaps **312** and midspan flaps **316** by the same amount.

For motion of outboard flaps **313**, outboard differential motor **644** provides motion with respect to motion provided by midspan differential **651**. Therefore, if outboard differential motor **644** is activated while midspan flaps **316** are moving, outboard flaps **313** will be provided with power by both midspan differential **651** and by outboard differential motor **644**, and outboard flaps **313** will move differentially with respect to midspan flaps **316**.

If it is desirable to move outboard flaps **313** by a displacement amount which is greater than the displacement amount of midspan flaps **316**, outboard differential motor **644** may be activated in the same direction as motion of the midspan flaps **316**.

If it is desirable to move the outboard flaps **313** by a displacement amount which is less than the displacement amount of midspan flaps **316**, outboard differential motor **644** may be activated in the opposite direction as motion of the midspan flaps **316**.

Finally, if it is desirable to move outboard flaps **313** by a displacement amount which is the same as the displacement amount of midspan flaps **316**, outboard differential motor **644** need not be activated. Instead, outboard differential brake **642** may be set in order to prevent differential motion of outboard flaps **313** with respect to midspan flaps **316**.

The procedures shown and described for determining the commanded amount for movement of right outboard differential motor and movement of right midspan differential motor are also used to determine commanded movement for left midspan differential motor **482** and left outboard differential motor **481**, with current left midspan differential position **677**, current left outboard differential position **676**, ideal left midspan position **1040** and ideal left outboard position **1042**.

It should be noted that motors **633**, **644** and **655** need not be activated simultaneously in order to provide differential motion to inboard, midspan and outboard flaps. Differential brakes **652**, **642** may be set to allow any or all surfaces to move together. Subsequently, differential motors **644**, **655** may be activated to provide differential motion to flap surfaces **316**, **312**.

Systems and methods are therefore provided which generate differential motion between flap surfaces such that optimal efficiency is provided during the take-off and landing flight envelope.

While the invention has been described with reference to various embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation to the teachings of the invention without departing from the essential scope thereof. Therefore it is intended that the invention not be limited to the particular embodiments for carrying out this invention disclosed hereinabove.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for differentially adjusting a first deployable lift device and a second deployable lift device on an aircraft wing of an aircraft within a takeoff and landing envelope, wherein said first deployable lift device and said second deployable lift device are coupled to a single power drive link, said method comprising causing a controller to, within the takeoff and landing envelope:

determine a first desired position for said first deployable lift device and a second desired position for said second deployable lift device, based on a desired position signal;

activate a first motor of the single power drive link to move said first deployable lift device by a first total movement amount, said first total movement amount being determined by subtracting a first current position of said first deployable lift device from said first desired position;

determine a second total movement amount for said second deployable lift device by subtracting a second current position of said second deployable lift device from said second desired position;

determine a first differential movement amount by subtracting said first total movement amount from said second total movement amount; and

activate a second motor to move said second deployable lift device by said first differential movement amount.

2. The method of claim **1**, wherein:

said first desired position and said second desired position are further determined based on weight, altitude and airspeed of the aircraft.

3. The method of claim **1**, further comprising causing the controller to:

engage a first differential brake prior to activating said first motor;

disengage said first differential brake after moving said first deployable lift device is complete; and

activate said second motor.

4. The method of claim **1**, further comprising causing the controller to:

determine said second current position by adding said first current position to a first differential position.

5. The method of claim **1**, further comprising causing the controller to:

determine a third total movement amount for a third deployable lift device by subtracting a third current position of said third deployable lift device from a third desired position for said third deployable lift device;

determine a second differential movement amount for said third deployable lift device by subtracting said second total movement amount from said third total movement amount; and

activate a third motor to move said third deployable lift device by said second differential movement amount.

6. The method of claim **5**, further comprising causing the controller to:

determine said third current position by adding said second current position to a second differential position.

7. The method of claim **5**, further comprising causing the controller to:

engage a second differential brake prior to activating said second motor;

disengage said second differential brake after moving said second deployable lift device is complete; and

activate said third motor.

8. The method of claim **1** further comprising causing the controller to:

determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

9. An aircraft wing system for differentially adjusting a first deployable lift device and a second deployable lift device on an aircraft wing of an aircraft within a takeoff and landing envelope, said system comprising:

a first deployable lift device;

a second deployable lift device, wherein said first deployable lift device and said second deployable lift device are coupled to a single power drive link;

a high horsepower motor providing power to said power drive link;

a first low horsepower motor, said first low horsepower motor having a lower horsepower than said high horsepower motor;

a first differential configured to receive power from said drive link and said first low horsepower motor, and to provide power to said second deployable lift device; and a controller programmed to, within the takeoff and landing envelope:

determine a first desired position for said first deployable lift device and a second desired position for said second deployable lift device, based on a desired position signal;

activate said high horsepower motor to move said first deployable lift device by a first total movement amount, said first total movement amount being determined by subtracting a first current position of said first deployable lift device from said first desired position;

determine a second total movement amount for said second deployable lift device by subtracting a second current position of said second deployable lift device from said second desired position;

determine a first differential movement amount by subtracting said first total movement amount from said second total movement amount; and

activate said first low horsepower motor to move said second deployable lift device by said first differential movement amount.

10. The system of claim **9**, wherein:

said controller is programmed to determine said first desired position and said second desired position based on weight, altitude and airspeed of the aircraft.

11. The system of claim **9**, wherein:

said controller is further programmed to:

engage a first differential brake prior to activating said high horsepower motor;

disengage said first differential brake after moving said first deployable lift device is complete; and

activate said first low horsepower motor.

12. The system of claim **9**, wherein:

said controller is further programmed to determine a second current position by adding said first current position to a first differential position.

13. The system of claim **9**, further comprising:

a third deployable lift device;

wherein said controller is further programmed to:

determine a third total movement amount for said third deployable lift device by subtracting a third current position of said third deployable lift device from a third desired position;

determine a second differential movement amount for said third deployable lift device by subtracting said second total movement amount from said third total movement amount; and

activate a second low horsepower motor to move said third deployable lift device by said second differential movement amount, said second low horsepower motor having a lower horsepower than said high horsepower motor.

14. The system of claim **13**, wherein:

said controller is further programmed to:

determine said third current position by adding said second current position to a second differential position.

15. The system of claim **14**, wherein:

said controller is further programmed to:

engage a second differential brake prior to activating said first low horsepower motor;

disengage said second differential brake and engage said first differential brake after moving said second deployable lift device is complete; and

activate said second low horsepower motor.

16. The system of claim **9**, wherein:

said controller is further programmed to:

determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

17. An aircraft employing an aircraft wing system for differentially adjusting a first deployable lift device and a second deployable lift device within a takeoff and landing envelope, said aircraft comprising:

an aircraft body;

a wing having a first deployable lift device and a second deployable lift device, wherein said first deployable lift device and said second deployable lift device are coupled to a single power drive link;

a high horsepower motor providing power to said power drive link;

a first low horsepower motor, said first low horsepower motor having a lower horsepower than said high horsepower motor;

a first differential configured to receive power from said drive link and said first low horsepower motor, and to provide power to said second deployable lift device; and

a controller programmed to, within the takeoff and landing envelope:

determine a first desired position for said first deployable lift device and a second desired position for said second deployable lift device, based on a desired position signal;

activate said high horsepower motor to move said first deployable lift device by a first total movement amount, said first total movement amount being determined by subtracting a first current position of said first deployable lift device from said first desired position;

determine a second total movement amount for said second deployable lift device by subtracting a second current position of said second deployable lift device from said second desired position;

determine a first differential movement amount by subtracting said first total movement amount from said second total movement amount; and

activate said first low horsepower motor to move said second deployable lift device by said first differential movement amount.

18. The aircraft of claim **17**, wherein:

said controller is programmed to determine said first desired position and said second desired position based on weight, altitude and airspeed of the aircraft.

19. The aircraft of claim **17**, wherein:

said controller is further programmed to:

engage a first differential brake prior to activating said high horsepower motor;

disengage said first differential brake after moving said first deployable lift device is complete; and

activate said first low horsepower motor.

20. The aircraft of claim **17**, wherein:

said controller is further programmed to determine a second current position by adding said first current position to a first differential position.

21. The aircraft of claim **17**, further comprising:

a third deployable lift device;

wherein said controller is further programmed to:

determine a third total movement amount for said third deployable lift device by subtracting a third current position of said third deployable lift device from a third desired position;

determine a second differential movement amount for said third deployable lift device by subtracting said second total movement amount from said third total movement amount; and

activate a second low horsepower motor to move said third deployable lift device by said second differential movement amount, said second low horsepower motor having a lower horsepower than said high horsepower motor.

22. The aircraft of claim **21**, wherein:

said controller is further programmed to:

determine said third current position by adding said second current position to a second differential position.

23. The aircraft of claim **17**, wherein:

said controller is further programmed to:

determine that the aircraft is within the takeoff and landing envelope when altitude and airspeed of the aircraft are within altitude and airspeed boundaries of the takeoff and landing envelope.

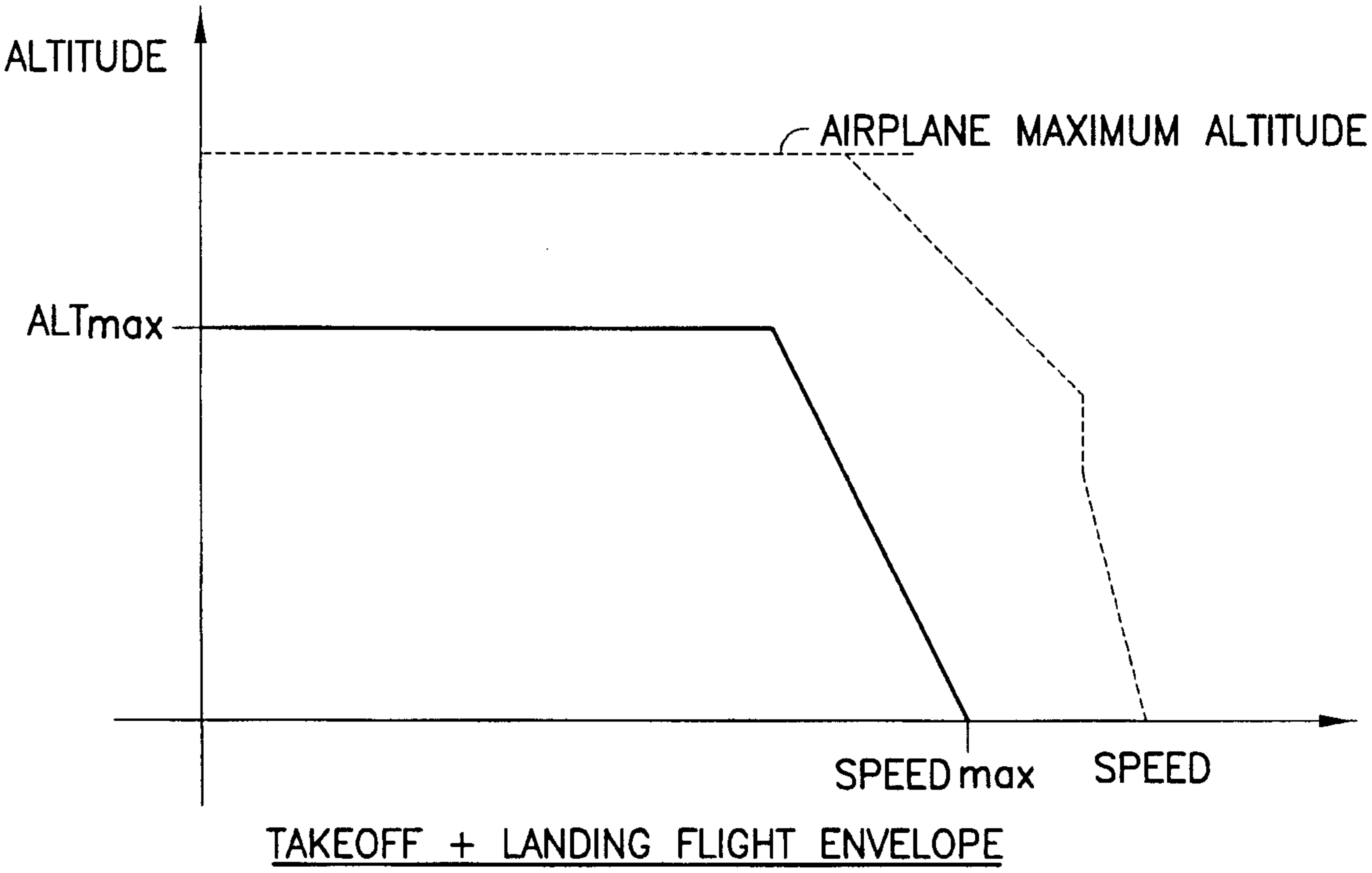

ALTITUDE
AIRPLANE MAXIMUM ALTITUDE
ALTmax
SPEED max
SPEED
TAKEOFF + LANDING FLIGHT ENVELOPE

FIG.1

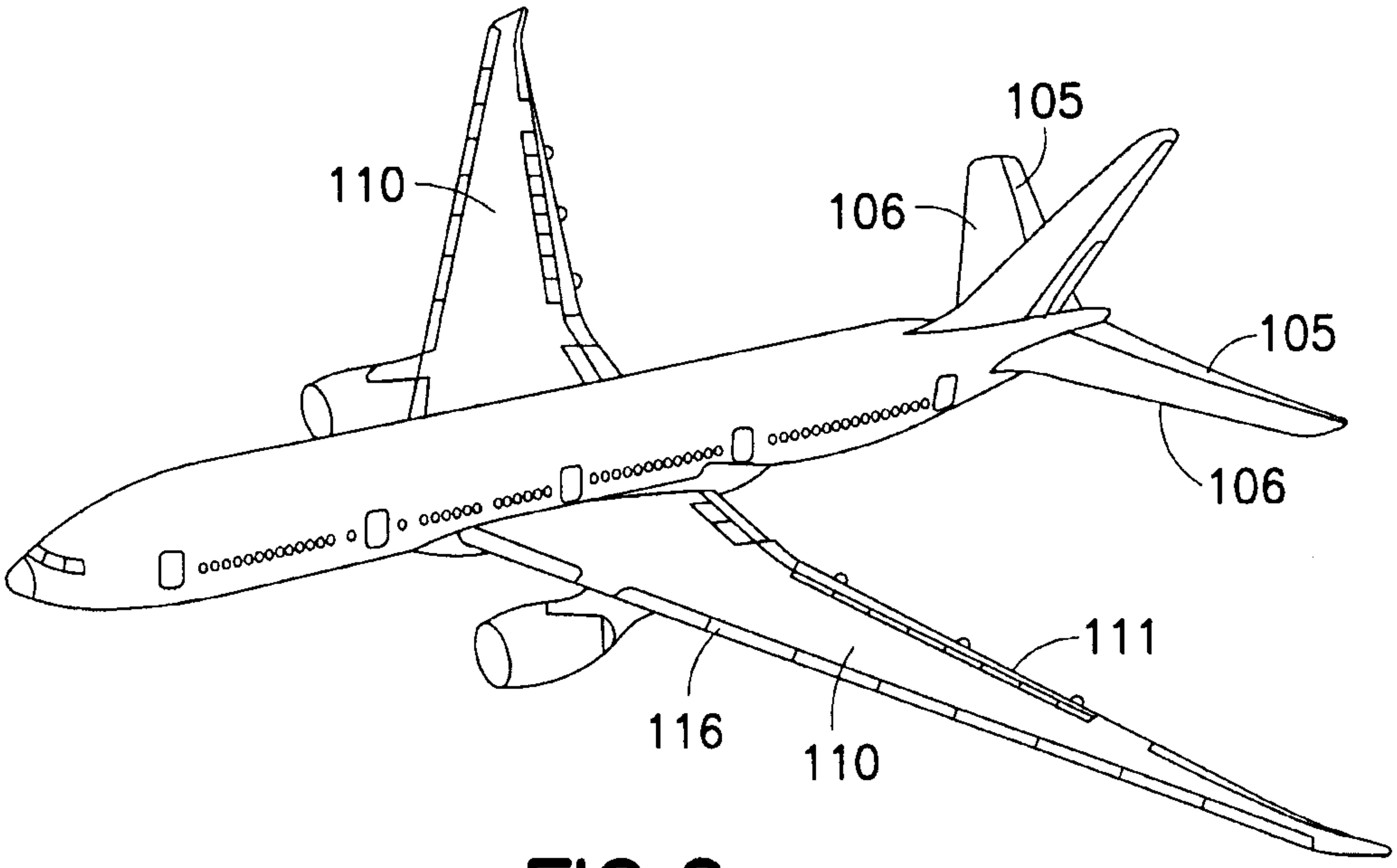
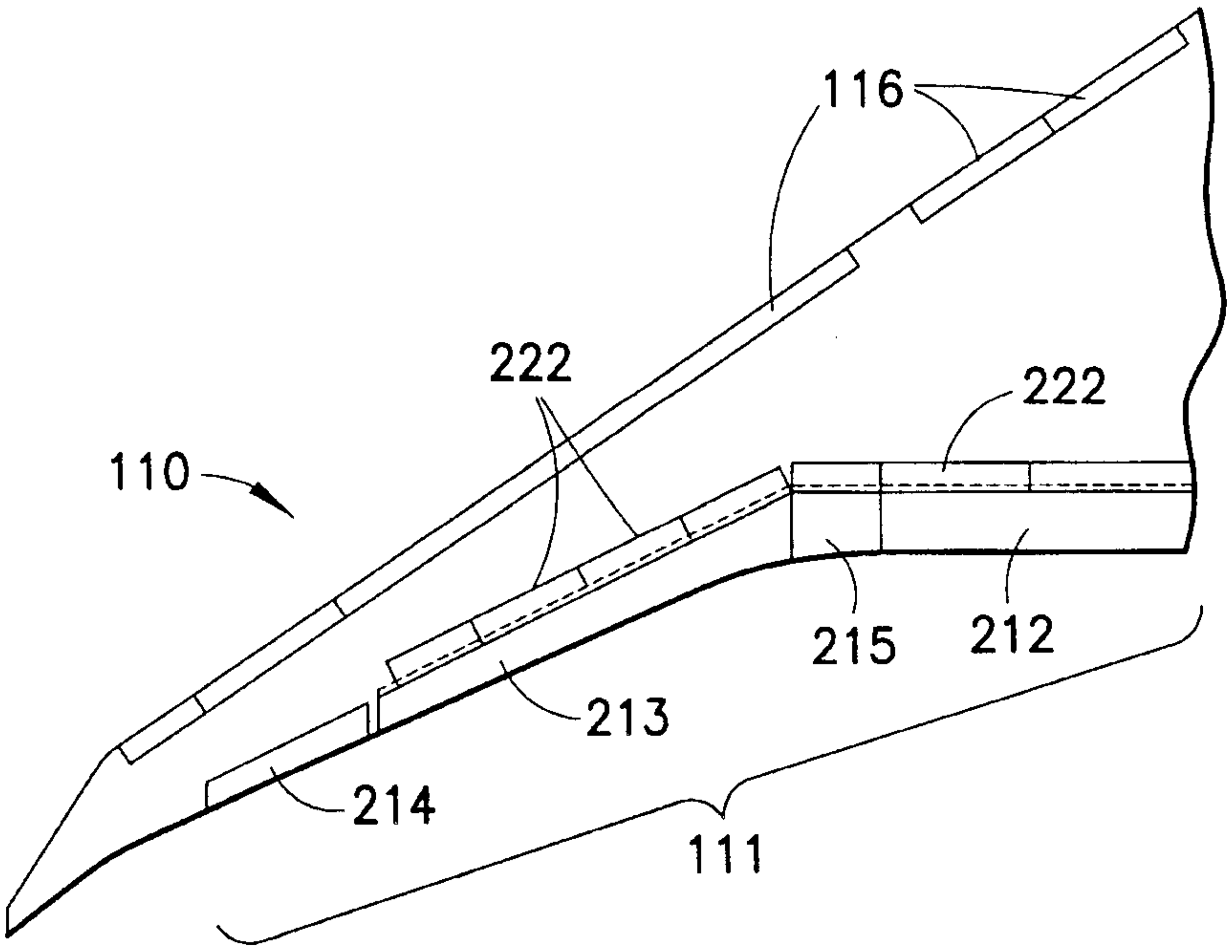

110
105
106
105
106
111
116
110

FIG.2


116
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222
110
215
212
213
214
111

FIG.3

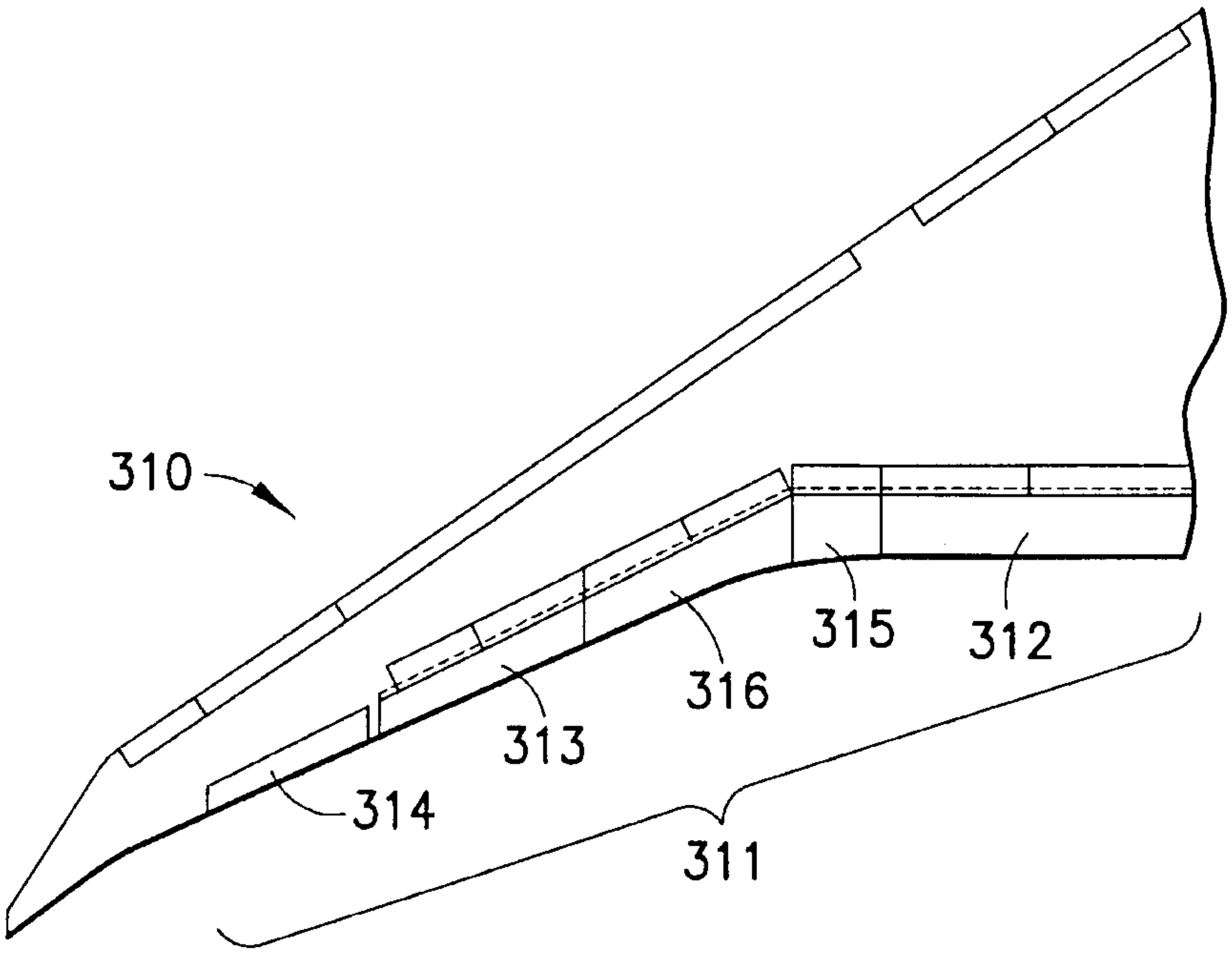


FIG.4

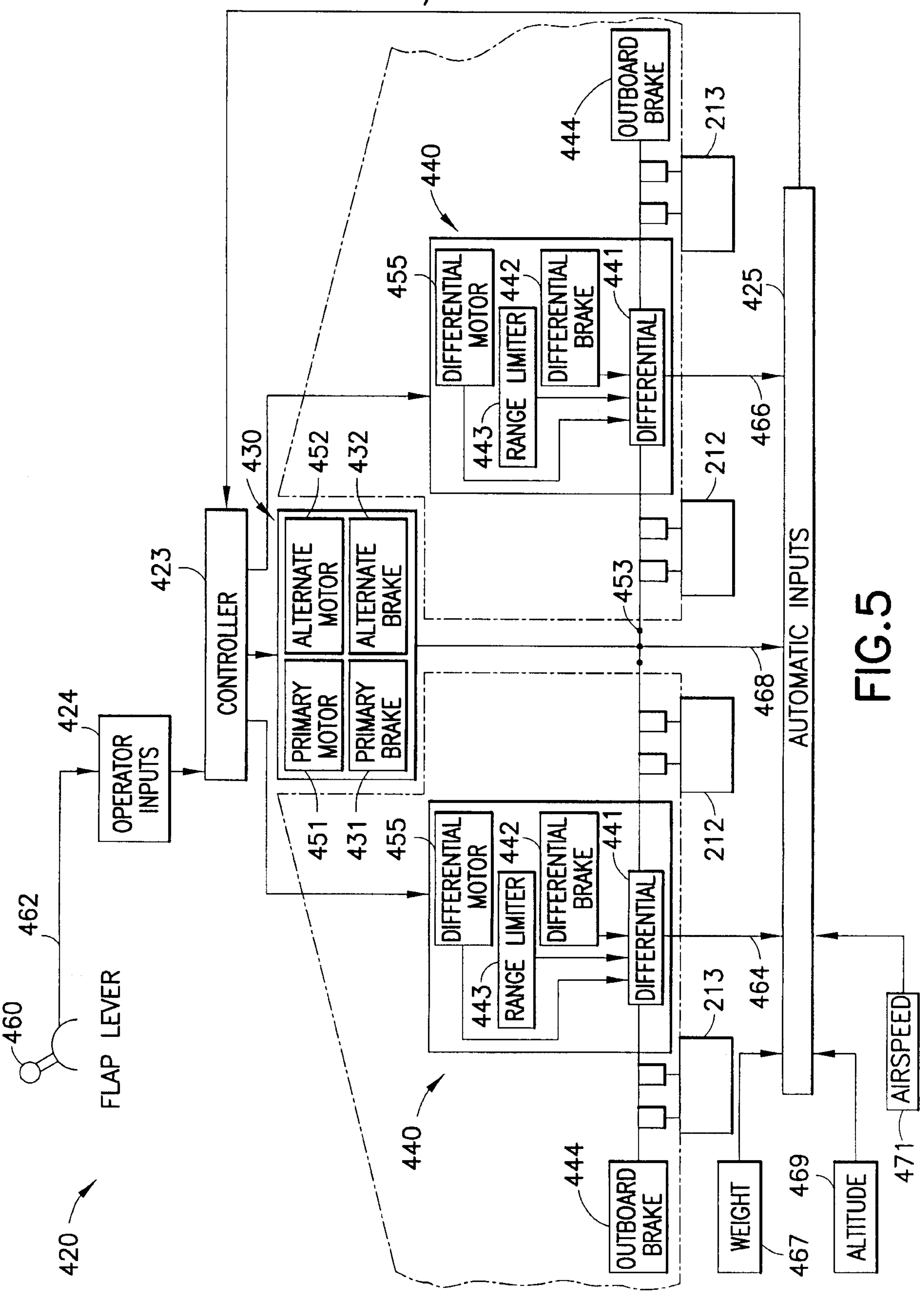
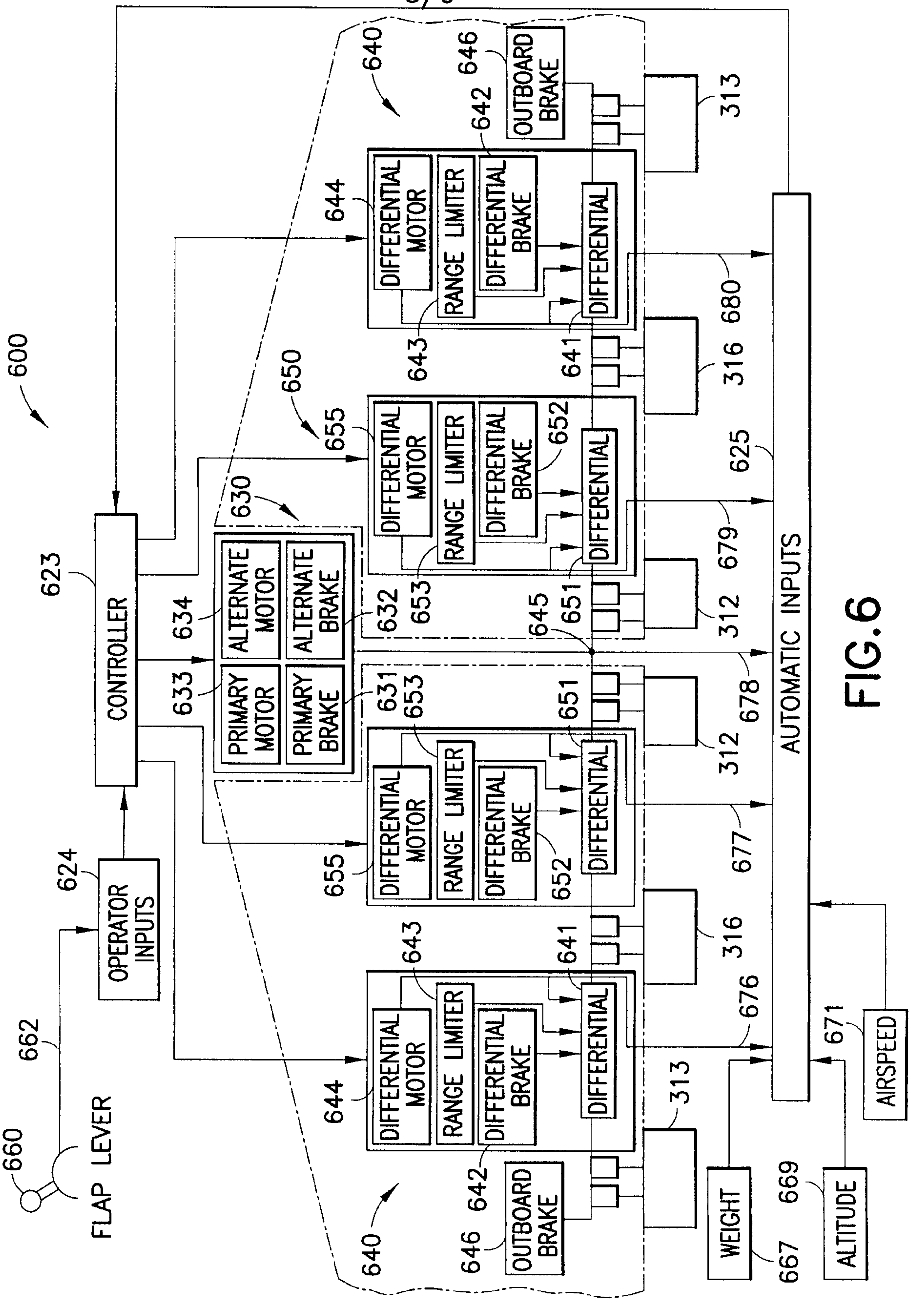

420
460
FLAP LEVER
462
424
OPERATOR INPUTS
423
CONTROLLER
430
452
ALTERNATE MOTOR
432
ALTERNATE BRAKE
PRIMARY MOTOR
PRIMARY BRAKE
451
431
455
DIFFERENTIAL MOTOR
442
RANGE LIMITER
443
DIFFERENTIAL BRAKE
441
DIFFERENTIAL
440
444
OUTBOARD BRAKE
213
212
453
425
466
468
464
AUTOMATIC INPUTS
WEIGHT
467
ALTITUDE
469
AIRSPEED
471

FIG.5


600
FLAP LEVER
660
662
OPERATOR INPUTS
624
CONTROLLER
623
630
ALTERNATE MOTOR
634
ALTERNATE BRAKE
632
PRIMARY MOTOR
633
PRIMARY BRAKE
631
640
650
DIFFERENTIAL MOTOR
644
655
RANGE LIMITER
643
653
DIFFERENTIAL BRAKE
642
652
DIFFERENTIAL
641
651
645
OUTBOARD BRAKE
646
313
316
312
AUTOMATIC INPUTS
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676
677
678
679
680
WEIGHT
667
ALTITUDE
669
AIRSPEED
671

FIG.6

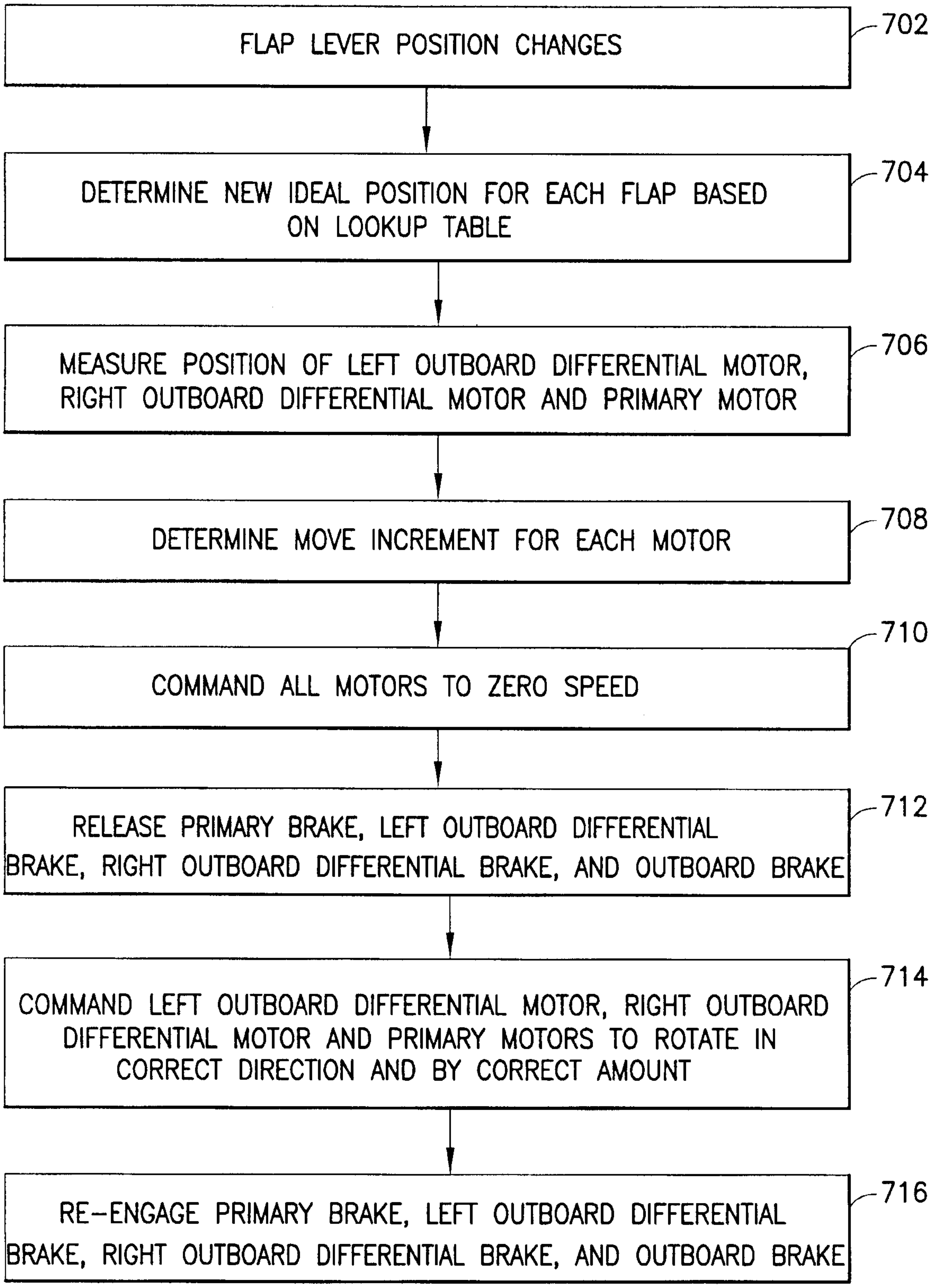

FLAP LEVER POSITION CHANGES
702
DETERMINE NEW IDEAL POSITION FOR EACH FLAP BASED ON LOOKUP TABLE
704
MEASURE POSITION OF LEFT OUTBOARD DIFFERENTIAL MOTOR, RIGHT OUTBOARD DIFFERENTIAL MOTOR AND PRIMARY MOTOR
706
DETERMINE MOVE INCREMENT FOR EACH MOTOR
708
COMMAND ALL MOTORS TO ZERO SPEED
710
RELEASE PRIMARY BRAKE, LEFT OUTBOARD DIFFERENTIAL BRAKE, RIGHT OUTBOARD DIFFERENTIAL BRAKE, AND OUTBOARD BRAKE
712
COMMAND LEFT OUTBOARD DIFFERENTIAL MOTOR, RIGHT OUTBOARD DIFFERENTIAL MOTOR AND PRIMARY MOTORS TO ROTATE IN CORRECT DIRECTION AND BY CORRECT AMOUNT
714
RE-ENGAGE PRIMARY BRAKE, LEFT OUTBOARD DIFFERENTIAL BRAKE, RIGHT OUTBOARD DIFFERENTIAL BRAKE, AND OUTBOARD BRAKE
716

FIG.7

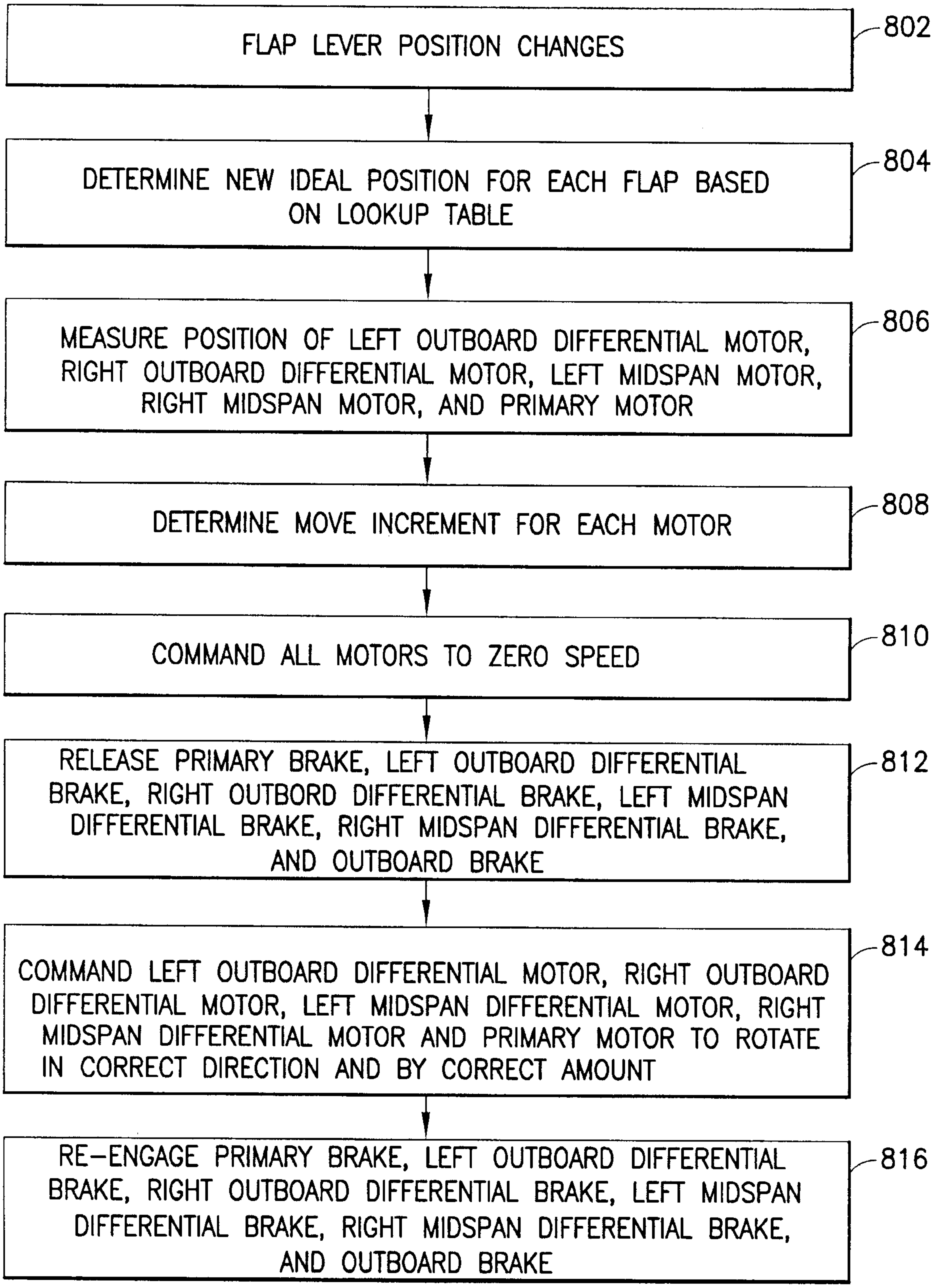

FLAP LEVER POSITION CHANGES
802
DETERMINE NEW IDEAL POSITION FOR EACH FLAP BASED ON LOOKUP TABLE
804
MEASURE POSITION OF LEFT OUTBOARD DIFFERENTIAL MOTOR, RIGHT OUTBOARD DIFFERENTIAL MOTOR, LEFT MIDSPAN MOTOR, RIGHT MIDSPAN MOTOR, AND PRIMARY MOTOR
806
DETERMINE MOVE INCREMENT FOR EACH MOTOR
808
COMMAND ALL MOTORS TO ZERO SPEED
810
RELEASE PRIMARY BRAKE, LEFT OUTBOARD DIFFERENTIAL BRAKE, RIGHT OUTBORD DIFFERENTIAL BRAKE, LEFT MIDSPAN DIFFERENTIAL BRAKE, RIGHT MIDSPAN DIFFERENTIAL BRAKE, AND OUTBOARD BRAKE
812
COMMAND LEFT OUTBOARD DIFFERENTIAL MOTOR, RIGHT OUTBOARD DIFFERENTIAL MOTOR, LEFT MIDSPAN DIFFERENTIAL MOTOR, RIGHT MIDSPAN DIFFERENTIAL MOTOR AND PRIMARY MOTOR TO ROTATE IN CORRECT DIRECTION AND BY CORRECT AMOUNT
814
RE-ENGAGE PRIMARY BRAKE, LEFT OUTBOARD DIFFERENTIAL BRAKE, RIGHT OUTBOARD DIFFERENTIAL BRAKE, LEFT MIDSPAN DIFFERENTIAL BRAKE, RIGHT MIDSPAN DIFFERENTIAL BRAKE, AND OUTBOARD BRAKE
816

FIG.8

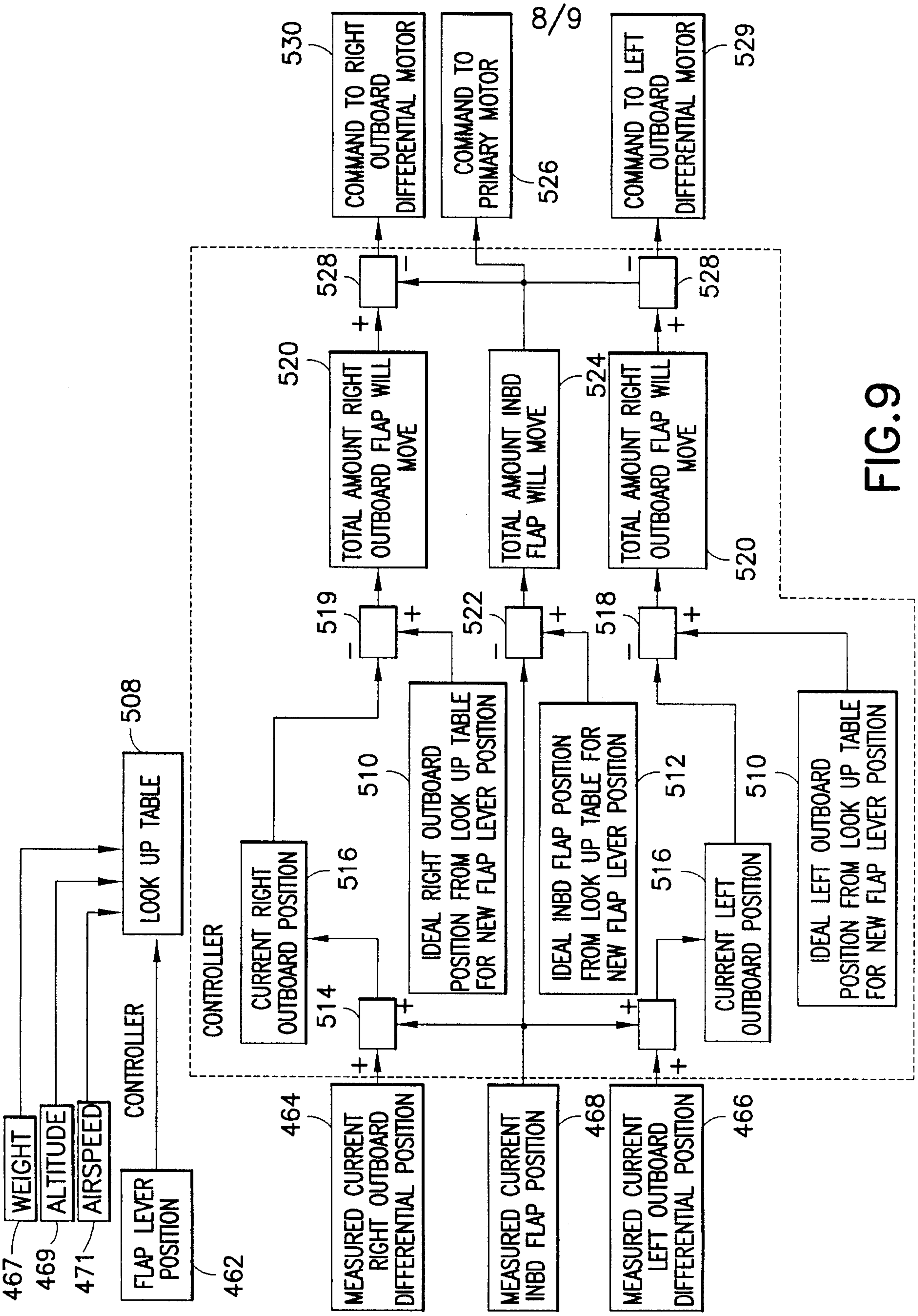

WEIGHT
467
ALTITUDE
469
AIRSPEED
471
FLAP LEVER POSITION
462
CONTROLLER
LOOK UP TABLE
508
CONTROLLER
MEASURED CURRENT RIGHT OUTBOARD DIFFERENTIAL POSITION
464
MEASURED CURRENT INBD FLAP POSITION
468
MEASURED CURRENT LEFT OUTBOARD DIFFERENTIAL POSITION
466
514
CURRENT RIGHT OUTBOARD POSITION
516
CURRENT LEFT OUTBOARD POSITION
516
IDEAL RIGHT OUTBOARD POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION
510
IDEAL INBD FLAP POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION
512
IDEAL LEFT OUTBOARD POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION
510
519
522
518
TOTAL AMOUNT RIGHT OUTBOARD FLAP WILL MOVE
520
TOTAL AMOUNT INBD FLAP WILL MOVE
524
TOTAL AMOUNT RIGHT OUTBOARD FLAP WILL MOVE
520
528
528
COMMAND TO RIGHT OUTBOARD DIFFERENTIAL MOTOR
530
COMMAND TO PRIMARY MOTOR
526
COMMAND TO LEFT OUTBOARD DIFFERENTIAL MOTOR
529
+
-

FIG.9

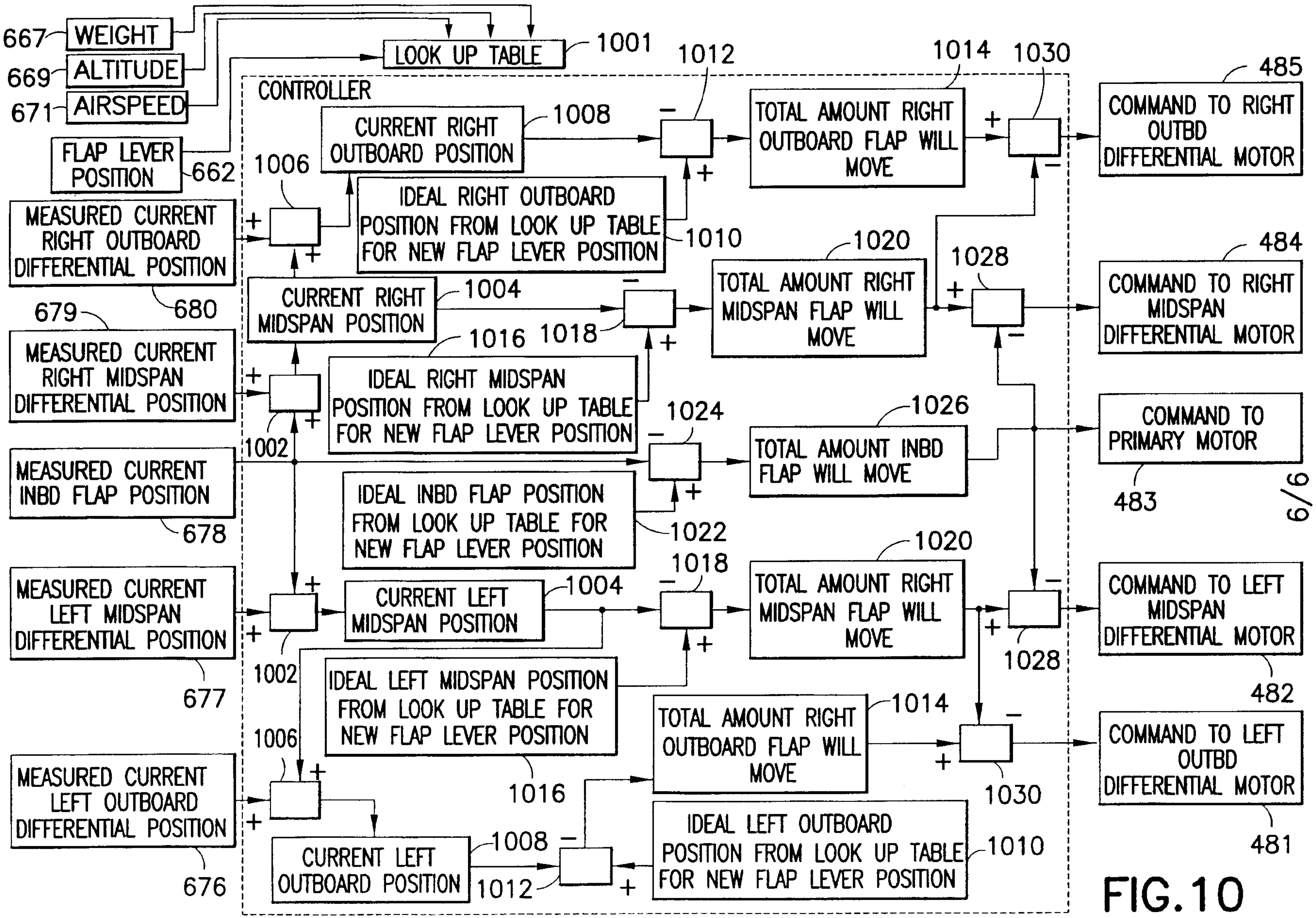
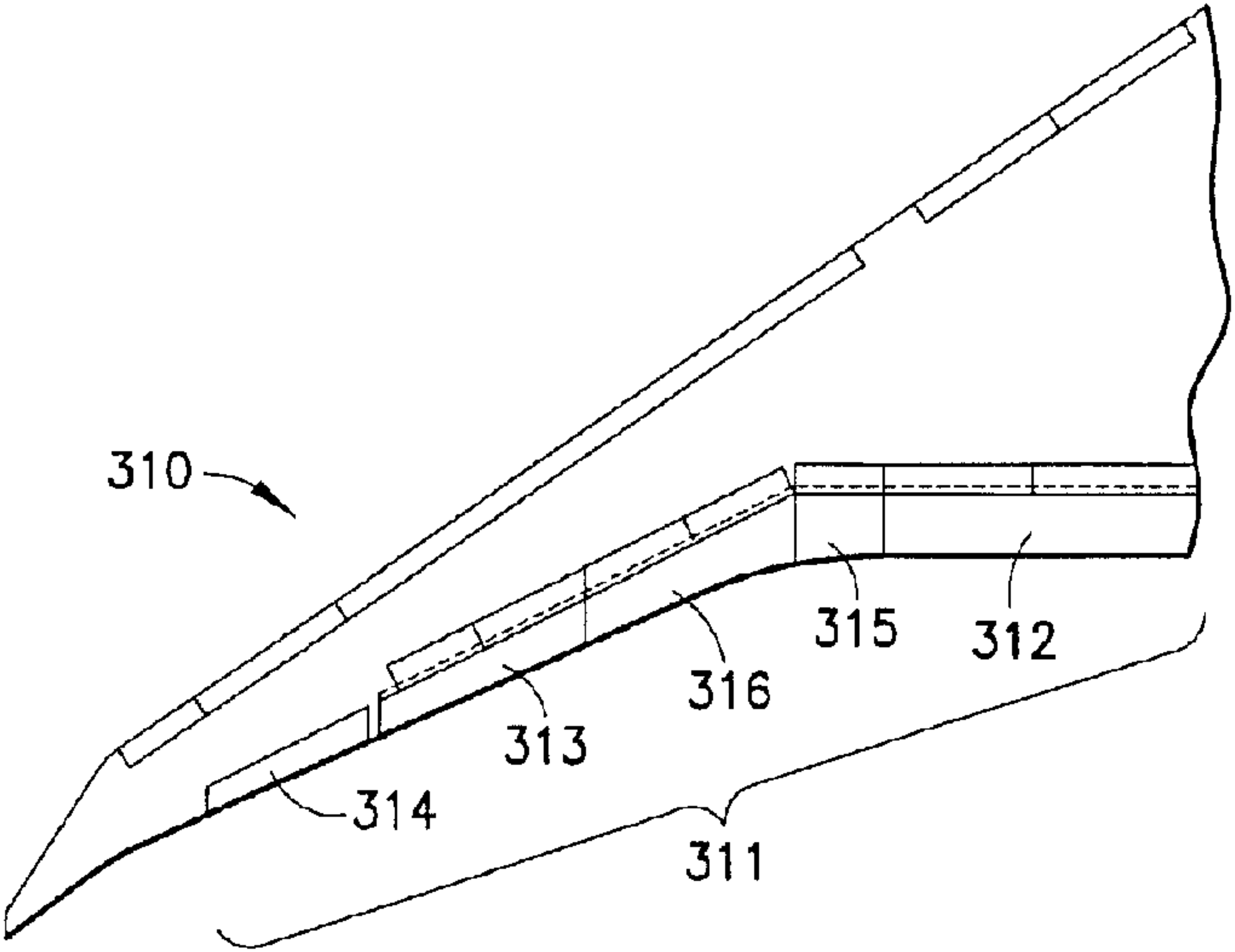

667 WEIGHT
669 ALTITUDE
671 AIRSPEED
FLAP LEVER POSITION 662
LOOK UP TABLE 1001
CONTROLLER
MEASURED CURRENT RIGHT OUTBOARD DIFFERENTIAL POSITION 680
679 MEASURED CURRENT RIGHT MIDSPAN DIFFERENTIAL POSITION
MEASURED CURRENT INBD FLAP POSITION 678
MEASURED CURRENT LEFT MIDSPAN DIFFERENTIAL POSITION 677
MEASURED CURRENT LEFT OUTBOARD DIFFERENTIAL POSITION 676
1006
1002
1002
1006
CURRENT RIGHT OUTBOARD POSITION 1008
IDEAL RIGHT OUTBOARD POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION 1010
CURRENT RIGHT MIDSPAN POSITION 1004
IDEAL RIGHT MIDSPAN POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION 1016
IDEAL INBD FLAP POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION 1022
CURRENT LEFT MIDSPAN POSITION 1004
IDEAL LEFT MIDSPAN POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION 1016
CURRENT LEFT OUTBOARD POSITION 1008
1012
1018
1024
1018
1012
TOTAL AMOUNT RIGHT OUTBOARD FLAP WILL MOVE 1014
TOTAL AMOUNT RIGHT MIDSPAN FLAP WILL MOVE 1020
TOTAL AMOUNT INBD FLAP WILL MOVE 1026
TOTAL AMOUNT RIGHT MIDSPAN FLAP WILL MOVE 1020
TOTAL AMOUNT RIGHT OUTBOARD FLAP WILL MOVE 1014
IDEAL LEFT OUTBOARD POSITION FROM LOOK UP TABLE FOR NEW FLAP LEVER POSITION 1010
1030
1028
1028
1030
+
−
485 COMMAND TO RIGHT OUTBD DIFFERENTIAL MOTOR
484 COMMAND TO RIGHT MIDSPAN DIFFERENTIAL MOTOR
COMMAND TO PRIMARY MOTOR 483
COMMAND TO LEFT MIDSPAN DIFFERENTIAL MOTOR 482
COMMAND TO LEFT OUTBD DIFFERENTIAL MOTOR 481

FIG.10


310
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311