



(86) Date de dépôt PCT/PCT Filing Date: 2012/10/19
(87) Date publication PCT/PCT Publication Date: 2013/04/25
(85) Entrée phase nationale/National Entry: 2014/04/16
(86) N° demande PCT/PCT Application No.: US 2012/061069
(87) N° publication PCT/PCT Publication No.: 2013/059625
(30) Priorité/Priority: 2011/10/20 (US61/549,627)

(51) Cl.Int./Int.Cl. *A47D 9/02* (2006.01)
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(54) Titre : DISPOSITIF D'AIDE AU SOMMEIL/A LA TRANQUILLISATION DE BEBE ET PROCEDE D'UTILISATION
(54) Title: INFANT CALMING/SLEEP-AID DEVICE AND METHOD OF USE

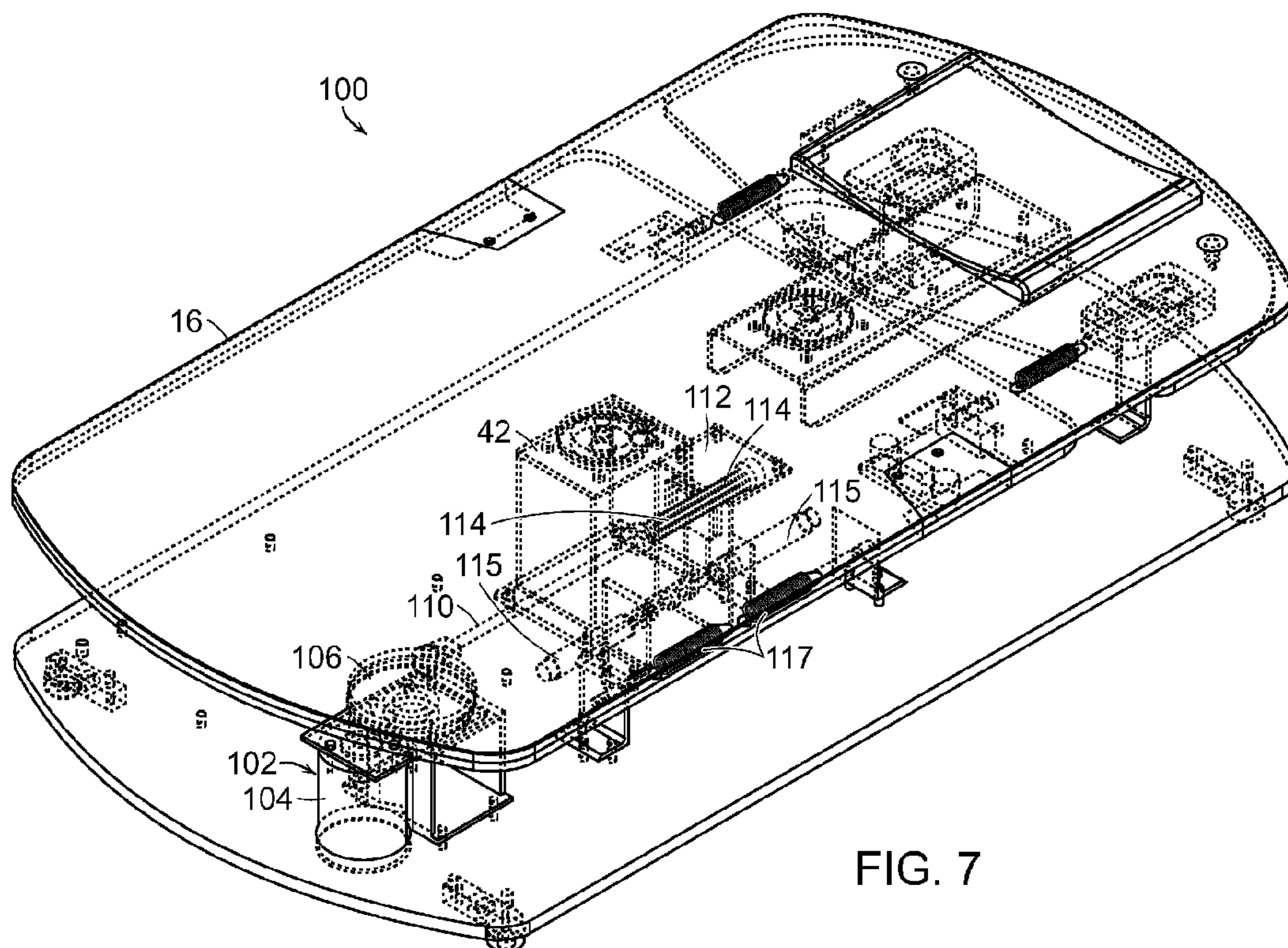


FIG. 7

(57) Abrégé/Abstract:

An infant calming/sleep-aid device includes a main moving platform that moves in a reciprocating manner and an actuator that drives the reciprocating movement of the main moving platform. The moving head platform is linked to the main moving platform and at least one of a motion sensing device and a sound sensing device are either at or proximate to a moving head platform that is pivotally linked to the main moving platform. A logic circuit links at least one of the motion and sound sensing devices of the infant calming/sleep aid-device to the main moving platform whereby signals detected modulate movement of the main moving platform. A sound generating device is linked to the logic circuit.



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

(19) World Intellectual Property

Organization

International Bureau

(43) International Publication Date
25 April 2013 (25.04.2013)(10) International Publication Number
WO 2013/059625 A1

(51) International Patent Classification:

A47D 9/02 (2006.01)

(21) International Application Number:

PCT/US2012/061069

(22) International Filing Date:

19 October 2012 (19.10.2012)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/549,627 20 October 2011 (20.10.2011) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

[Continued on next page]

(54) Title: INFANT CALMING/SLEEP-AID DEVICE AND METHOD OF USE

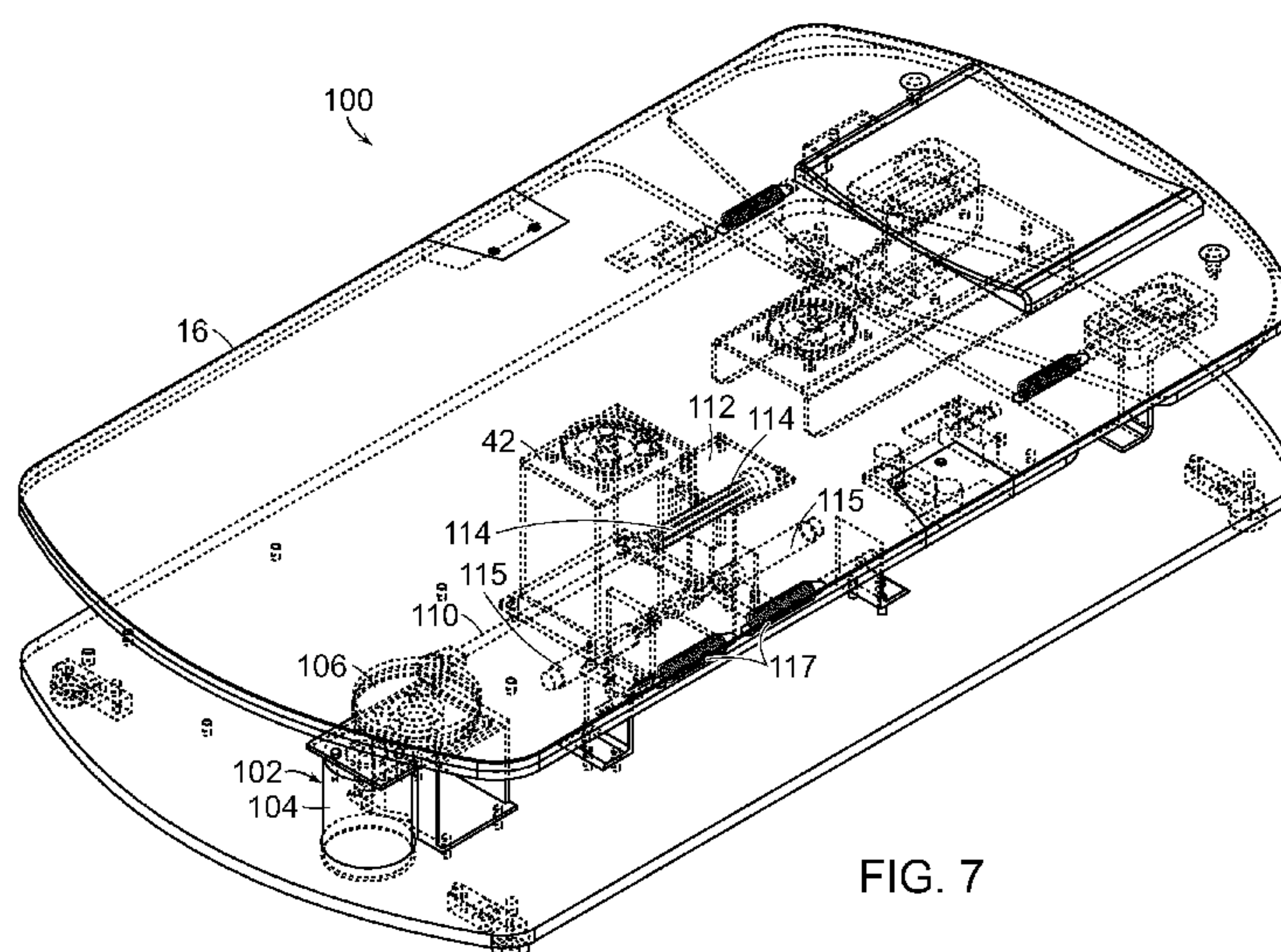


FIG. 7

(57) Abstract: An infant calming/sleep-aid device includes a main moving platform that moves in a reciprocating manner and an actuator that drives the reciprocating movement of the main moving platform. The moving head platform is linked to the main moving platform and at least one of a motion sensing device and a sound sensing device are either at or proximate to a moving head platform that is pivotally linked to the main moving platform. A logic circuit links at least one of the motion and sound sensing devices of the infant calming/sleep aid-device to the main moving platform whereby signals detected modulate movement of the main moving platform. A sound generating device is linked to the logic circuit.

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- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

INFANT CALMING/SLEEP-AID DEVICE AND METHOD OF USE

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/549,627, filed on October 20, 2011. The entire teachings of the above
5 application are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Persistent crying and poor infant sleep are perennial and ubiquitous causes of parent frustration. During the first months of life, babies fuss/cry an average of
10 about 2 hours/day and wake about 2 to 3 times a night. One in six infants are brought to a medical professional for evaluation for sleep/cry issues.

Infant crying and parental exhaustion are often demoralizing and lead to marital conflict, anger towards the baby and impaired job performance. In addition, they are primary triggers for a cascade of serious/fatal health sequelae, including
15 postpartum depression (which affects about 15% of all mothers and about 25 to about 50% of their partners), breastfeeding failure, child abuse and neglect, suicide, SIDS/suffocation, maternal obesity, cigarette smoking, excessive doctor visits, overtreatment of infants with medication, automobile accidents, dysfunctional bonding, and perhaps infant obesity.

20 Traditional parenting practices have utilized swaddling, rhythmic motion and certain sounds to soothe fussing infants and promote sleep (by reducing sleep latency and increasing sleep efficiency). "Sleep latency" is defined as the length of time between going to bed and falling asleep. "Sleep efficiency" is defined as the ratio of time spent asleep (total sleep time) to the amount of time spent in bed.
25 Swaddling, rhythmic motion and certain sounds imitate elements of a baby's in utero sensory milieu and activate a suite of brainstem reflexes, the *calming reflex*. Swaddling is a method of snug wrapping with the arms restrained at the baby's sides. This imitates the tight confinement babies experience in the womb. Swaddling also inhibits startling and flailing, which often interrupts sleep and
30 starts/exacerbates crying.

Rhythmic motion replicates the movement fetuses experience when the mother is walking. The motion stimulates the vestibular apparatus in the semicircular canals of the inner ear. A specific, rumbling low-frequency noise imitates the sound created by the turbulence of the blood flowing through the uterine and umbilical arteries. In utero the sound level babies hear has been measured at between 72 and 92 dB. Each baby has a specific and distinctive unique mix of motion and sound that most efficiently activates his or her *calming reflex*. This preferred mix stays consistent through the first months of life (i.e. babies who respond best to swaddling plus motion continue to respond to those modalities over time and don't abruptly switch their preference to swaddling plus sound).

The *calming reflex* has several constant characteristics. It is triggered by a stereotypical sensory input; produces a stereotypical behavioral output; demonstrates a threshold phenomenon (i.e. stimuli that are too mild may not be sufficient to activate a response); has a threshold that varies between individuals (i.e. is higher or lower for any given child); the threshold varies by state (e.g. fussing and crying raise the level of stimulation required to exceed threshold and bring about reflex activation).

Since the nominal level of a stimulus needed to reach the triggering threshold of the *calming reflex* differs from one child to the next, failure to exceed a particular child's threshold level often results in a total absence of a calming response. For example, slow smooth motion may calm one upset infant, yet be too subdued to calm another. Likewise, moderately loud sound may reach the calming threshold for one child, but not another. Once triggered, the stereotypical output of the *calming reflex* is a reduction of motor output and state. The intensity of sound and motion needed to trigger any particular baby's *calming reflex* is much greater than the levels needed to keep the *calming reflex* activated. "State" describes an infant's level of attention to and interaction with the environment. Infants experience six states: quiet sleep, active sleep, drowsiness, quiet alert, fussing and crying.

However, despite the convenience and availability of swaddling, rhythmic motion and sound, these methods fail to calm and promote sleep in a large portion of the infant population because they are not being applied correctly. To reduce infant crying and promote sleep parents often bring the baby into their own bed. However, this is problematic because sharing a bed with a parent has been proven to raise an

infant's risk of Sudden Infant Death Syndrome (SIDS) and accidental suffocation (which has been increasing by 14% per year for approximately twenty years). The hazard of bed sharing is further elevated if the parent is extremely fatigued. Like inebriation, exhaustion reduces adult judgment and responsiveness. Over 50% of new parents report sleeping fewer than 6 hours/night, the level demonstrated in adults to simulate a level of attention impairment comparable to inebriation. For this reason, sleeping with an exhausted parent further increases the SIDS risk associated with bed sharing and further increases the suffocation risk (e.g. from accidental overlaying of the parents body over the infant's head).

Other behaviors that exhausted parents engage in to calm crying and promote sleep also directly raise the risk of SIDS and suffocation (e.g. falling asleep with the baby on a couch, placing the baby on the stomach to sleep). Medical authorities recommend parents avoid bed sharing and place sleeping babies in cribs. However, cribs are problematic. Babies sleeping supine in cribs have a higher risk of plagiocephaly (flattening of the skull), which may require expensive and inconvenient medical treatment, and may result in a permanent deformity. In addition, a crib's flat, quiet, nonmoving surface is devoid of the swaddling, rhythmic motion and sound that reduce crying, reduce sleep latency and increase sleep efficiency.

In an attempt to improve infant sleep in cribs, parents have employed several methods (prone sleeping, swaddling, rocking motion, sound), however each is problematic. For example, the prone position is associated with a 3-4 fold increased risk of SIDS. Swaddled babies can roll to the stomach position (prone), which is associated with an 8-19 fold increased risk of SIDS. Rocking motion delivery systems (e.g. swings, cradles and hammocks) all present problems. When sitting in a swing, a baby's head can roll forward and create an airway obstruction. Cradles and hammocks require parents to be the motion-powering energy source, and thus can be done for only a limited part of the sleep period. Sound delivery devices (e.g. fans, air filters, hair driers, sound machines and white noise CDs) may be cumbersome and expensive and the volume, quality or frequency profile of the sound they produce may be excessive or too different from in utero sound to be effective.

Over the past twenty years, attempts have been made to engineer technological methods to create infant calming/sleep devices to deliver sound and motion more conveniently. One such device, a motorized cradle, was designed to rock sleeping babies in an arc along the head-foot axis. This product allowed the cradle to come to rest at an angle, in a partial swing position, which resulted in multiple infant deaths. Another device, designed to simulate a car traveling at about 55 miles per hour, is comprised of 2 parts: a vibrating motor that fixes to the underside of the crib and a speaker that fixes to the sidewall. Still another device has a motorized crib that moves back and forth (about 10 cm in each direction along the head-foot axis; each swing lasting about 1.8 seconds). A sensor activates the device's motor for a limited period of time when it detects the infant's cry. Still other devices have introduced sound machines or mats that vibrate for short periods of time to be placed under the baby to encourage sleeping.

These and other current infant calming/sleep devices deliver fixed and unchangeable motion and sound. This is a problem because each baby has a different mix of sound and motion that most efficiently calms the child and promotes sleep. For example, some babies respond best to swaddling plus motion, others swaddling plus sound. Another problem with fixed motion and sound infant calming/sleep devices is that each baby has a unique level of motion and sound that induces calming and sleep most efficiently. For example, slow rocking may reduce sleep latency for one infant, yet be too subdued to do so in another infant. And, quiet sound may be sufficient to increase sleep efficiency for one baby, but not another. Also, the intensity of sound and motion that a baby needs to trigger the *calming reflex* is much greater than the levels needed to keep the *calming reflex* activated.

Still another problem with fixed motion and sound infant calming/sleep devices is that the intensity of the stimuli needed to activate the *calming reflex* and induce calm and sleep varies substantially as a child's state changes. For example, most fussy babies require more vigorous, jiggly motion (with rapid acceleration-deceleration) and more vigorous sound inputs (as loud as a vacuum cleaner - 75 to 80 dB). On the other hand, calm, sleepy babies need less vigorous inputs. Further, current infant calming/sleep devices do not continue all night long; do not deliver optimal sound and motion for triggering the *calming reflex*; do not increase and

decrease their sensory input in a step-wise fashion to vary the sensory input intensity to give the baby the most effective level of stimulation; lack the ability to reduce the sensory input over time to wean a baby off the stimuli as he or she ages.

Therefore, a need exists for an infant calming/sleep system that overcomes or
5 minimizes the above-mentioned problems.

SUMMARY OF THE INVENTION

The invention generally is directed to a method for aiding calming and sleep of an infant.

In one embodiment, the invention is an infant calming/sleep-aid device that
10 includes a main moving platform that moves in a reciprocating manner. An actuator drives the reciprocating movement of the main moving platform and a moving head platform linked to the main moving platform reciprocates in response to reciprocating movement of the main moving platform. In a preferred embodiment, at least one of a motion sensing device and a sound sensing device are, respectively,
15 at or proximate to the moving head platform. A logic circuit links at least one of the motion sensing device and the sound sensing device to the main moving platform, whereby signals detected by at least one of the motion sensing device and the sound sensing device cause the logic circuit to modulate the movement of the main moving platform.

20 In another embodiment, the infant calming/sleep-aid device includes a rigid base and a main movement linkage or bearing extending from the base. The main moving platform is mounted on the main movement linkage or bearing, whereby the main moving platform is movable on the main movement linkage or bearing relative to the base. An actuation assembly that controls movement of the main moving
25 platform about the main movement linkage or bearing relative to the rigid base includes an actuator mounted to the rigid base.

In another embodiment, the invention is a method for aiding the calming of a fussy infant or the sleep of an infant, comprising the step of moving the infant in a reciprocating manner about an axis that intersects the infant at a 90° angle to a major
30 plane of the surface supporting the infant.

In another embodiment, the invention is an adaptive calming and sleep aid method, including the steps of moving an infant in a reciprocating manner about an

axis that intersects the infant and is orthogonal to a major plane of the surface supporting the infant. At least one of a sound generated by a sound generating device and a reciprocating movement is modulated in an updating and adaptive matter by a logic circuit-controlled actuation in response to at least one of the sound
5 of the infant and the motion of the platform.

The present invention has many advantages. For example, the system and method of the invention provides for modulation of reciprocating movement of an infant in an updating and adaptive manner. The rapidly accelerating and decelerating reciprocal motion of the device which induces the infant's head to
10 accelerate and decelerate over a short distance in a safe and specifically controlled manner induces the infant's natural *calming reflex*. The device's specifically designed motion and sound, along with its adaptive control system reduce irritability during awake hours and improve infant sleep (specifically reducing irritability during periods of sleep, reducing sleep latency and increasing sleep efficiency) for
15 babies up to about twelve months old.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one embodiment of the infant calming/sleep-aid device of the invention, with a depiction of an infant asleep inside the device.

20 FIG. 2 is a perspective view of the infant calming/sleep-aid device of FIG. 1 with swaddle fastening straps and without an enclosure.

FIG. 3 is a perspective view of the infant calming/sleep-aid device of FIG. 2, showing apparatus beneath the main moving platform in broken lines.

FIG. 4 is a plan view of the apparatus supporting the main moving platform
25 of the infant calming/sleep-aid device of FIG. 3, with the rigid base and main moving platform shown in outline.

FIG. 5 is a side view of the infant calming/sleep-aid device shown in FIG. 4, taken along line 5-5.

FIG. 6 is a side view of the infant calming/sleep-aid device shown in FIG. 4.

30 FIG. 7 is a perspective view of yet another embodiment of the calming/sleep-aid device of the invention, showing components of the device beneath the main moving platform in broken lines.

FIG. 8 is a plan view of the apparatus supporting the main moving platform of the calming/sleep-aid device of FIG. 7, with the rigid base and main moving platform shown in outline.

FIG. 9 is a side view of the embodiment of the device shown in FIG. 7.

5 FIG. 10 is a schematic representation of one embodiment of a software control system of the invention, along with inputs and outputs of the software control system.

FIG. 11 is a schematic representation of one embodiment of a crying detection module of the invention.

10 FIG. 12 is a schematic representation of one embodiment of a motion analysis module of the invention.

FIG. 13 is a schematic representation of one embodiment of a behavior state machine module of the invention.

15 FIG. 14 is a schematic representation of one embodiment of an audio generation module of the invention.

FIG. 15 is a schematic representation of a motion generation module of the invention.

FIG. 16 is a schematic representation of a motion generation module of the invention.

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DETAILED DESCRIPTION OF THE INVENTION

In one embodiment of the invention, shown in FIGs. 1 through 6, infant calming/sleep-aid device **10** includes enclosure **12** about infant **14**. Enclosure **12** surrounds main moving platform **16**. As can be seen in FIG. 2, main moving platform **16** includes base **18**, moving head platform **19**, padding **20** and cloth covering **22**. Swaddle fastening straps **24** extend from main moving platform **16** for securing infant **14** in suitable swaddling clothes **26**. Head pad insert **28** supports the head of infant **14**. Preferably, head pad insert **28** includes a gel in order to reduce the risk of plagiocephaly. Handles **30** extend laterally from main moving platform **16**. Main moving platform **16** is supported and rotatable about a main support shaft (not shown) that is fixed to rigid base **32**. Control panel **34**, which includes speed control knobs **35**, status lights **37** and controls **39** for microphone **38**. Rigid base

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control electronics **36**, include drive electronics of infant calming/sleep-aid device **10**.

In another representative view of infant calming/sleep-aid device **10** of FIG. 2, shown in FIG. 3, main moving platform **16** is supported by main support shaft **40** at main rotation bearing **42**. Moving head platform **19** supports head pad insert **28** and is rotatable about head rotation bearing **46** through arm **48** extending between head rotation bearing **46** and moving head platform **19**. Motion sensing device **50**, such as an accelerometer, at moving head platform **44** detects motion of moving head platform **19**. Microphones **38** at moving head platform **19** detect sound emitted by the infant (not shown) when supported by infant aid sleep device **10**. Speakers **52**, supported by brackets **54** mounted on rigid base **18**, are located directly beneath moving head platform **19**. Springs **56** linking either side of moving head platform **19** to main moving platform **16** dampen motion of moving head platform **19** relative to main moving platform **16** during reciprocal motion of moving head platform **19** induced by reciprocating motion of main moving platform **16**.

Reciprocating motion of main moving platform **16** about main support shaft **36** is about an axis that is orthogonal to a major plane of main moving platform **16**. Reciprocating motion of main moving platform **16** is driven by actuator assembly **58**.

In some embodiments, the body and the head of the infant can be out of phase. For example, at relatively slow speeds, the motion of the head of the infant can be in the same direction as that of the motion of the upper body of the infant. At relatively high speeds, the reciprocal motion of the head of the infant can be in the opposite direction as that of the upper body of the infant. In another embodiment of the invention (not shown), reciprocal motion of the head of the infant can be in some other direction, such as orthogonally relative to the plane of the main support platform.

Actuator assembly **58** includes drive motor **60** mounted to rigid base **32** and gear assembly **62** linked to drive motor **60** and also mounted to rigid base **32**. Actuation of drive motor **60** causes rotation gear assembly **62** to drive eccentric drive plate **64** about an axis normal to a major plane of rigid base **32**. Eccentric drive plate **64** is linked to swing arm plate **66** of actuator assembly **58** that extends from eccentric drive plate **64** to rod end **68** of screw **70** and is pivotally mounted to

rod end 68 of screw 70. Screw 70 is mounted to amplitude modulation assembly 72. Amplitude modulation assembly 72 includes amplitude modulation motor 74, nut 76, mounted on nut frame 78, which swivels on rotation bearing 80 mounted to rigid base 32. The axis of rotation of nut frame 78 on rotation bearing 80 is, like that of eccentric drive plate 64, normal to a major plane of rigid base 32. Actuation of amplitude modulation assembly 72 causes movement of screw 70 along its major longitudinal axis to thereby cause rod end 68 to become more proximate or less proximate to amplitude modulation assembly 72. Arm 82 extends from an end of screw 70 opposite to rod end 68 to elastic actuator catch bracket 84, which is mounted on base 18 of main moving platform 16. Arm 82 extends through an opening defined by elastic actuator catch bracket 84 and is linked to main moving platform 16 by springs 86, 88 held in place on either side of elastic actuator catch bracket 84 by nuts 90, 92, respectively.

Actuation of actuation assembly drive motor 60 causes rotation of eccentric drive plate 64 about an axis normal to a major plane of rigid base 32 which, in turn, causes reciprocal motion of swing arm plate 66 roughly along a major longitudinal axis of swing arm plate 66. Such reciprocal motion of swing arm plate 66 causes rod end 68 to move in a reciprocal motion from side-to-side of a major longitudinal axis of screw 70 which causes reciprocal rotation of nut frame 80 about an axis normal to major plane rigid base 18 and side-to-side motion of the opposite end of screw 70 opposite that of rod end 68 of screw 70. Such side-to-side movements of the opposite end of screw 70 causes reciprocal longitudinal movement of arm 82 extending through the opening defined by elastic actuator catch bracket 84. Resistance to such reciprocal motion of arm 82 causes alternating reciprocal compression and relaxation of springs 86, 88, which thereby causes reciprocal motion of main moving platform 16 about main support shaft 40 linking main moving platform 16 to rigid base 32.

The amplitude of reciprocal motion of main moving platform 16 about main support shaft 40 is controlled by the location of screw 70 relative to amplitude modulation assembly 72. For example, if actuation of amplitude modulation assembly 70 causes rod end 68 to become more proximate to amplitude modulation assembly 70, the side-to-side motion of the opposite end of screw 70 will become greater, thereby causing the amplification of reciprocal motion of main moving

platform 16 about main support shaft 40 to increase. Conversely, actuation of amplitude modulation assembly 72 to cause rod end 68 of screw 70 to become more remote from amplitude modulation assembly 72 will diminish the side-to-side motion of opposite end of screw 70, thereby reducing the amplitude of reciprocal
5 motion of main moving platform 16 about main support shaft 40.

Reciprocal motion of main moving platform 16 causes a delayed reciprocal motion of moving head platform 44 about head rotation bearing 46. The reciprocal motion of moving head platform 44, although delayed, has greater amplitude about main support shaft 40 because of the rotation of moving head platform 44 about
10 head rotation bearing 46. However, the amplitude of reciprocal motion of moving head platform 44 about head rotation bearing 46 is dampened by springs 56. Nevertheless, the reciprocal motion of main moving platform 16 and moving head platform 44 about main support shaft 40 is measured by motion sensing device 50 at moving head platform 44. Measurements by motion sensing device 50 are relayed
15 back to control panel 34 and rigid base control electronics 36 which, alone, or optionally, in combination with external computer software programming, modulate actuator assembly drive motor 60 and amplitude modulation motor 74. Motion detection by motion sensing device 50 can also, optionally, modulate computer programming to affect selection and volume of sounds emitted by speakers 52.
20 Microphones 38, in addition, or optionally, receive acoustical signals that can be fed back through rigid base control electronics 36 or/and control panel 34 to software, either on-board or remote from infant calming/sleep-aid device 10, that further modulates actuator assembly drive motor 60, amplitude modulation motor 74 and/or sounds emitted from speakers 52. Algorithms associated with modulation of
25 actuator assembly drive motor 60, amplitude modulation motor 74 and speakers 52 will be more fully discussed below.

In one embodiment, the device allows for a reciprocating motion at 0.5-1.5 cps of ~2" excursions, but if the baby is fussy the device responds by delivering a smaller excursion (e.g.<1") at a faster rate (~ 2-4.5 cps). This fast and small motion
30 delivers the specific degree of acceleration-deceleration force to the semicircular canals in the vestibular mechanism of the inner ear that is required to activate the *calming reflex*.

Also, the reciprocating motion typically has a maximum amplitude of less than one inch during the rapid phase of motion (~2-4.5 cps), further ensuring safety of the infant.

In another embodiment, shown in FIGs. 7 through 9 calming/sleep-aid device **100** includes actuator assembly **102**, which substitutes for actuator assembly **58** of the embodiment shown in FIGs. 2 through 6. Specifically, as shown in FIGs. 7 through 9, drive motor **104** of calming/sleep-aid device **100** is linked to bearing **106**, which is, in turn, leads to the eccentric drive plate **108**. Eccentric drive plate **108** is connected to push/pull rod **110** that extends through an opening defined by elastic actuator catch bracket **112**. Springs **114** about push/pull rod **110** link push/pull rod **110** to main moving platform **16** through elastic actuator catch bracket **112**. Springs **114** are series elastic actuator push-springs; they transfer force from actuator assembly **102** to catch bracket **112**. Balancing dampers **115** beneath push/pull rod **110** dampen the motion of moving platform **16**. Springs **117** are pull-balancing springs; they pull on bracket **112** in parallel with balancing dampers **115** to create the desired smooth sinusoidal motion of moving platform **16** at low frequencies and the rapid accelerating motion at high frequencies.

Actuation of drive motor **104** causes reciprocal longitudinal movement of push/pull rod **110** through the opening defined by elastic actuator catch bracket **112** and translates that reciprocal movement into reciprocal motion of main moving platform **16** about main rotation bearing **42**, as does reciprocal motion of arm **82** through elastic actuator catch bracket **84** of the embodiment shown in FIGs. 2 through 6. Other components of the embodiments shown in FIGs. 7 through 9 operate in the same manner as those of infant calming/sleep-aid device **10** represented in FIGs. 2 through 6.

As shown FIG. 10, software control system **120**, processes inputs from microphones and generates outputs to speakers represented in FIGs. 2 through 9, also processes inputs from speed control knob **121**, also shown in FIGs. 2 through 9, and from a three-axis USB accelerometer **123**, represented as motion sensing device in FIGs. 2 through 9. In addition, software control system **120** generates an output signal to multichannel USB motor controller **122**, which controls actuator assembly drive motor **60** (not shown) and amplitude modulation motor **74** (not shown) or, alternatively, as shown in FIGs. 7 through 9, drive motor **104** (not shown). Status

lights, such as tricolor USB DEs **121**, are represented as lights **37** in FIGs. 2 through 9. Modules of software control system **120** can be located on-board or remotely from the embodiments of infant calming/sleep-aid devices **10,100** shown in FIGs. 2 through 9. The modules include a crying detection module **124** that receives data from microphones **125**, represented at microphones **38** in FIGs. 2 through 9, and relays to a behavior state machine module **126** whether or not an infant on infant calming/sleep-aid device is crying or not crying. Depending upon the input received by behavior state machine module **126**, output signals will control motion generation module **128** or audio generation module **130**. Actuation of motion generation module **128** will modulate the actuator assemblies of the embodiments shown in FIGs. 2 through 9. Alternatively, or in addition, output signals from behavior state machine module **126** will modulate generation of audio data output from audio generation module **130** to speakers **131**, represented as speakers **52** in FIGs. 2 through 9.

Data received from accelerometer **123** is processed by motion analysis module **132** to thereby modulate the actuator assembly through motion generation module **128** and/or audio generation module **130** to thereby control the actuators assemblies or speakers, respectively. In addition, motion analysis module **132** controls status light module **134** to alert, through the status lights, whether motions of the main moving platform and the head platform are nominal or not nominal, or alternatively, through feedback, soothing or not soothing to the infant. "Nominal", as that term is defined herein, refers to any and all motion for which the filtered acceleration signal does not exceed a specified, or predetermined maximum motion threshold for a specific length of time. The process by which the motion analysis module classifies motion as nominal or not nominal is detailed in FIG. 12 and in the accompanying text below.

In one embodiment the rate of the reciprocating rotation is in a range of between about two and about four and one-half cycles per second and an amplitude of the reciprocating motion at a center of a head of the infant is in a range of between about 0.2 inches and about 1.0 inches. In another embodiment, the rate of reciprocating motion is in a range of between about 0.5 and about 1.5 cycles per second and an amplitude of the reciprocating rotation at a center of the head of the infant is in a range of between about 0.5 inches and about 2.0 inches.

The software weans the infant off the device by incorporating the infant age as a variable used by the behavior state module control system, wherein modulation is further controlled by at least one of the weight of the infant, the age of the infant, and the duration of the detected sounds made by the infant.

5 Referring to FIG. 11, crying detection module **124** receives audio data from the microphones of infant calming/sleep-aid devices **10,100**, which is processed through digital band-pass filter **136** to generate filtered audio data. Energy-based threshold **138** receives filtered audio data to determine whether the audio energy is over threshold or under threshold. Time-based filter **140** receives data from energy-
10 based threshold **138** to provide an indication as to whether the infant is crying or not crying. The information, as discussed above with respect to software control system **120** (FIG. 10), is received from crying detection module **124** by behavior state machine module **126** that will then modulate either motion generation module **128** or audio generation module **130**.

15 Motion analysis module **132**, shown and represented in more detail in FIG. 12, receives a signal from the motion sensing device of infant calming/sleep-aid devices **10,100**, at digital filter bank **142**. Digital filter bank **142** filters the signal to generate a filtered motion amplitude estimate that is used as input to motion generation module **128** (FIG. 10). In addition, the filtered motion amplitude
20 estimate passes through a range check **144** to determine whether the motion is within a soothing or known soothing range. Time-based filter **146** receives data from range check **144** to provide an indication as to whether a motion is soothing or not soothing. Filtered motion sensor, or accelerometer, data from digital filter bank **142** also passes through threshold crossing-based motion frequency estimator **148**.
25 Outputted data from threshold-crossing-based motion frequency estimator **148** passes through range check **144** for indicating whether the motion is or is not soothing, and also provides input to motion generation module **128** (FIG. 10). Filtered accelerometer data from digital filter bank **142** also is processed to determine whether or not the acceleration exceeds a specific maximum motion
30 threshold **150** and, depending on the result, processes that data through time-based filter **152** to provide an indication as to whether the motion is nominal or not nominal. This indication as to whether the motion is nominal or not nominal is used

as input to motion generation module **128** (FIG. 10), and is additionally used to control status lights **37** (FIG. 2) via status light module **134** (FIG. 10).

As can be seen in FIG. 13, behavior state machine module **126** receives information from crying detection module **124** (FIG. 11) as to whether the infant is in a state of crying or not crying. This information is used by the state machine's state transition rules **156** to select an active state from a library of states **154**, thereby outputting a desired motion state, a desired audio track and/or desired volume/equalizer settings to audio generation module **130** (FIG. 10).

Audio generation module **130**, represented in FIG. 14, receives signals of a desired audio track and desired volume/equalizer settings from behavior state machine module **126** (FIG. 10) and signals of motion analysis, specifically, whether the motion is nominal or not nominal, from motion analysis module **132** (FIG. 10). Audio generation module **130** includes a library of "soothing" audio tracks **160**, a digital equalizer/volume control **162** and alarm sound **164**. Upon receipt of a new command from motion analysis module **132** (FIG. 10), audio generation module **130** will cross-fade to a desired audio track and volume, and crossfade to desired equalizer settings. If the motion is not nominal, then an alarm signal will be output to override the audio signal with an alarm. The audio signal from the audio generation module is output to the speakers of infant calming/sleep-aid device **10,100**.

At baseline, the audio generator will produce an output of a low-pitch, rumbling sound at about 65 dB to about 70dB. Upon receipt of a new command from crying detection module **124** (FIG. 11), audio generation module **130** will cross-fade to a more high pitched audio track and louder volume, at about 75dB to about 80dB.

Two variations of motion generation module are represented in FIGs. 15 and 16. In the first embodiment, shown in FIG. 12, motion generation module **128** receives a desired motion state input from behavior state machine module **126** (FIG. 10), a motion frequency/amplitude signal from motion analysis module **132** (FIG. 10), a desired system speed signal from speed control knob **121** (FIG. 10), and a signal as to whether a motion is nominal or is not nominal. The "desired system speed" is the setting of speed control knob **121**, whereby the operator can limit the motions allowed by infant calming/sleep-aid device **10,100**. The desired motion

state signal goes to lookup within motion generation module **128**, which outputs a reference motor command based on a desired motion state. If the currently-active motor commands are close to the reference motor commands, then the motor commands are actively adjusted within an allowable envelope via a gradient ascent based on observed motion frequency and amplitude. If the current motor commands are not close to the reference motor commands, then the motion generation module will set desired motor commands via path planning in a motor command space. “Path planning” transitions motor settings to desired motor settings by inserting intermediate motor settings as necessitated by nest dynamics to ensure that motion stays in a desirable range during transition. If the desired system speed is less than “full,” then a signal is sent to adjust the desired motor commands in proportion to the desired system speed. “Full” is the fully-on position of the knob, and means that infant calming/sleep-aid device **10,100** is not being limited by this knob and is allowed to perform all of the motions it determines to be relevant. If speed control knob 121 is turned down from “full,” motions of infant calming/sleep-aid device **10,100** start to become constrained, so speed control knob 121 acts as an operator to override the normal motion behavior of infant calming/sleep-aid device **10,100**. If not, then a comparison is made as to whether the observed motion is nominal. If it is not, then motor output is disabled. If it is nominal, then an output signal of desired motor commands is given to target motor positions and speeds of the actuator of the multichannel USB motor controller.

In an alternative embodiment of motion generation module **128**, shown in FIG. 16, there is no receipt by the module of signals related to motion frequency and amplitude. Therefore, it is only necessary to set desired motor commands by interpolating from a current command based on a look up table of motor commands based on a desired motion state in response to receiving a signal with respect to the desired motion state. All of the components of motion generation are the same as represented in FIG. 15.

30 EXPERIMENTAL SECTION

Materials

Two versions of the infant calming/sleep-aid device as shown in FIGs. 2 through 9 of the invention were created, with microphones to detect infant crying,

motion and sound actuators, a swaddling system to keep the baby in optimal position and a gel pad to reduce the pressure on the back of the skull that predisposes to plagiocephaly. The device also contained a logic board to accomplish two tasks; deliver staged interventions of specially engineered sound and to deliver motion created by two linked platforms attached to a motor and rod actuator (as well as a series of springs and dampeners to modulate the activity.) These platforms acted in a reciprocating manner about an axis that intersected the infant and was orthogonal to a major plane of the surface supporting the infant to provide a motion that varies from slow smooth rocking (0.5-1.5 cps) to keep babies calm- and promote sleep...ramping up to a faster, smaller, "jiggly" motion (2-4.5 cps) with a more "spiked" waveform to deliver a sufficiently abrupt acceleration-deceleration action to stimulate the vestibular mechanism of the inner ear, trigger *calming reflex* and soothe the baby when she cried (head rocking back and forth in excursions of less than 1"). The sound in the device was also designed to respond to the baby's upset by starting a specially engineered loud, harsh and high pitched and then stepping down to quieter, lower pitched white noise over several minutes. The device was specifically designed to gradually reduce ("wean") the intensity of the sound and motion over several months.

The device worked in the following way:

The baby was placed in a swaddling sack (with arms in or out) attached to the mattress of the device and securely laid on his/her back. The device produced a baseline level of low pitched, rumbling noise at approximately 65 dB and baseline motion of a smooth, side-to-side rocking (2 inch excursions to either side). When the baby cried for more than ~10 seconds, the device responded by playing a specially engineered sound that was harsher, higher pitched, more multi-frequency (75-80 dB) to mimic the intensity of the sound that the baby heard inside the mother's uterus prenatally. (This sound can be measured in situ at up to 92 dB.) If the crying continued another ~10 seconds (despite the sound), the motion accelerated to a faster, more jiggly action of the head (2-4.5 cps, but no more than 1 inch head excursions to either side). The combination of fast movements delivered with sufficient vigor, the harsh loud sound, and the secure swaddling sack all worked together to activate the *calming reflex*, in the majority of irritable babies and inducing either calmness or sleep. The device responded to the baby's cry in a step-

wise fashion-gradually increasing sound and then motion-to a maximal level. Once the baby was calmed the motion and sound of the device was gradually reduced in a specific, step-wise fashion back to the baseline activity.

5 Subjects

The device was tested on over twenty babies (12 girls, 10 boys) were in the device. The babies ranged from 5 weeks to 6 months of age. Their weights ranged from 8 pounds to 18 pounds.

10 Methods and Procedures

The subjects were tested to record their resting and sleeping in the device. The tests usually began when the baby was hungry and tired (immediately before their usual naptime). The parents were introduced to the device and given a brief demonstration of how it worked. We recorded when the baby last fed and napped and then put the baby in the swaddling sack and placed the infant in the device. We observed and videotaped the session. In addition, we collected data from 3 accelerometers and a device-mounted camera to detect the vigor of activity and measure the exact excursions of the baby's head. We started each test with the device set at its lowest level for sound and motion. We observed as the device responded to the baby's cries. We allowed the device to quickly advance through each of its stages as the cries escalated. Once the baby was calmed, the device's motion would slow, in a stepwise fashion, and the loudness and pitch of the sound would decrease, in a stepwise fashion. We repeated this format 2-4 times during our sessions with each of the subjects. The first set of studies was done using a prototype with a dual motion actuator and the second set of studies was done with a prototype with a single motion actuator.

Results

As shown on the attached table, during twenty-one tests, 19 babies were either significantly calmed or put to sleep by our device (absence of calming was due to hunger). Most calming and sleep occurred within 2 minutes of placing the baby in the device.

We hypothesized that a device could be built that responded to the baby's needs,

Parent's/Baby's Name	Test Date	Baby's Age	Baby's Weight	No. of times baby wakes during the night	Time since last nap	Time since last feeding	Calmed or put to sleep?
Candace/Dannielle		13 weeks	14.11 lbs	1-2 times			Calmed
Amanda/James							Calmed
Jenn/Mackienze			13.5 lbs	2 times			Calmed
Sarah/Sloane	10/22/11	5 weeks		5-6 times			Sleep
Sheela/Julia			9.5 lbs	3-4 times			Calmed
Sally/Elise	3/5/12	7 weeks	8.1 lbs	2-3 times	2.0 hours	10 minutes	Sleep
Emily/Reese	3/5/12	7 weeks	8.3 lbs	3-4 times	1.5 hours	30 minutes	Sleep
Jackie/Drew	3/6/12	5.5 months	12.0 lbs	3-4 times	2.0 hours	1.0 hours	Calmed
Jackie/Tessa	3/6/12	5.5 months	11.0 lbs	3-4 times	2.0 hours	1.0 hours	Calmed
Jessica/Noah	3/13/12	4.5 months	14.4 lbs	4-6 times	1.5 hours	1.0 hours	Sleep
Charisse/Rhett	3/8/12	4.0 months	14.0 lbs	3-4 times	10 minutes	2.0 hours	Sleep
Dolge/Ashee	3/12/12	4.0 months	14.0 lbs	5-7 times	3.0 hours	1.5 hours	Sleep
Laura/Charlotte	3/13/12	4 weeks	10.0 lbs	3-5 times	1.0 hours	10 minutes	Sleep
Laura/John	3/15/12	6 weeks	10.5 lbs	1-3 times	2.0 hours	1.0 hours	Sleep
Amelia/Arthur	3/15/12	6.0 months	15.9 lbs	3-4 times	10 minutes	1.0 hours	No

such that an infant's upsets would be soothed by vigorous stimulation to activate the *calming reflex*, followed by a diminution of those stimuli to help keep the *calming reflex* turned on and sustain the baby in a calm state and/or promote sleep (i.e. reducing sleep latency and increasing sleep efficiency).

Parent's/Baby's Name	Test Date	Baby's Age	Baby's Weight	No. of times baby wakes during the night	Time since last nap	Time since last feeding	Calmed or put to sleep?
Iris/Charlie	4/23/12	4 weeks	10.0 lbs	4-6 times	1.0 hours	1.0 hours	Calmed
Elyse/Christian	4/23/12	5 months	13.5 lbs	3-4 times	1.0 hours	1.0 hours	Sleep
Margaret/Halina	4/28/12	4.5 months	16.2 lbs	3-4 times	1.0 hours	30 minutes	Sleep
Laine/Lucas	5/7/12	4 weeks	9.5 lbs	4-6 times	2.0 hours	30 minutes	Sleep
Rachel/Cade	5/7/12	5 months	18.0 lbs	3-4 times	1.0 hours	2.0 hours	Sleep
Rose/Elsie	5/8/12	4 weeks	10.0 lbs	4-6 times	10 minutes	2.0 hours	No

10

("Sleep latency" is defined as the length of time between going to bed and falling asleep. "Sleep efficiency" is defined as the ratio of time spent asleep - total sleep time - to the amount of time spent in bed.)

15 Conclusion

It was possible to promote infant calming and sleep through the use of swaddling plus very specific sound and motion stimuli to activate the *calming reflex*.

Equivalents

20

While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

The relevant teachings of all references cited herein are incorporated by reference in their entirety.

CLAIMS

What is claimed is:

1. An infant calming/sleep-aid device, comprising:
 - a) a main moving platform that moves in a reciprocating manner;
 - 5 b) an actuator that drives the reciprocating movement of the main moving platform;
 - c) a moving head platform linked to the main moving platform, whereby reciprocating motion of the main moving platform causes reciprocating motion of the moving head platform;
 - 10 d) at least one of a motion sensing device at the moving head platform and a sound sensing device proximate to the moving head platform; and
 - e) a logic circuit linking at least one of the motion sensing device and the sound sensing device to the main moving platform, whereby
15 signals detected by at least one of the motion sensing devices or the sound sensing device cause the logic circuit to modulate the movement of the main moving platform.
2. The infant calming/sleep-aid device of claim 1, further including a sound
20 generating device linked to the logic circuit.
3. The infant calming/sleep-aid device of claim 2, wherein the main moving platform is rotatable about an axis orthogonal to a major plane of the platform.
25
4. The infant calming/sleep-aid device of claim 3, wherein the actuator includes a drive motor.
5. The infant calming/sleep-aid device of claim 4, wherein the moving head
30 platform is linked to the main moving platform by a hinge.

6. The infant calming/sleep-aid device of claim 5, wherein reciprocating rotation of the main moving platform causes reciprocating motion of the moving head platform about the hinge that is greater than the reciprocating motion of the main moving platform.
- 5
7. The infant calming/sleep-aid device of claim 6, wherein the motion sensing device includes an accelerometer.
8. The infant calming/sleep-aid device of claim 7, wherein the sound sensing
10 device includes a microphone.
9. The infant calming/sleep-aid device of claim 8, further including a rigid base and a main movement linkage or bearing extending from the rigid base, wherein the main moving platform is mounted on the main movement
15 linkage or bearing, whereby the main moving platform is moveable about said main movement linkage or bearing relative to the rigid base.
10. The infant calming/sleep-aid device of claim 9, wherein the main moving platform is moveable about said main movement linkage or bearing in a
20 plane substantially parallel to a major plane of the rigid base.
11. The infant calming/sleep-aid device of claim 10, wherein the drive motor is mounted to the rigid base, and further including,
- 25 a) a catch bracket mounted to the main moving platform;
b) an eccentric drive plate engaged with the drive motor, and
c) a linkage connecting the eccentric drive plate to the catch bracket, whereby actuation of the drive motor drives rotation of the main moving platform about the main movement linkage or bearing in the reciprocating manner.
- 30
12. The infant calming/sleep-aid device of claim 11, further including a hinge linking the main moving platform to the moving head platform, whereby reciprocating rotation of the main moving platform about the main

movement linkage or bearing causes reciprocating motion of the moving head platform about the hinge that is greater than the reciprocating motion of the main moving platform.

- 5 13. The infant calming/sleep-aid device of claim 12, wherein the hinge linking the moving head platform to the main moving platform is a head movement linkage or bearing.
- 10 14. The infant calming/sleep-aid device of claim 13, further including a spring on either side of the head movement linkage or bearing, thereby modulating the reciprocating motion of the moving head platform.
- 15 15. The infant calming/sleep-aid device of claim 14, wherein the accelerometer is mounted at the moving head platform, whereby the rate of acceleration of the rotating head platform can be monitored.
- 20 16. The infant calming/sleep-aid device of claim 15, wherein at least one speaker is mounted proximate to the moving head platform.
- 25 17. The infant calming/sleep-aid device of claim 16, further including means for controlling actuation of the drive motor, wherein at least one of the accelerometer and the microphone are linked to means for controlling actuation of the drive motor, whereby at least one of monitored acceleration of the accelerometer and sound detected by the microphone will control the speed of the drive motor and, therefore, the rate of reciprocation of the main moving platform.
- 30 18. The infant calming/sleep-aid device of claim 9, wherein the linkage connecting the eccentric drive plate to the catch bracket is a single rod.
19. The infant calming/sleep-aid device of claim 18, wherein the linkage connecting the eccentric drive plate to the catch bracket includes,

- a) a plurality of rods, at least a portion of which are hinged to each other; and
- b) a rotation bearing mounted to the rigid base and configured to cause pivoting of at least one of the rods, the rod being linked indirectly to the drive motor through another rod to which it is hinged and which is connected to the eccentric drive plate.
- 5
20. The infant calming/sleep-aid device of claim 19, further including an amplitude modulation motor connecting the main movement linkage or bearing to the pivoting rod, the amplitude modulation motor controlling a pivot point along a major axis of the rod to which it is connected about the main movement linkage or bearing, whereby the amplitude modulation motor controls the amplitude of reciprocating rotation of the main moving platform about the main movement linkage or bearing.
- 10
21. The infant calming/sleep-aid device of claim 20, wherein the plurality of rods includes a rod extending from and hinged to the rod connected to the amplitude modulation motor, and extending to the catch bracket.
- 15
22. The infant calming/sleep-aid device of claim 21, wherein the rod extending to the catch bracket is linked to the catch bracket by a spring or series of springs that modulates the reciprocating rotation of the main moving platform about the main movement or linkage bearing.
- 20
23. The infant calming/sleep-aid device of claim 22, further including a damper or series of dampers that is attached to the rigid base and that interacts with the main moving platform by modulating the reciprocating rotation of the main moving platform about the main movement or linkage bearing.
- 25
24. The infant calming/sleep-aid device of claim 23, further including means for controlling actuation of the amplitude modulation motor.
- 30

25. The infant calming/sleep-aid device of claim 24, wherein the means for controlling the drive motor and the means for controlling the amplitude modulation motor are linked.
- 5 26. The infant calming/sleep-aid device of claim 25, further including a logic circuit, wherein the means for controlling the drive motor and the means for controlling the amplitude modulation motor are linked by the logic circuit.
- 10 27. The infant calming/sleep-aid device of claim 26, wherein at least one of the accelerometers and the microphone are linked to the drive motor and to the amplitude modulation motor through the logic circuit.
- 15 28. The infant calming/sleep-aid device of claim 27, wherein both the accelerometer and the speaker are linked to the drive motor through the logic circuit.
29. The infant calming/sleep-aid device of claim 1, further including a head rest at the moving head platform, wherein the head rest includes a gel.
- 20 30. The infant calming/sleep-aid device of claim 1, further including a plurality at least two straps at the main moving platform to secure the infant to the calming/sleep-aid device.
- 25 31. An infant calming/sleep-aid device, comprising:
- a) a rigid base;
 - b) a main movement linkage or bearing extending from the rigid base;
 - c) a main moving platform mounted on the main movement linkage or bearing, whereby the main moving platform is moveable on the main movement linkage or bearing relative to the base; and
 - 30 d) an actuation assembly that controls movement of the main moving platform about the main movement linkage or bearing relative to the rigid base, the actuation assembly including an actuator mounted to the rigid base.

32. The infant calming/sleep-aid device of claim 31, wherein the main moving platform is moveable at least in a plane substantially parallel to a major plane of the rigid base.
- 5
33. The infant calming/sleep-aid device of claim 32, wherein the actuator includes a drive motor.
34. The infant calming/sleep-aid device of claim 33, wherein the actuation of assembly further includes a catch bracket mounted to the main moving platform.
- 10
35. The infant calming/sleep-aid device of claim 34, wherein the actuation assembly further includes an eccentric drive plate engaged with the drive motor.
- 15
36. The infant calming/sleep-aid device of claim 35, wherein the actuation assembly further includes a linkage connecting the eccentric drive plate to the catch bracket, whereby actuation of the drive motor drives movement of the main moving platform about the main movement linkage or bearing.
- 20
37. The infant calming/sleep-aid device of claim 36, wherein the movement of the main moving platform about the main movement linkage or bearing is a reciprocating movement.
- 25
38. The infant calming/sleep-aid device of claim 37, further including
- a) a moving head platform; and
 - b) a head movement linkage or bearing mounted to the main moving platform linking the main moving platform to the moving head platform.
- 30
39. The infant calming/sleep-aid device of claim 38, wherein movement of the main moving platform about the movement linkage or bearing causes

movement of the moving head platform about the head movement linkage or bearing that has a greater amplitude than the movement of the main moving platform.

- 5 40. The infant calming/sleep-aid device of claim 39, further including a spring on either side of the head movement linkage or bearing, thereby modulating the movement of the moving head platform.
- 10 41. The infant calming/sleep-aid device of claim 40, wherein the movement of the main moving platform is configured to move in a reciprocating manner.
42. The infant calming/sleep-aid device of claim 41, further including a motion detector sensor mounted at the moving head platform.
- 15 43. The infant calming/sleep-aid device of claim 42, wherein the motion detection sensor includes an accelerometer, whereby the rate of acceleration of the moving head platform can be monitored.
- 20 44. The infant calming/sleep-aid device of claim 43, further including a sound generating device.
45. The infant calming/sleep-aid device of claim 44, wherein the sound generating device includes a speaker.
- 25 46. The infant calming/sleep-aid device of claim 45, further includes at least one sound detection device mounted proximate to the moving head platform.
47. The infant calming/sleep-aid device of claim 46, wherein the sound detection device includes a microphone.
- 30 48. The infant calming/sleep-aid device of claim 47, further including means for controlling actuation of the drive motor, wherein at least one of the accelerometer and the microphone are linked to means for controlling

actuation of the drive motor, whereby at least one of monitored acceleration of the accelerometer and sound detected by the microphone will control the speed of the drive motor and, therefore, the rate of movement of the main moving platform.

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49. The infant calming/sleep-aid device of claim 48, wherein the linkage connecting the eccentric drive plate to the catch bracket is a single rod.

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50. The infant calming/sleep-aid device of claim 49, wherein the linkage connecting the eccentric drive plate to the catch bracket includes,

a) a plurality of rods, at least a portion of which are hinged to each other; and

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b) a rotation bearing mounted to the rigid base and configured to cause pivoting of at least one of the rods, the rod being linked indirectly to the drive motor through another of the rods to which it is hinged, and which is connected to the eccentric drive plate.

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51. The infant calming/sleep-aid device of claim 50, further including an amplitude modulation motor connecting the rotation bearing to the pivoting rod, the amplitude modulation motor controlling a pivot point along a major axis of the rod to which it is connected about the rotation bearing, whereby the drive motor controls the amplitude of reciprocating rotation of the main moving platform about the main movement linkage or bearing.

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52. The infant calming/sleep-aid device of claim 51, wherein the plurality of rods includes a rod extending from and hinged to the rod connected to the amplitude modulation motor, and extending to the catch bracket.

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53. The infant calming/sleep-aid device of claim 52, wherein the rod extending to the catch bracket is linked to the catch bracket by a spring or series of springs that modulates the reciprocating rotation of the main moving platform about the main movement linkage or bearing.

54. The infant calming/sleep-aid device of claim 53, further including a damper or series of dampers that is attached to the rigid base and that interacts with the main moving platform by modulating the reciprocating rotation of the main moving platform about the main movement or linkage bearing.
- 5
55. The infant calming/sleep-aid device of claim 54, further including means for controlling actuation of the amplitude modulation motor.
56. The infant calming/sleep-aid device of claim 55, wherein the means for
10 controlling the drive motor and the means for controlling the amplitude modulation motor are linked.
57. The infant calming/sleep-aid device of claim 56, further including a logic
15 circuit, wherein the means for controlling the drive motor and the means for controlling the amplitude modulation motor are linked by the logic circuit.
58. The infant calming/sleep-aid device of claim 57, wherein at least one of the
20 accelerometer and the microphone are linked to the drive motor and to the amplitude modulation motor through the logic circuit.
59. The infant calming/sleep-aid device of claim 58, wherein both the
accelerometer and the microphone are linked to the drive motor through the logic circuit.
- 25 60. The infant calming/sleep-aid device of claim 31, further including a head rest at the moving head platform, wherein the head rest includes a gel.
61. The infant calming/sleep-aid device of claim 31, further including at least
30 two straps at the main moving platform to secure the infant to the calming/sleep-aid device.

62. A method for calming or aiding sleep of an infant, comprising moving the infant in a reciprocating manner about an axis that intersects the infant at a 90 degree angle to a major plane of a surface supporting the infant.
- 5 63. The method of claim 62, wherein at least one of the rate and amplitude of the reciprocating rotation is controlled by a logic circuit.
64. The method of claim 62, wherein the rate and amplitude of the reciprocating rotation are controlled by the logic circuit.
- 10 65. The method of claim 63, wherein the logic circuit controls the rate and amplitude of the reciprocating rotation in response to signals obtained from a motion detection device that is connected to the logic circuit and that detects perturbations caused by the infant during reciprocating rotation.
- 15 66. The method of claim 63, wherein the logic circuit controls the rate and amplitude of the reciprocating rotation in response to sounds detected by at least one sound detection device connected to the logic circuit.
- 20 67. The method of claim 66, wherein the rate of the reciprocating rotation is in a range of between about two and about four and one-half cycles per second and an amplitude of the reciprocating rotation at a center of a head of the infant is in a range of between about 0.2 inches and about 1.0 inches.
- 25 68. The method of claim 67, wherein the rate of reciprocating rotation is in a range of between about 0.5 and about 1.5 cycles per second and an amplitude of the reciprocating rotation at a center of a head of the infant is in a range of between about 0.5 inches and about 1.5 inches.
- 30 69. The method of claim 63, wherein the logic circuit controls the rate and amplitude of the reciprocating rotation in response to signals obtained from a motion detection device that is connected to the logic circuit and in response

to sounds detected by at least one sound detection device connected to the logic circuit.

70. An adaptive calming/sleep-aid method, comprising the steps of:
- 5 a) moving an infant in a reciprocating manner about an axis that intersects the infant and is orthogonal to a major plane of a surface supporting the infant; and
- b) modulating at least one of the sounds generated by a sound
10 generating device and the reciprocating moving in an updating and adaptive manner by logic circuit -controlled actuation in response to at least one of sound and motion of the infant.
71. The adaptive calming/sleep-aid method of claim 70, wherein the modulation is further controlled by at least one of the weight of the infant, the age of the
15 infant, the duration of the detected sound made by the infant and the duration of the detected motion of the infant.
72. The method of claim 71, wherein the rate of the reciprocating rotation is in a range of between about two and about four and one-half cycles per second
20 and an amplitude of the reciprocating rotation at a center of a head of the infant is in a range of between about 0.2 inches and about 1.0 inches.
73. The method of claim 71, wherein the rate of reciprocating rotation is in a range of between about 0.5 and about 1.5 cycles per second and an amplitude
25 of the reciprocating rotation at a center of a head of the infant is in a range of between about 0.5 inches and about 1.5 inches.
74. The infant calming/sleep-aid device of claim 71, wherein the logic circuit includes a crying detection module having,
- 30 a) a band-pass filter to receive audio signals from the sound sensing device, whereby filtered audio data that exceeds an energy-based threshold is delivered as an output signal; and

- b) a time-based filter that receives the output signal and modulates reciprocating motion of the main moving platform in response to the output signal.

5 75. The infant calming/sleep-aid device of claim 74, wherein the band pass filter is a digital band pass filter.

76. The infant calming/sleep-aid device of claim 70, wherein the logic circuit includes a motion analysis module having,

- 10 a) a filter bank that delivers a motion amplitude estimate signal and a filtered accelerometer data signal; and
- b) a motion frequency estimator that receives the filtered accelerometer data signal and delivers a motion frequency estimate signal, whereby the logic circuit compares the filtered motion amplitude estimate and
- 15 the motion frequency estimate signals to thereby generate a signal that motion of the main rotating platform is nominal or not nominal, wherein the filtered accelerometer data signal will trigger the logic circuit to generate a signal that the motion of the main rotating platform is not nominal if it exceeds a motion safety threshold.

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77. The infant calming/sleep-aid device of claim 76, wherein the filter bank is a digital filter bank.

25 78. The infant calming/sleep-aid device of claim 76, wherein the signal that the motion of the main rotating platform is not nominal, whether from the comparison made by the logic circuit, or by exceeding the motion safety threshold of filtered accelerometer data, is delivered to a time-based filter that only outputs a signal if the input signal exceeds a time threshold.

30 79. The infant calming/sleep-aid device of claim 76, wherein the motion frequency estimator is a threshold-crossing-based motion frequency estimator.

80. The infant calming/sleep-aid device of claim 71, wherein the logic circuit includes a motion generation module that modulates the speed and amplitude of reciprocating rotation of the main rotating platform in response to input signals that include at least one member selected from the group consisting of a desired motion state, sensed motion frequency and amplitude of the main rotating platform, desired system speed, and whether motion of the main rotating platform exceeds a safety threshold.

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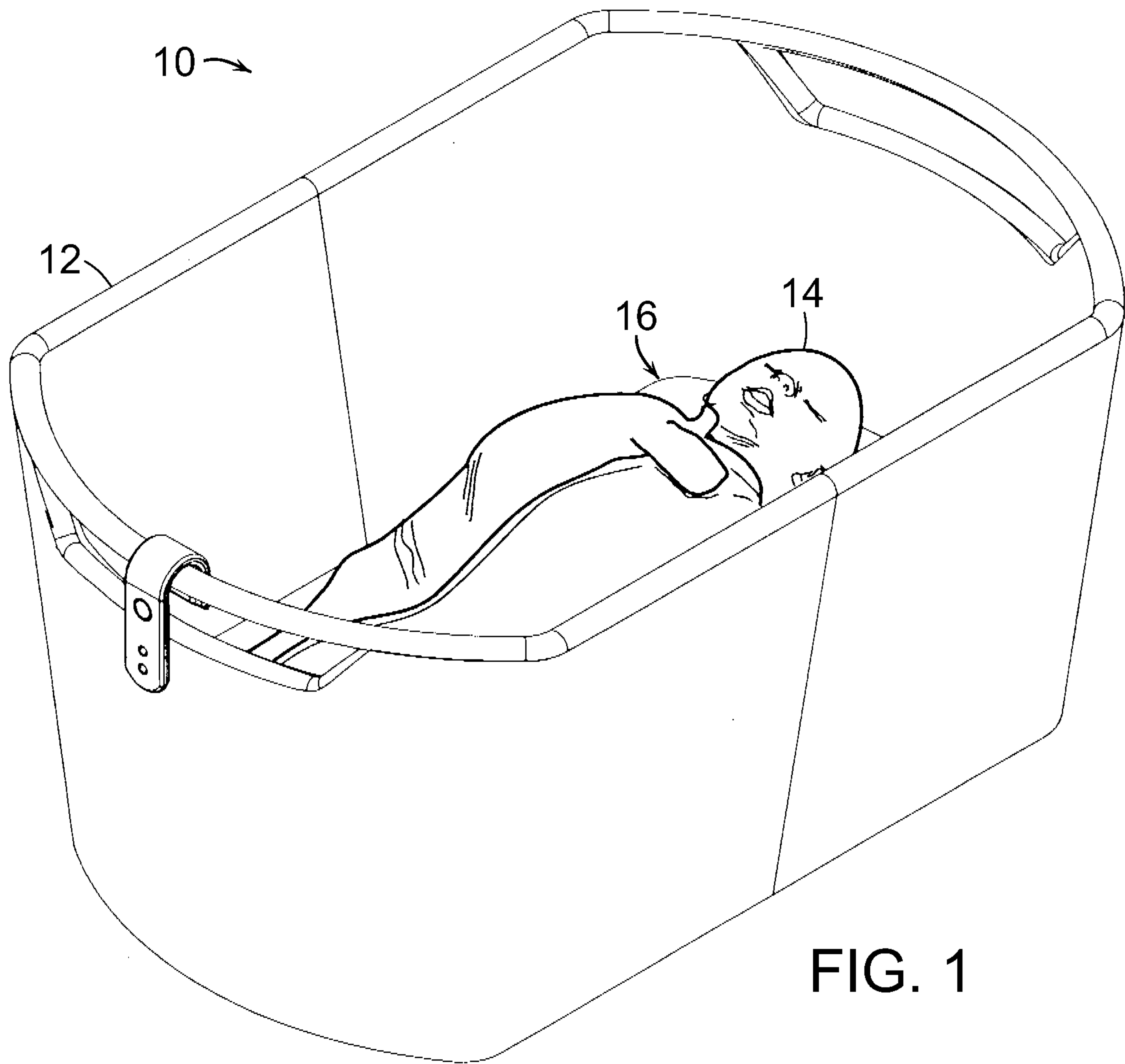


FIG. 1

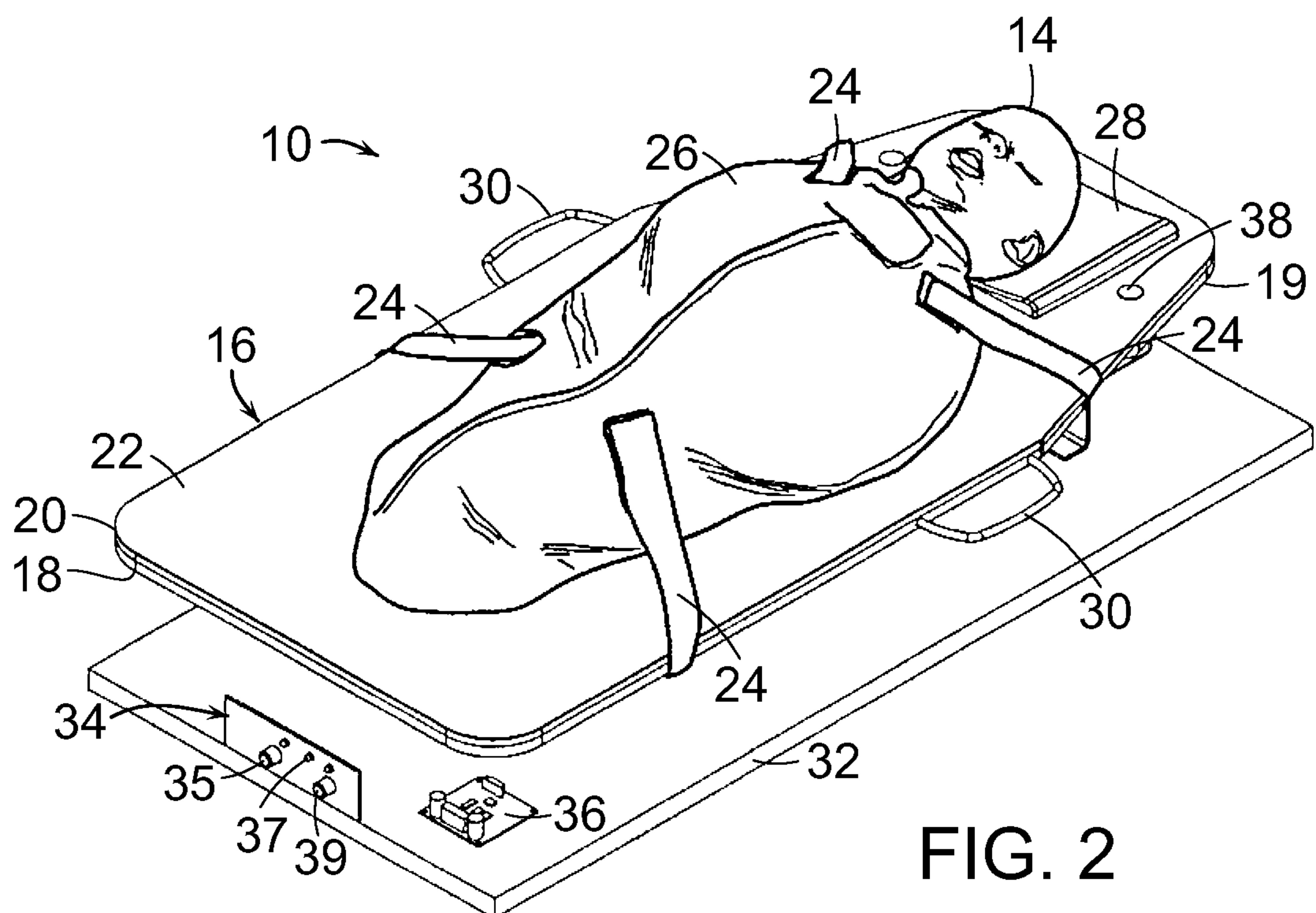


FIG. 2

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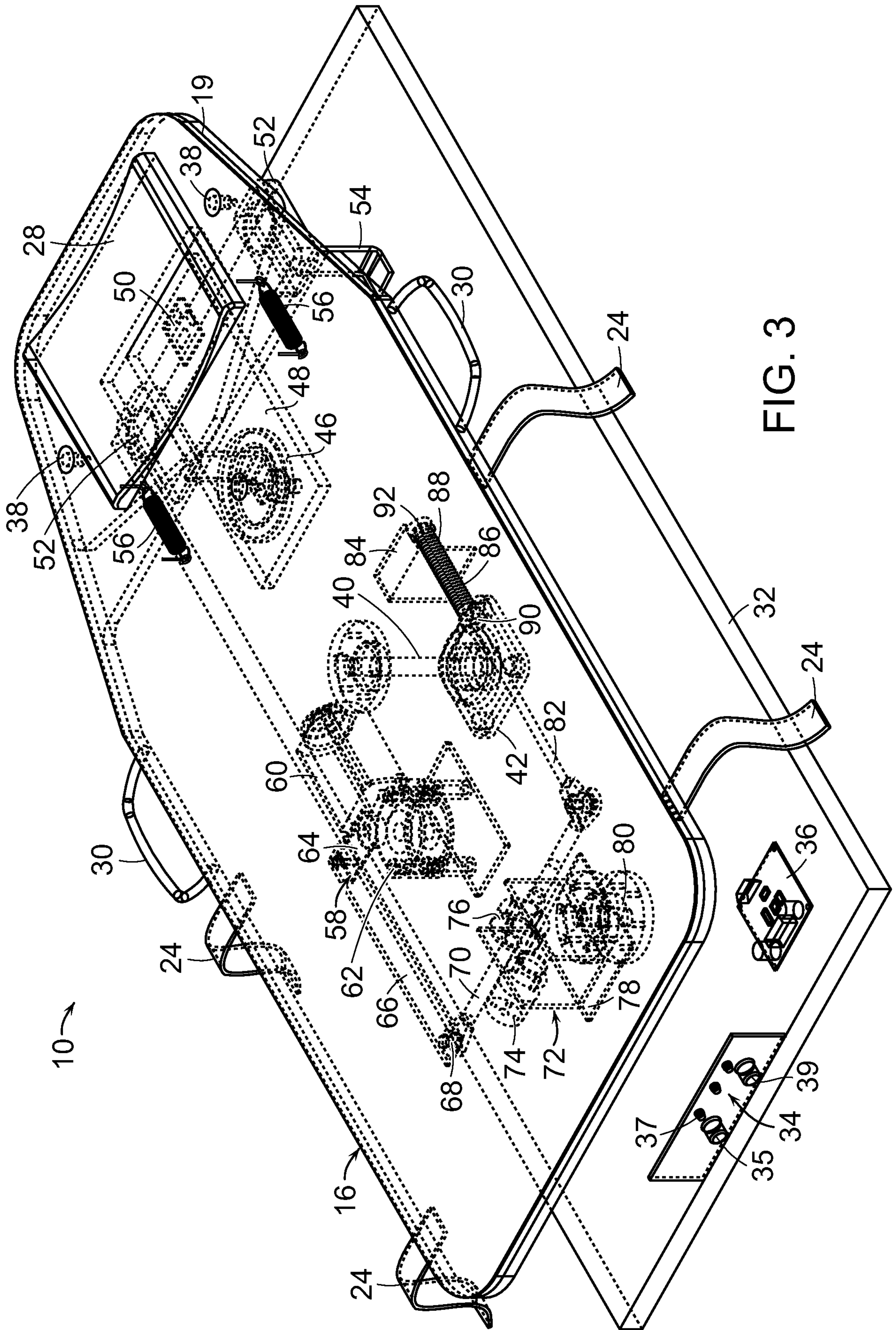


FIG. 3

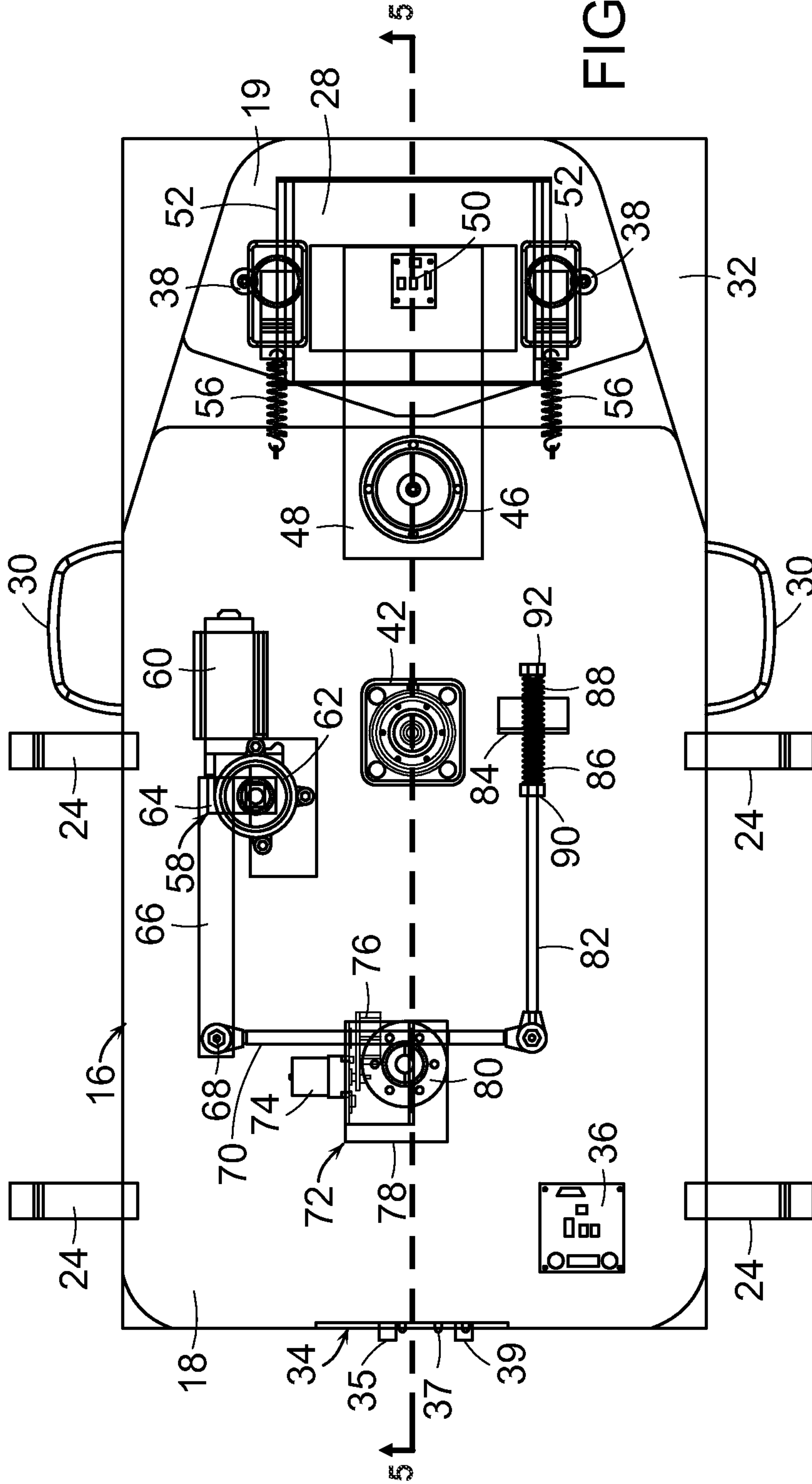


FIG. 4

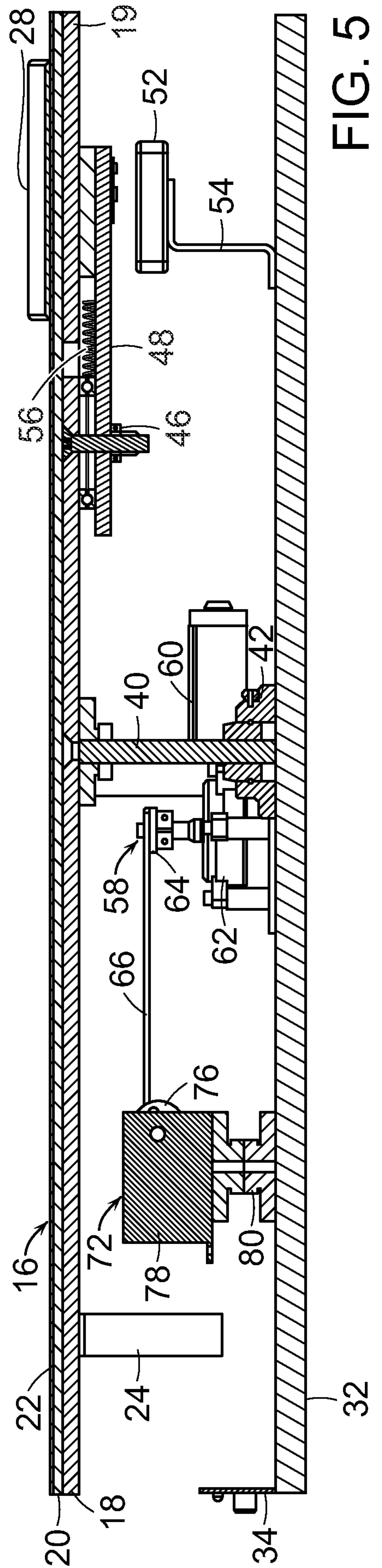


FIG. 5

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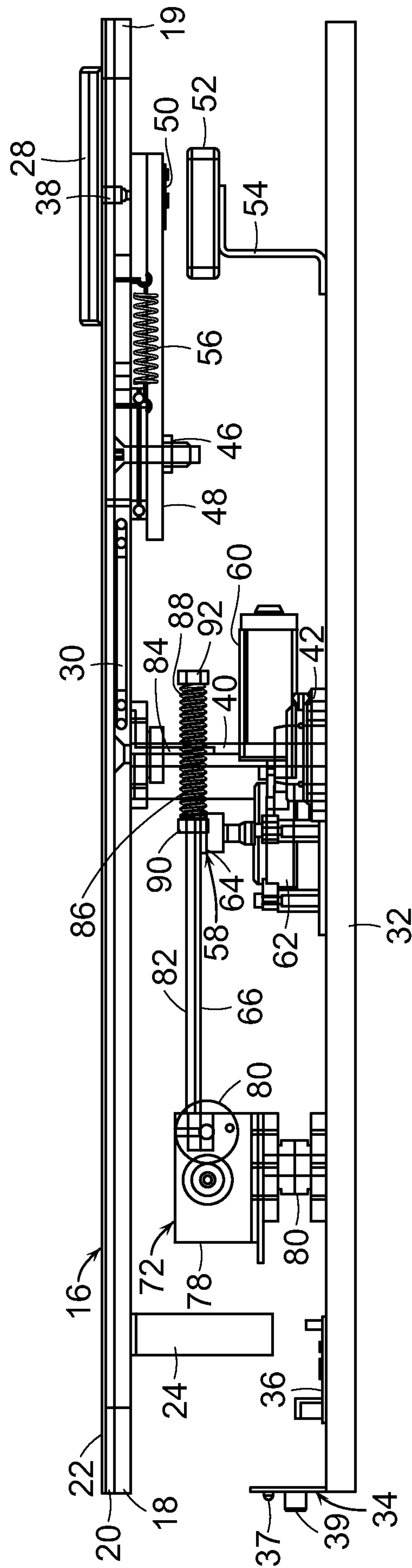


FIG. 6

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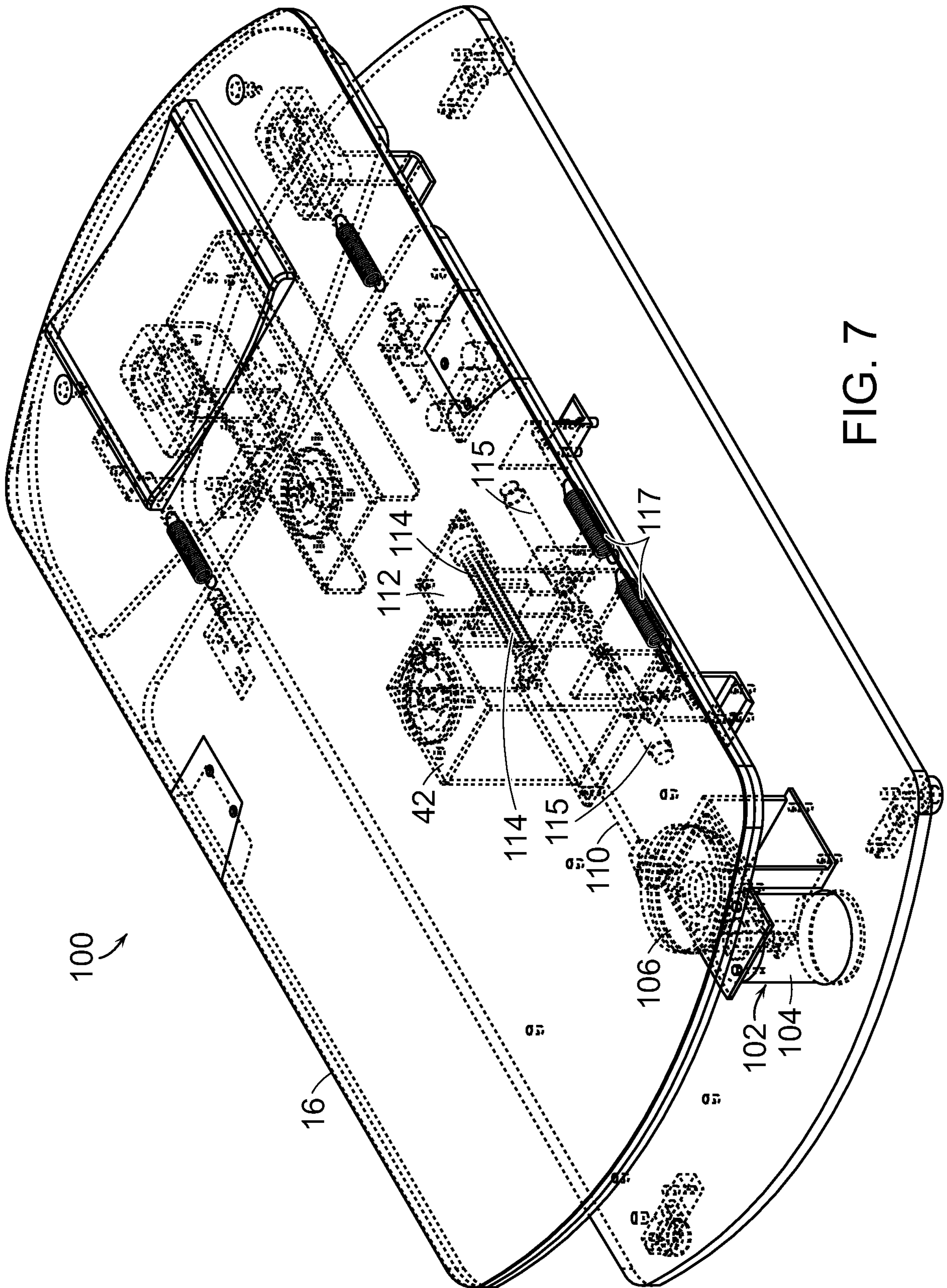
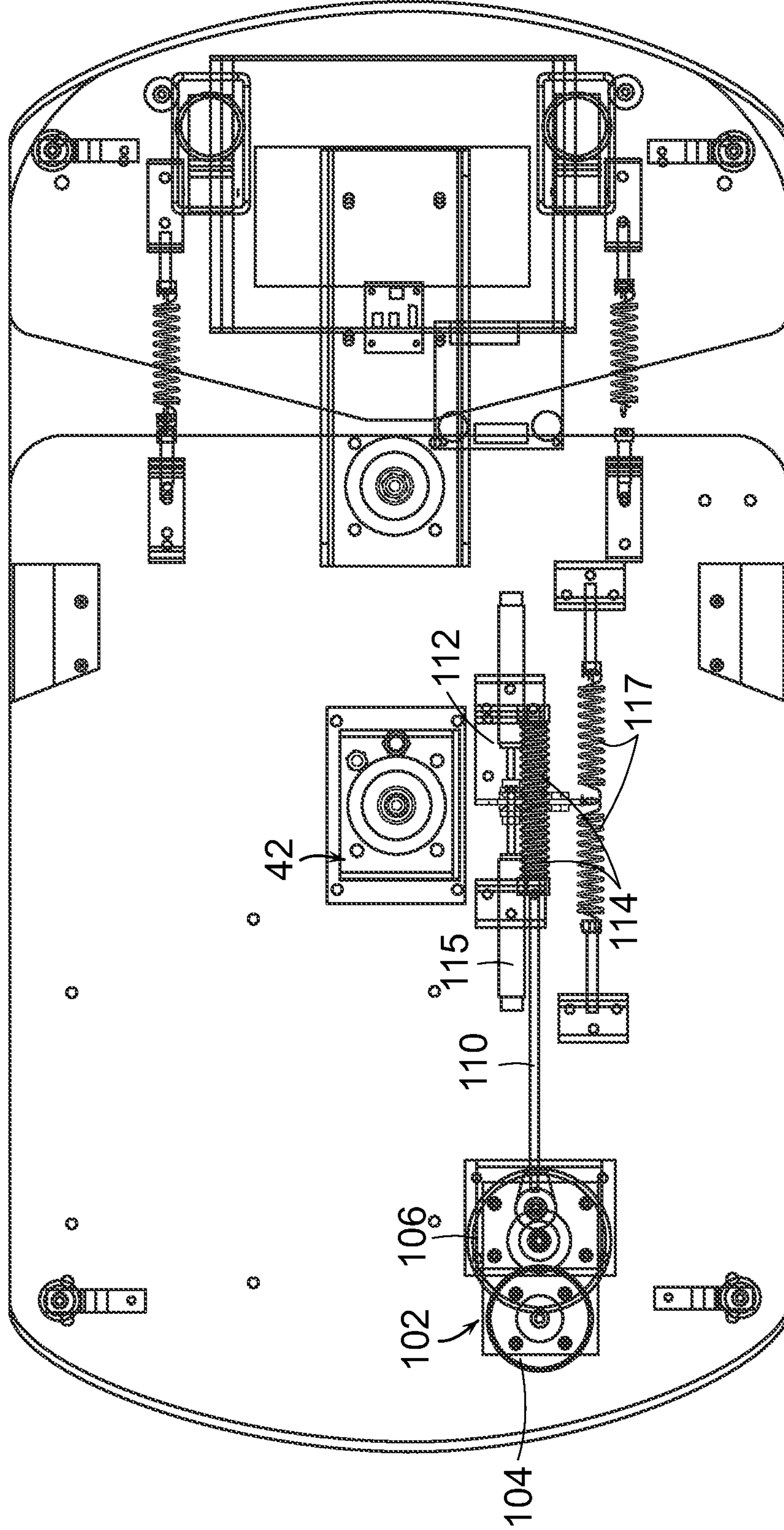


FIG. 7

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FIG. 8



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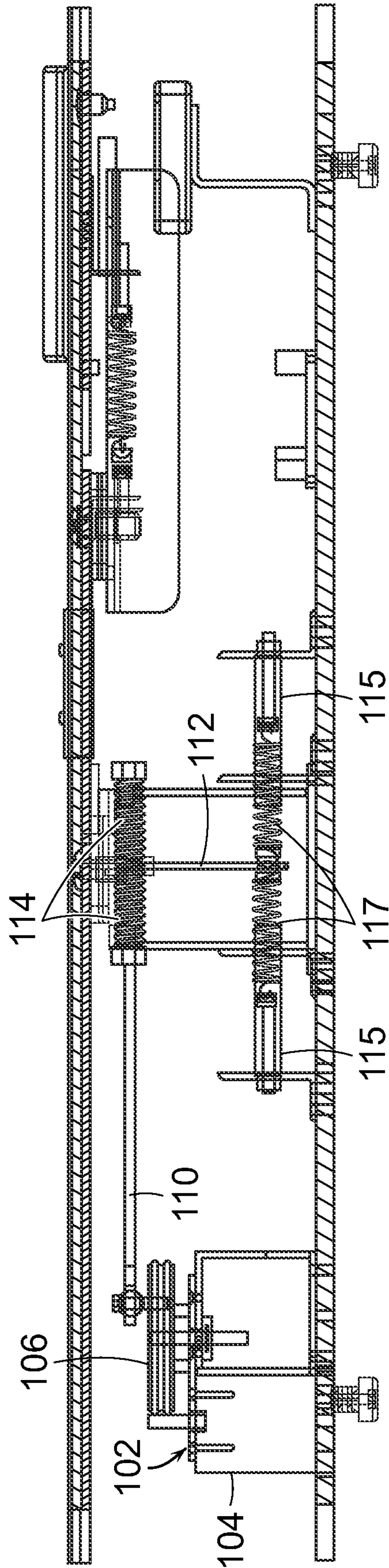


FIG. 9

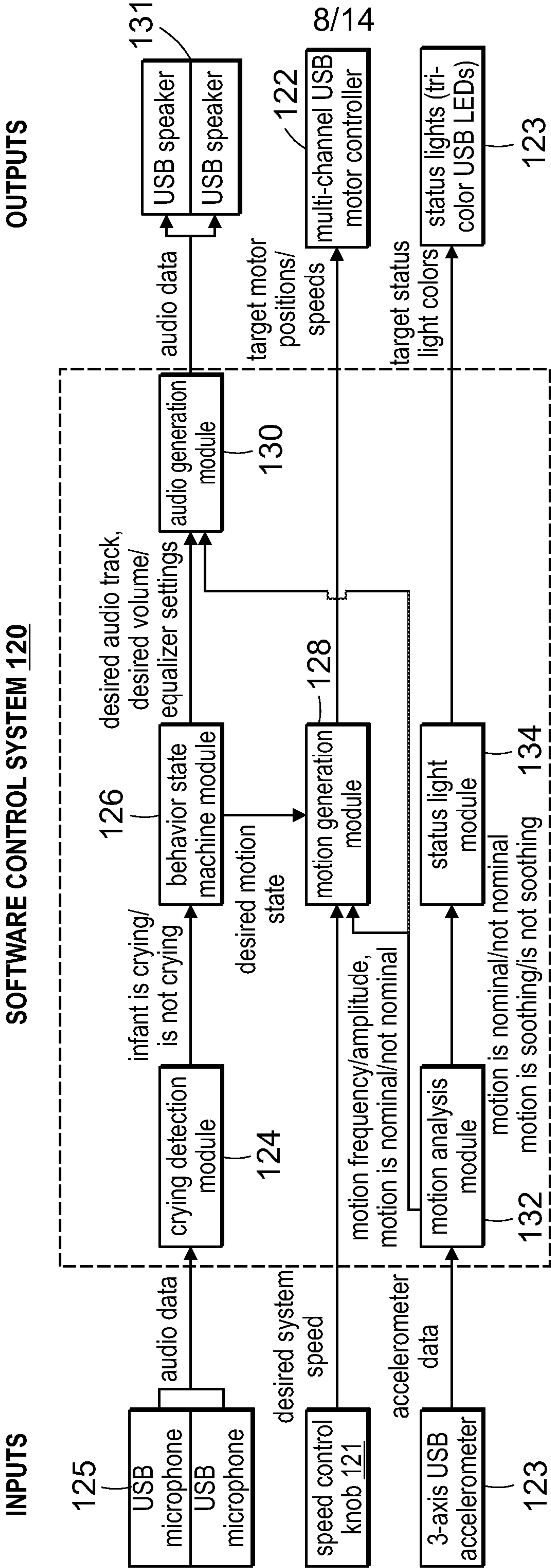


FIG. 10

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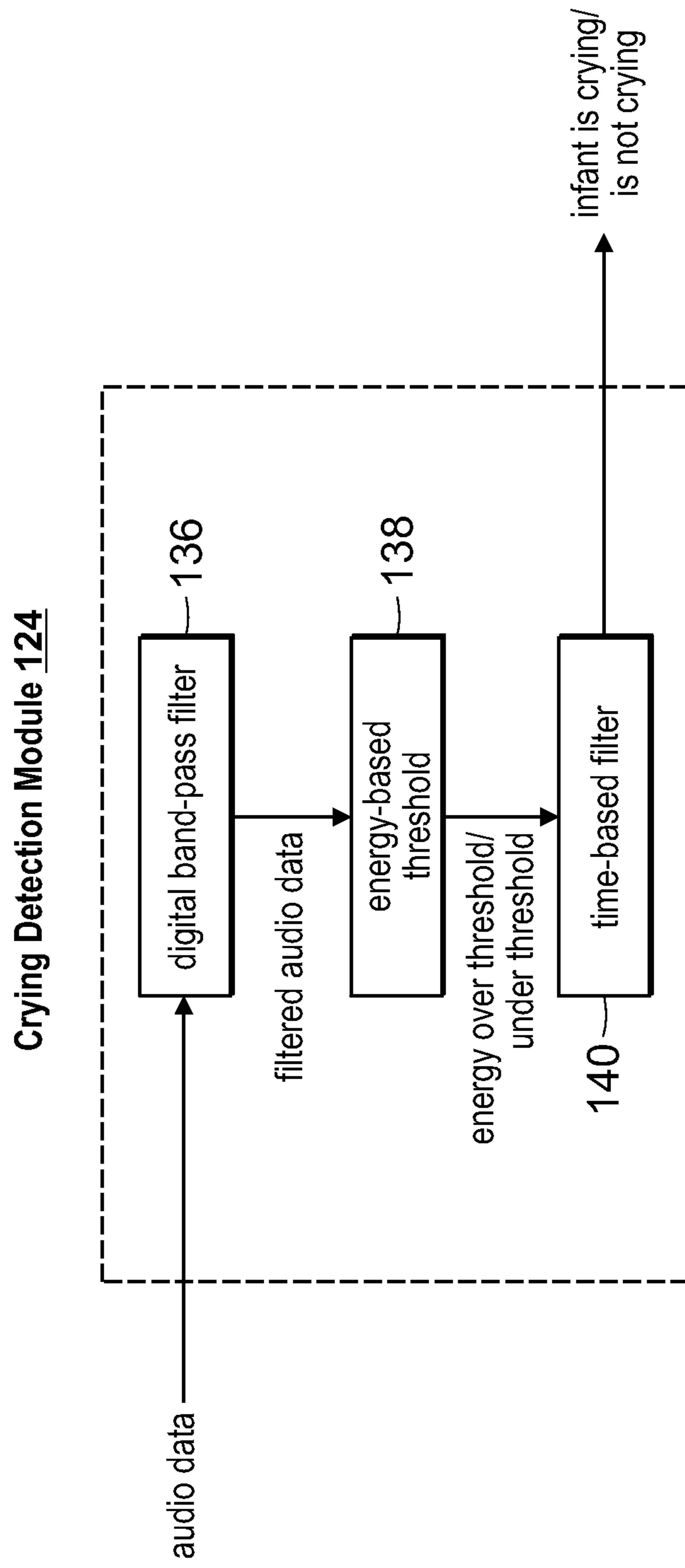


FIG. 11

Motion Analysis Module 132

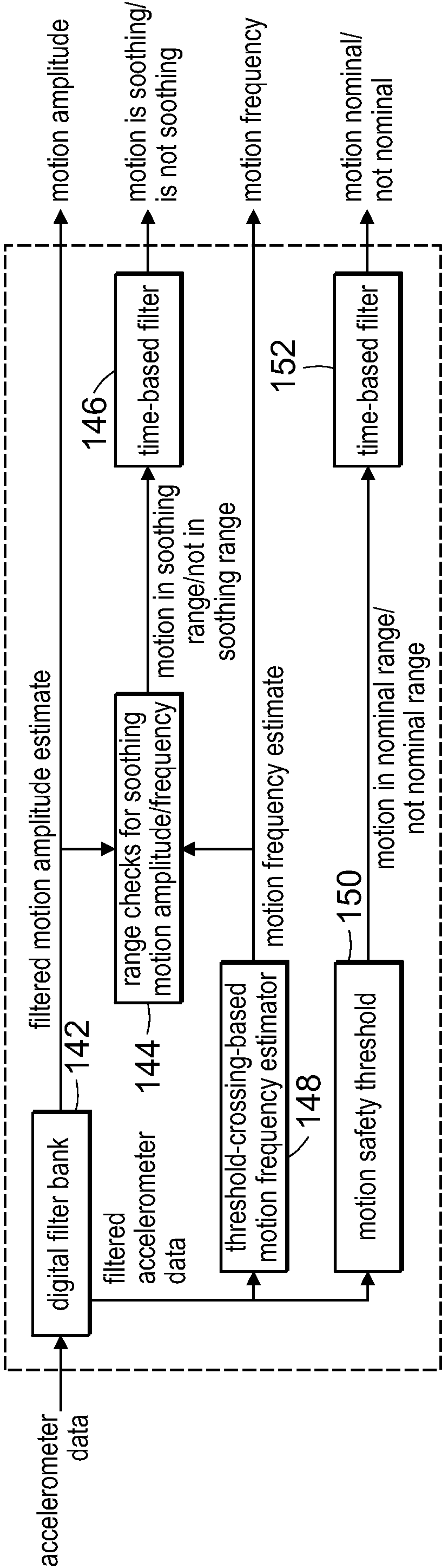


FIG. 12

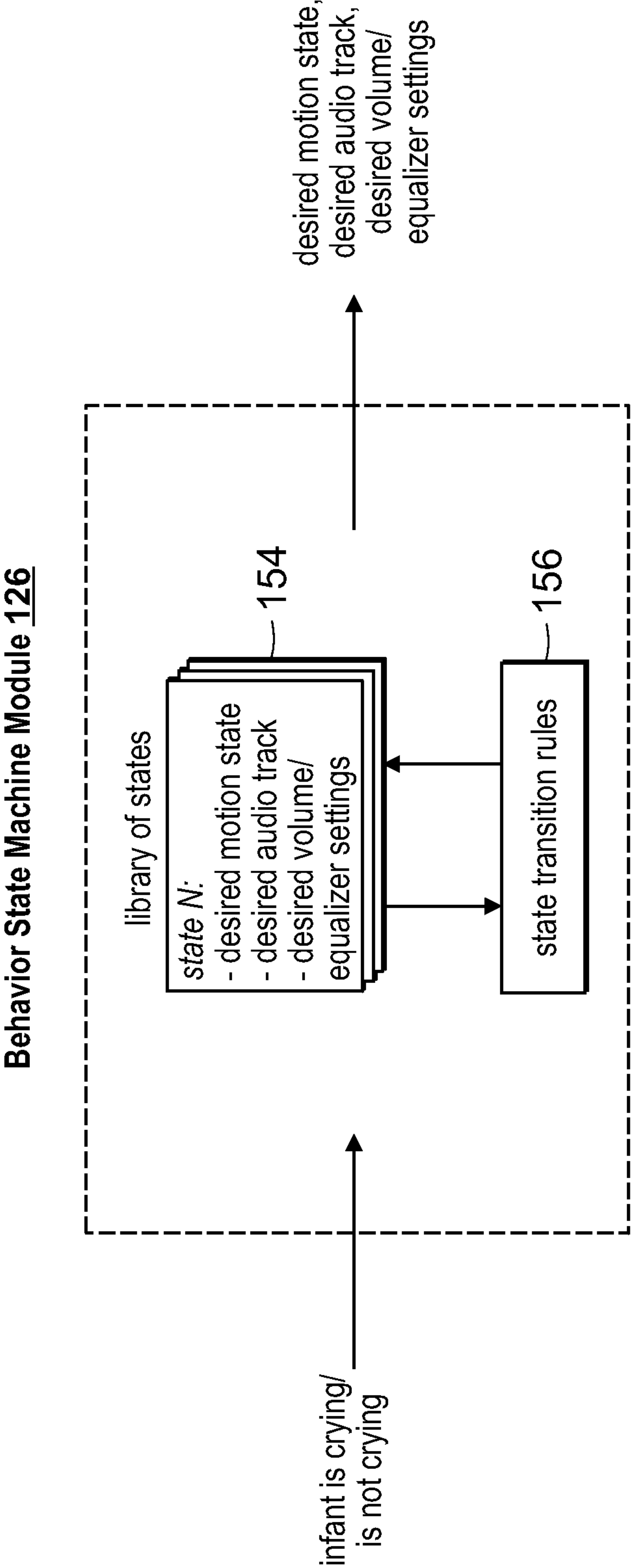


FIG. 13

Audio Generation Module 130

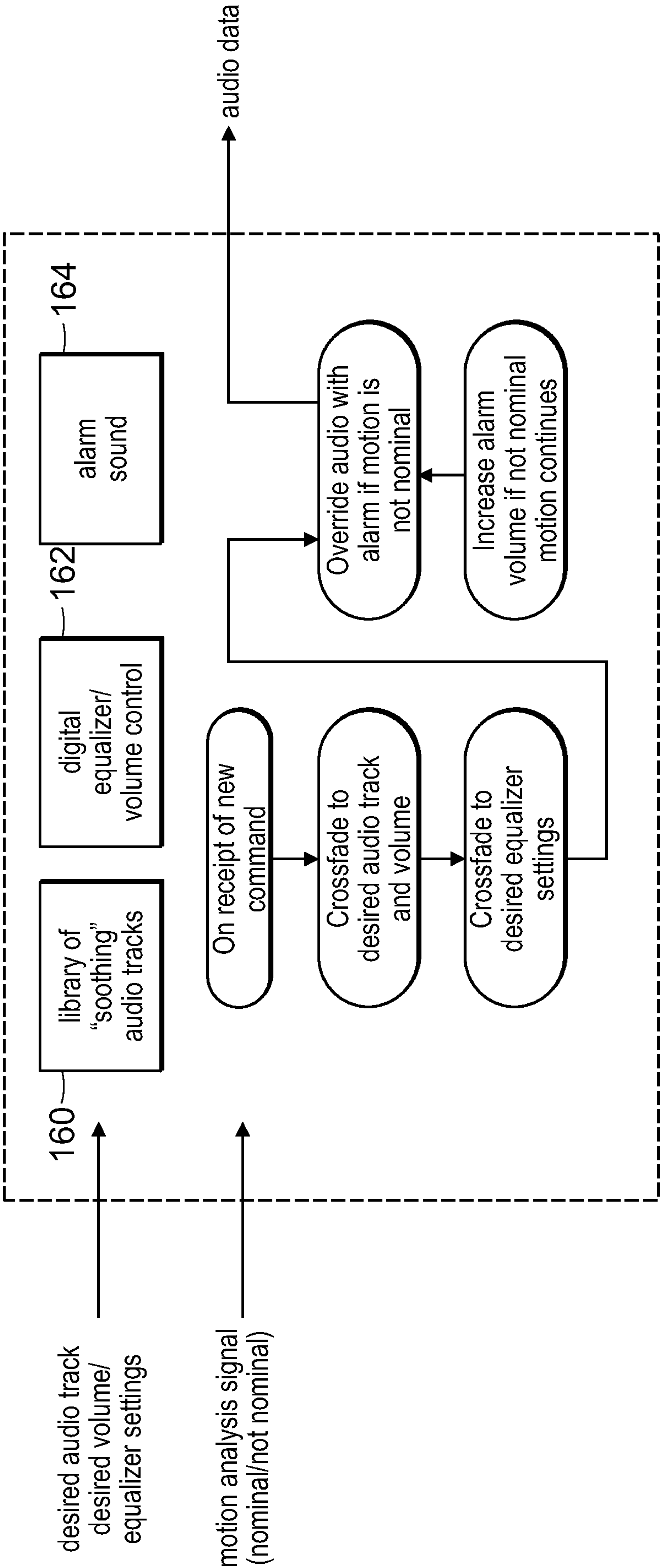


FIG. 14

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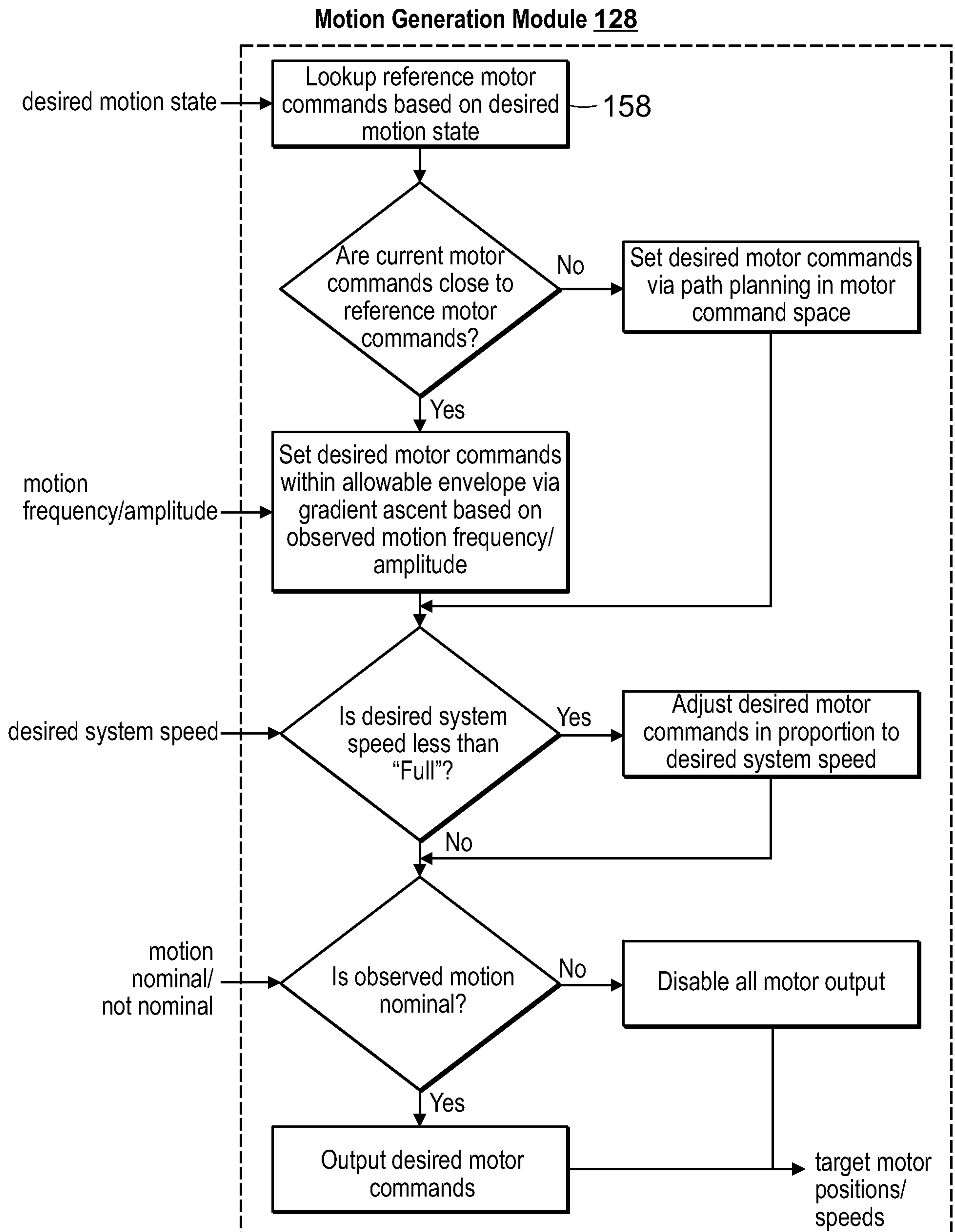
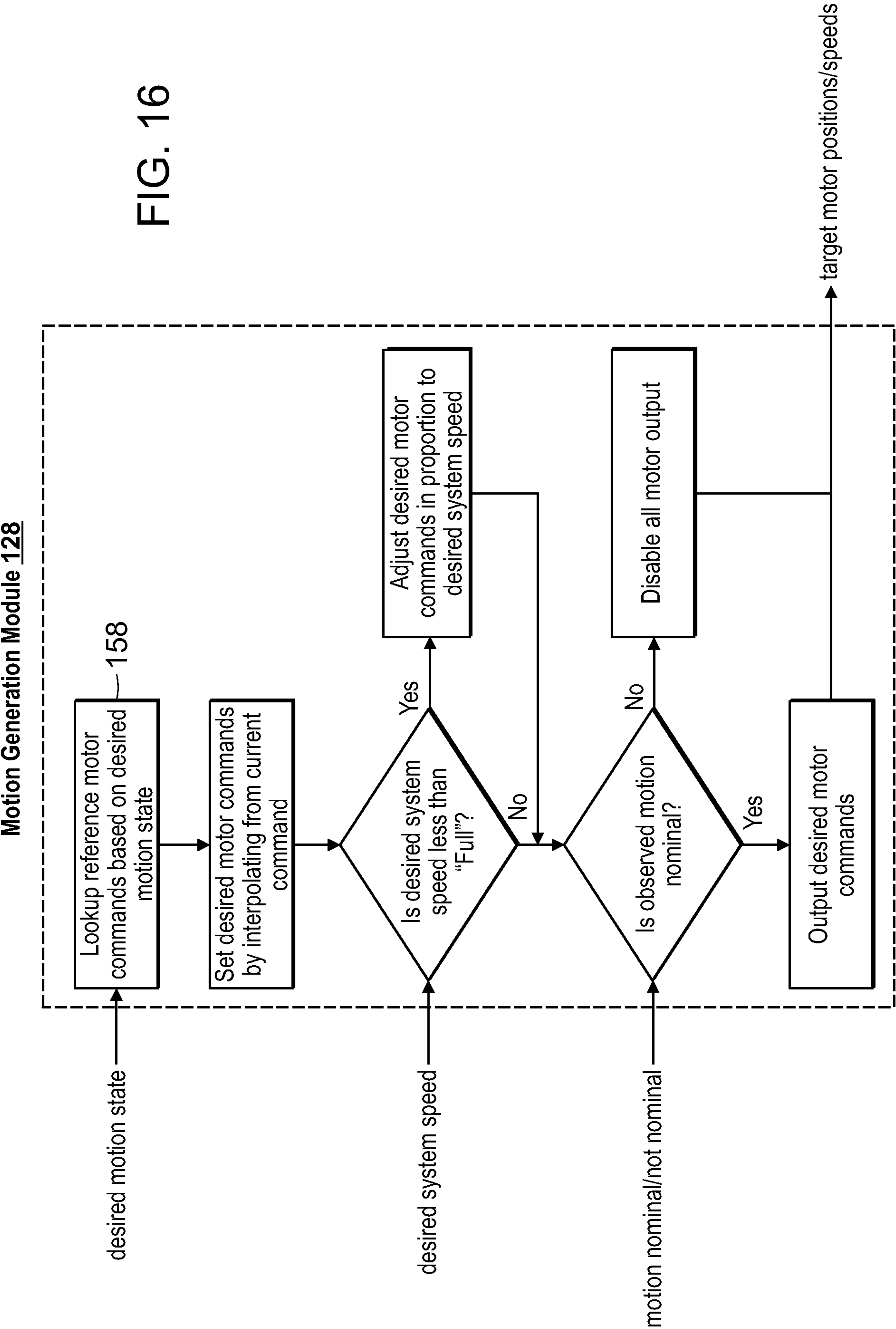


FIG. 15



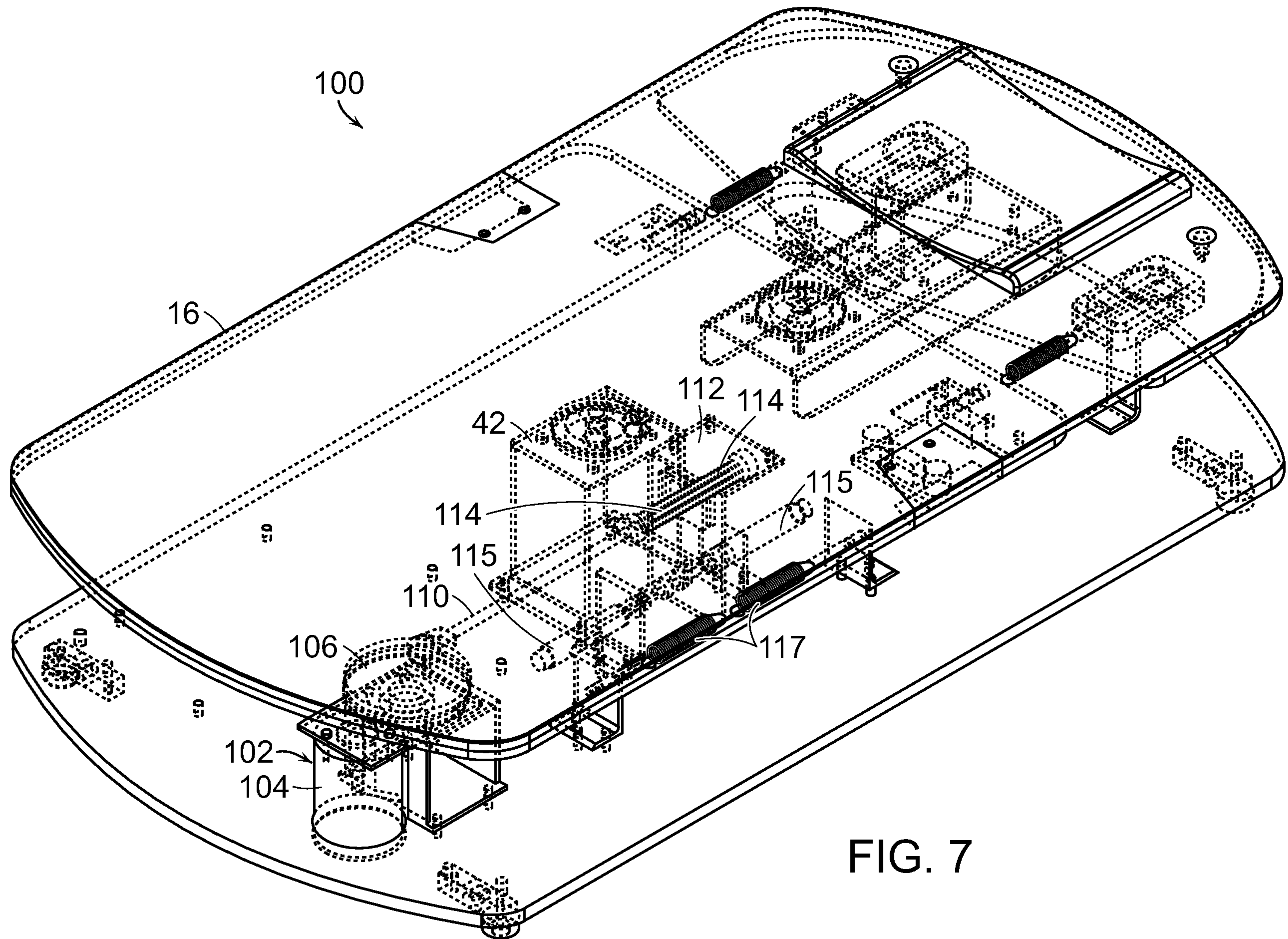


FIG. 7