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Suda

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(54) **ELECTRIC-POWERED WHEELBARROW**

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B60L 7/00 (2006.01)
B60L 50/60 (2019.01)
H02P 3/04 (2006.01)
H02P 23/14 (2006.01)

(52) **U.S. Cl.**

CPC ***H02P 3/18*** (2013.01); ***B60L 7/00*** (2013.01); ***B60L 50/60*** (2019.02); ***H02P 23/14*** (2013.01); *B60L 2200/36* (2013.01)

(58) **Field of Classification Search**

CPC B60L 50/60; B60L 7/00; B60L 2200/36; H02P 3/04; H02P 3/18; H02P 23/14

See application file for complete search history.

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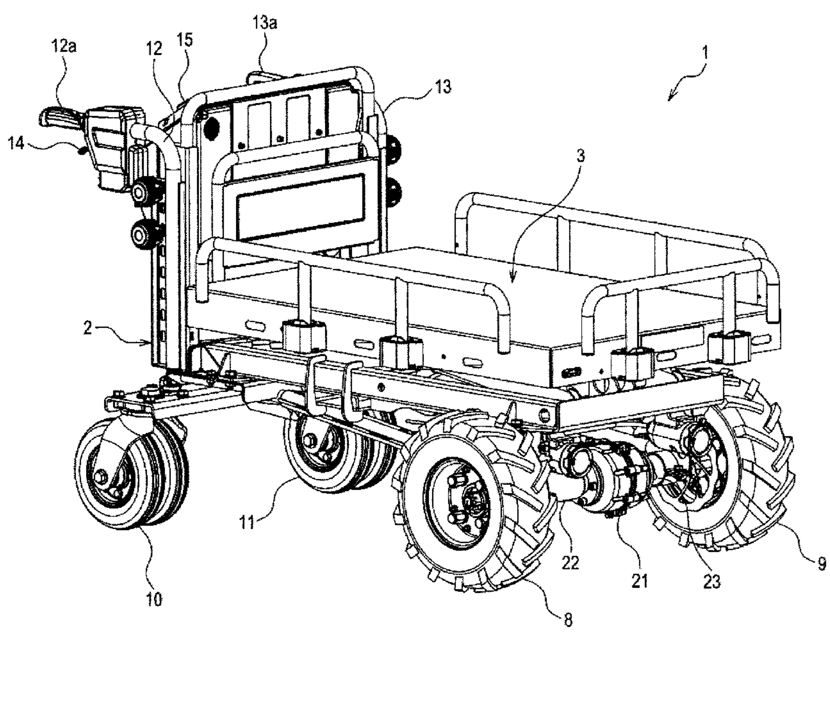
(57) **ABSTRACT**

An electric-powered wheelbarrow in one aspect of the present disclosure includes a motor, a wheel, an electromagnetic brake, a control circuit, a signal-processing circuit, and a drive circuit. The electromagnetic brake includes an electromagnetic coil. The electromagnetic brake (i) applies a braking force to the wheel in response to the electromagnetic coil being de-energized and (ii) releases the braking force from the wheel in response to the electromagnetic coil being energized. The control circuit outputs a first control signal and a second control signal. The signal-processing circuit receives the first and second control signals to thereby output a deactivating signal. The drive circuit receives the deactivating signal and delivers an excitation current to the electromagnetic coil.

19 Claims, 7 Drawing Sheets



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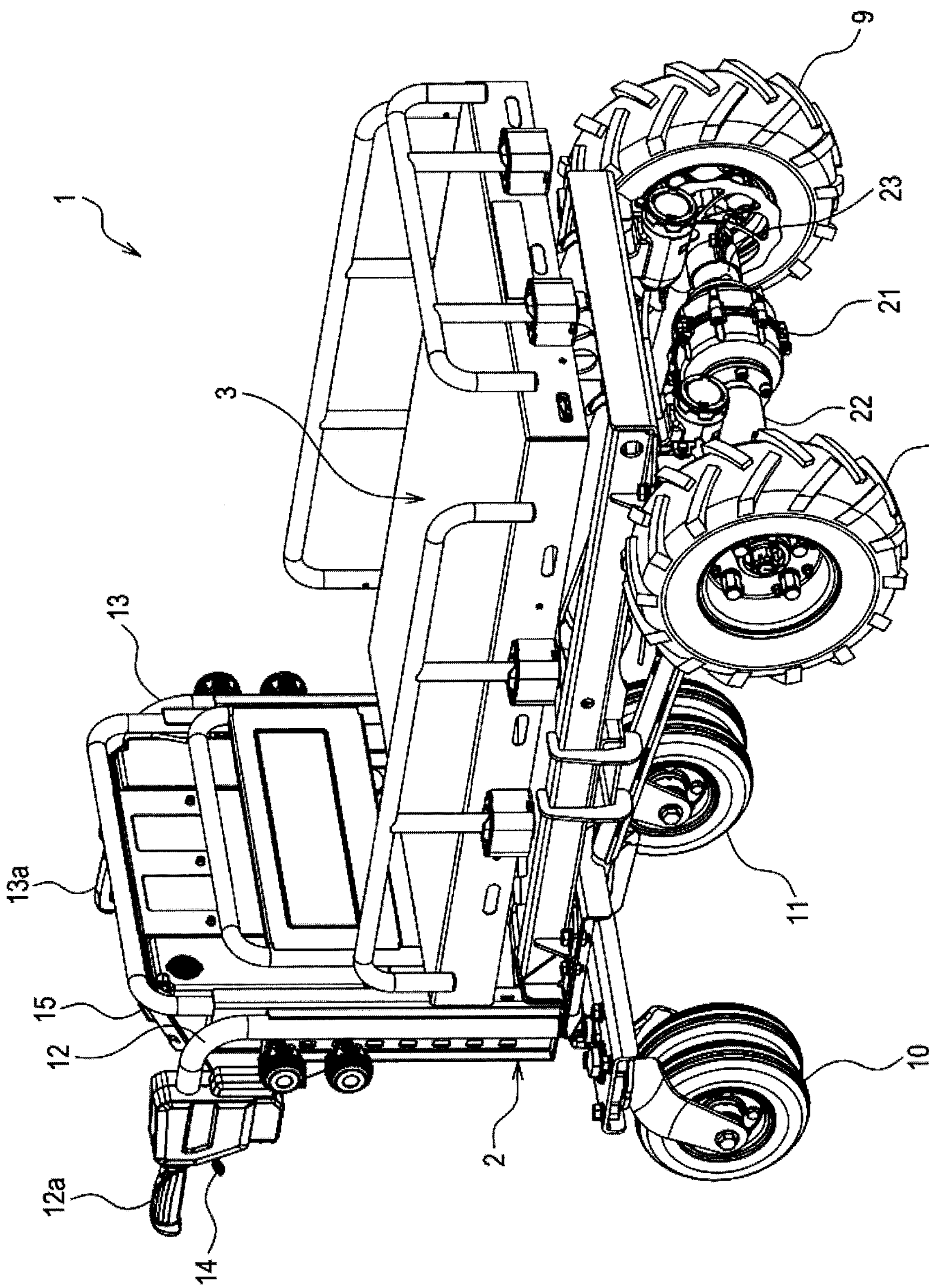

FIG. 1

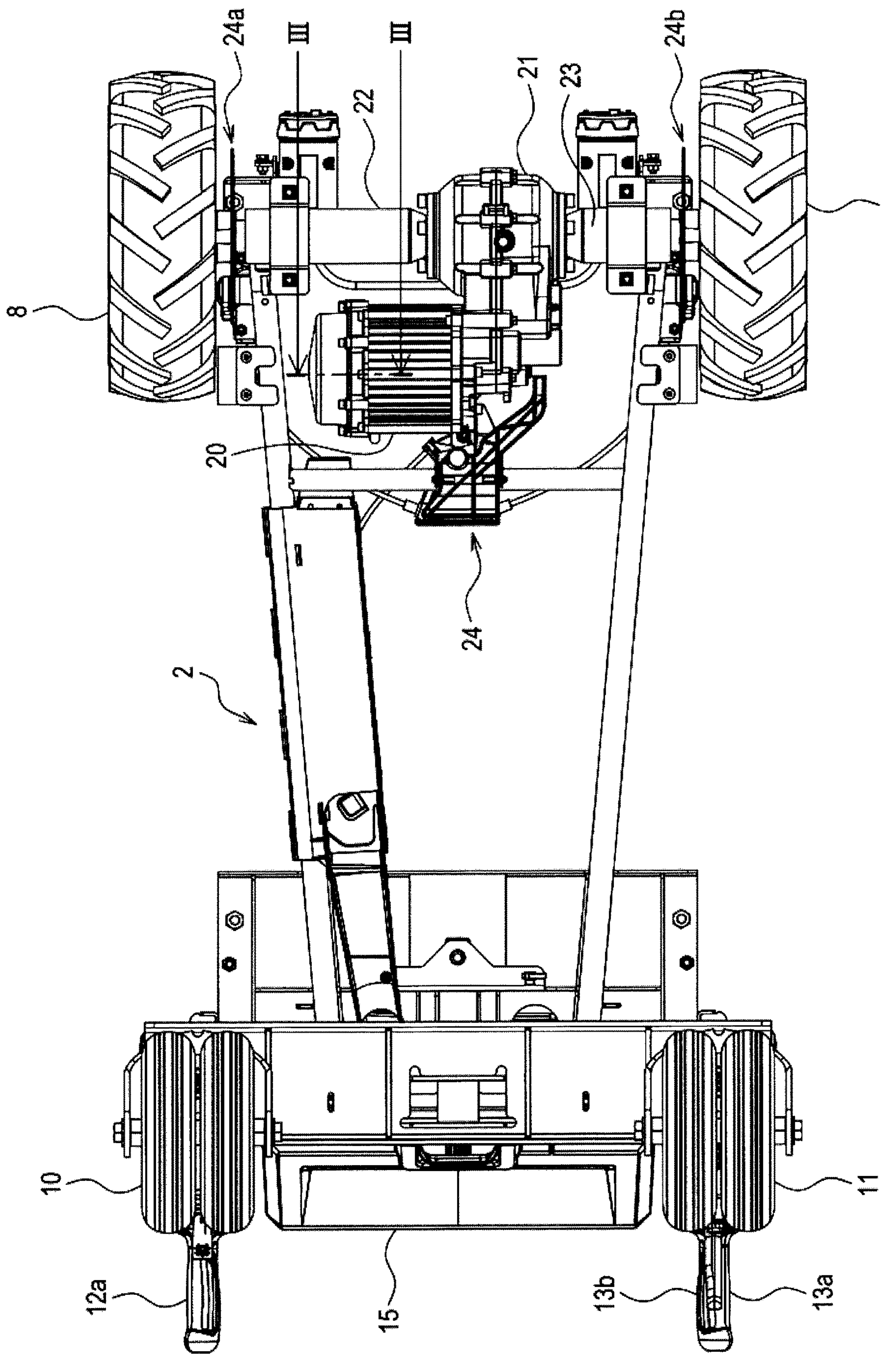

FIG. 2

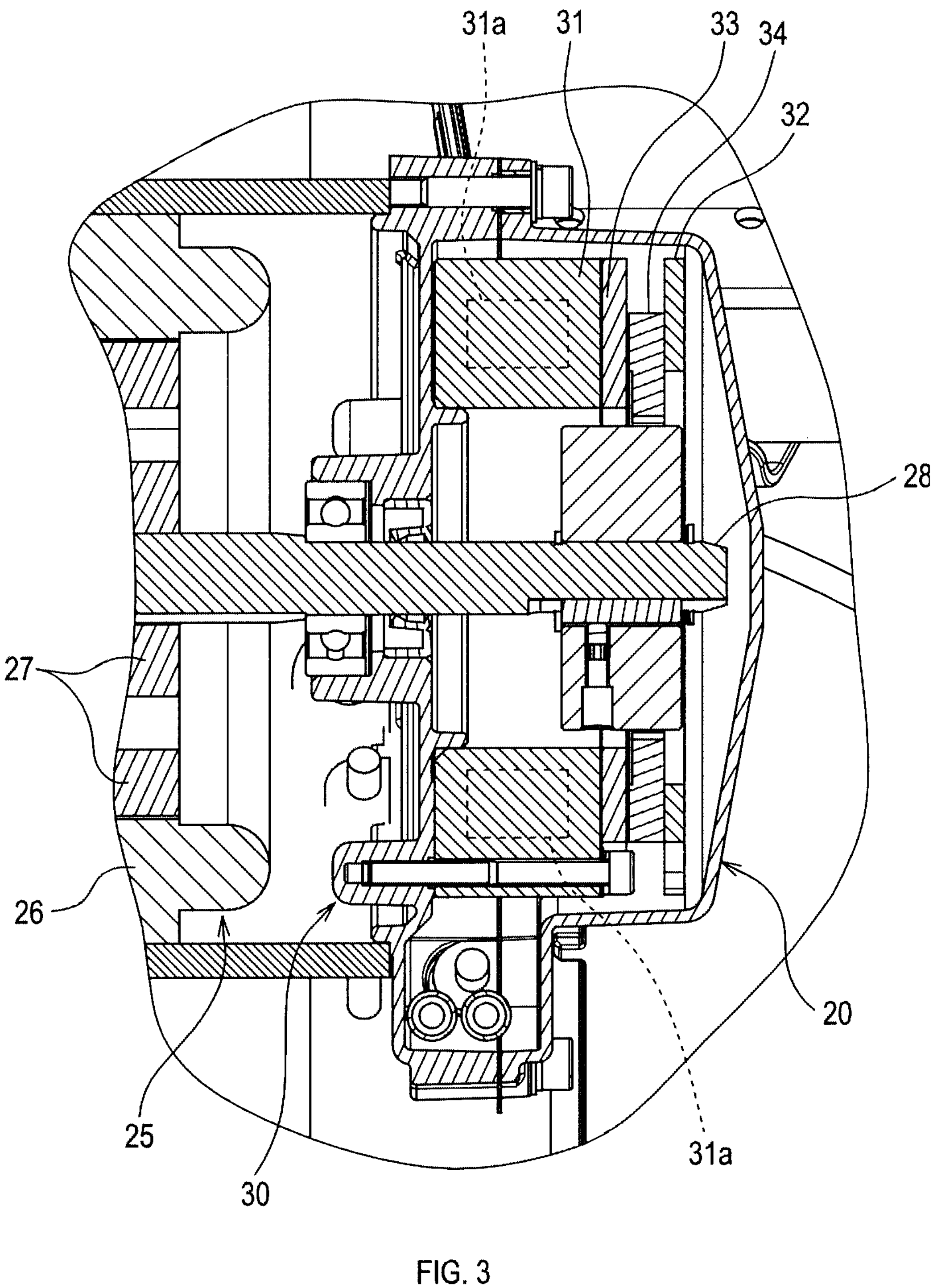

FIG. 3

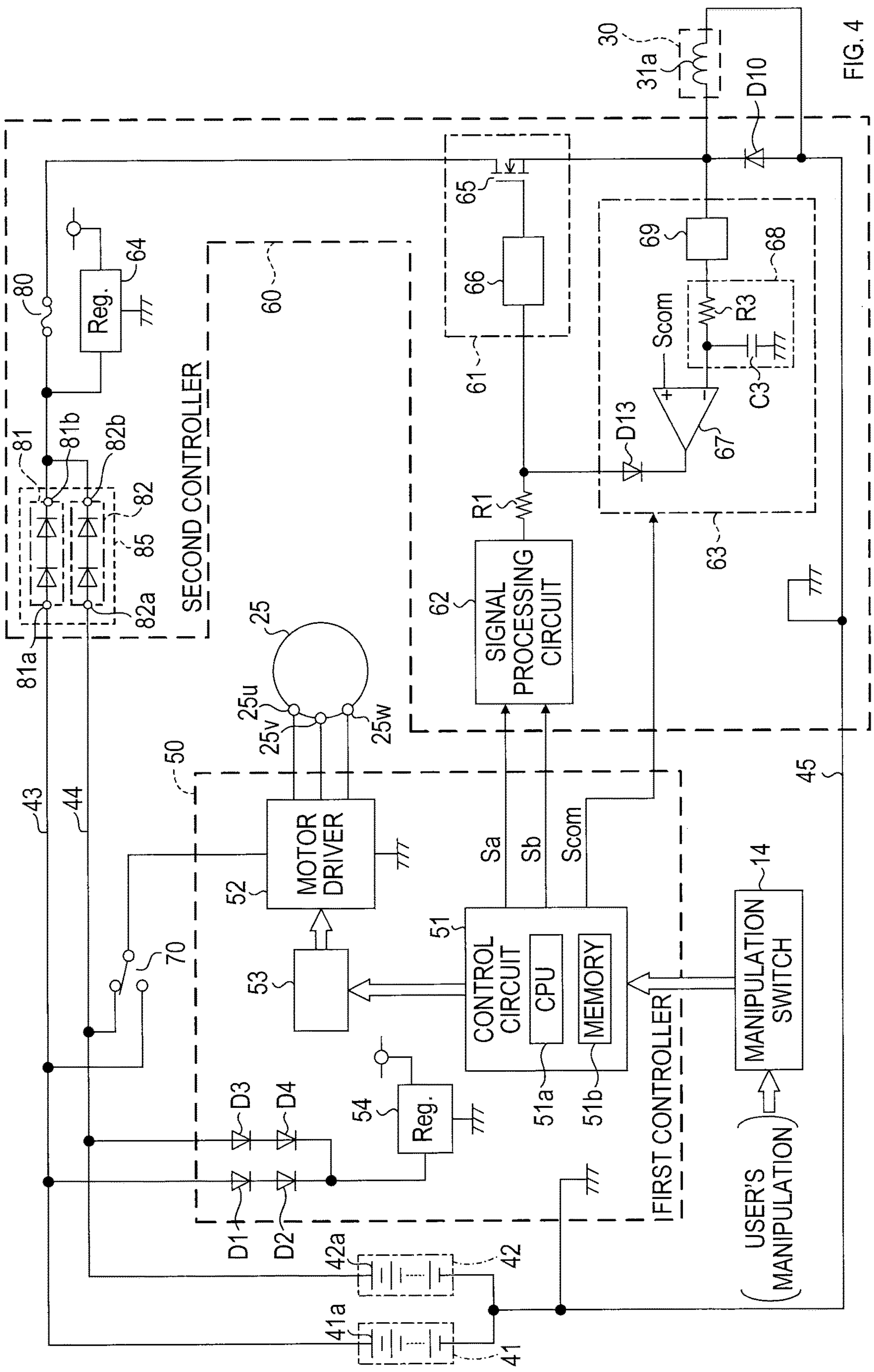
30
31a
D10
65
66
61
69
68
Scom
R3
C3
D13
67
63
R1
62
SIGNAL PROCESSING CIRCUIT
60
SECOND CONTROLLER
80
Reg.
64
81
81b
82b
82
85
82a
81a
25
25u
25v
25w
50
43
44
45
MOTOR DRIVER
52
Sa
Sb
Scom
51
CONTROL CIRCUIT
CPU
MEMORY
51a
51b
53
70
14
MANIPULATION SWITCH
FIRST CONTROLLER
54
Reg.
D1
D2
D3
D4
42a
42
41a
41
USER'S MANIPULATION

FIG. 4

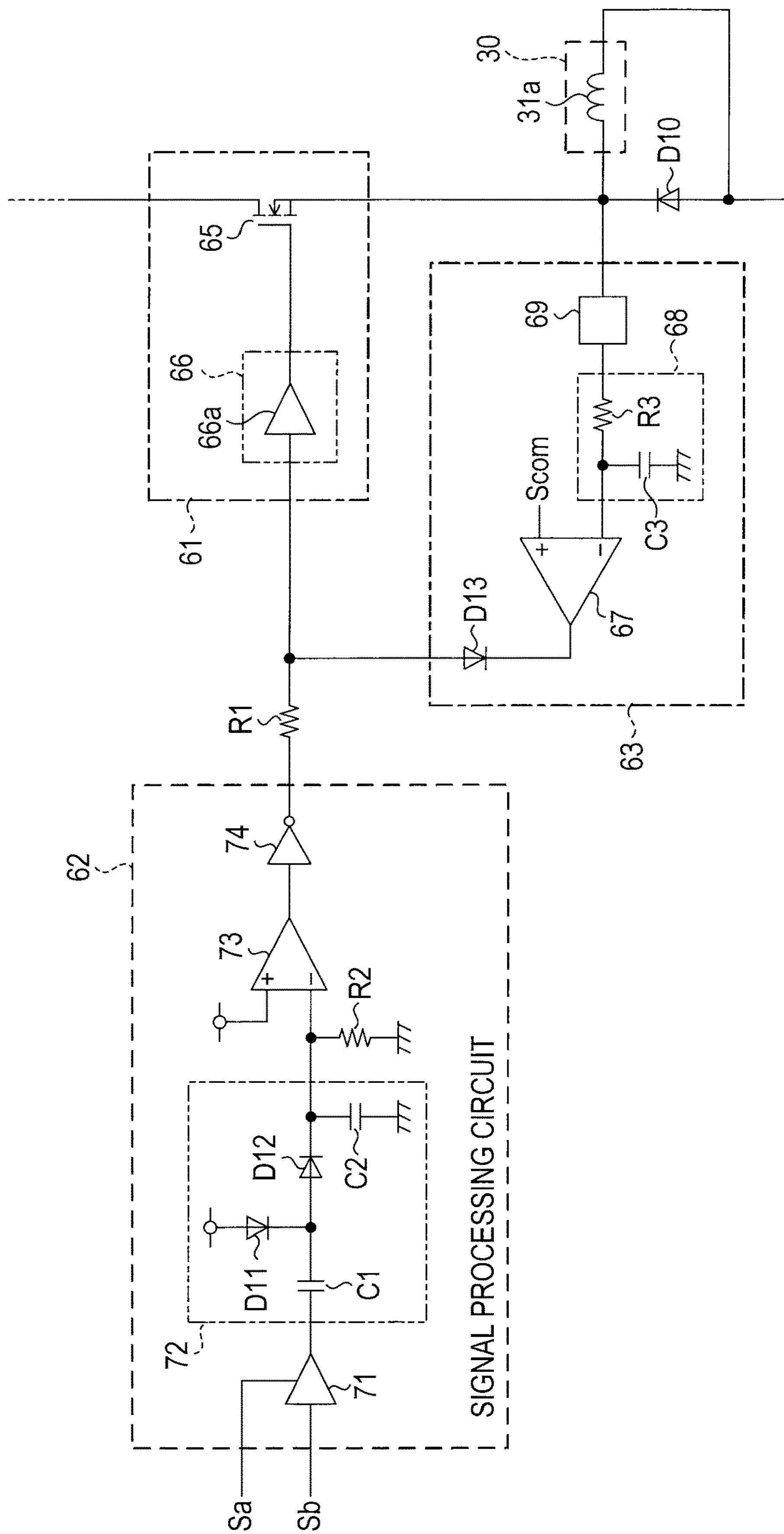
30
31a
D10
65
69
68
66
66a
R3
Scom
61
C3
D13
67
R1
63
62
74
73
R2
D12
C2
D11
C1
72
71
SIGNAL PROCESSING CIRCUIT
Sa
Sb

FIG. 5

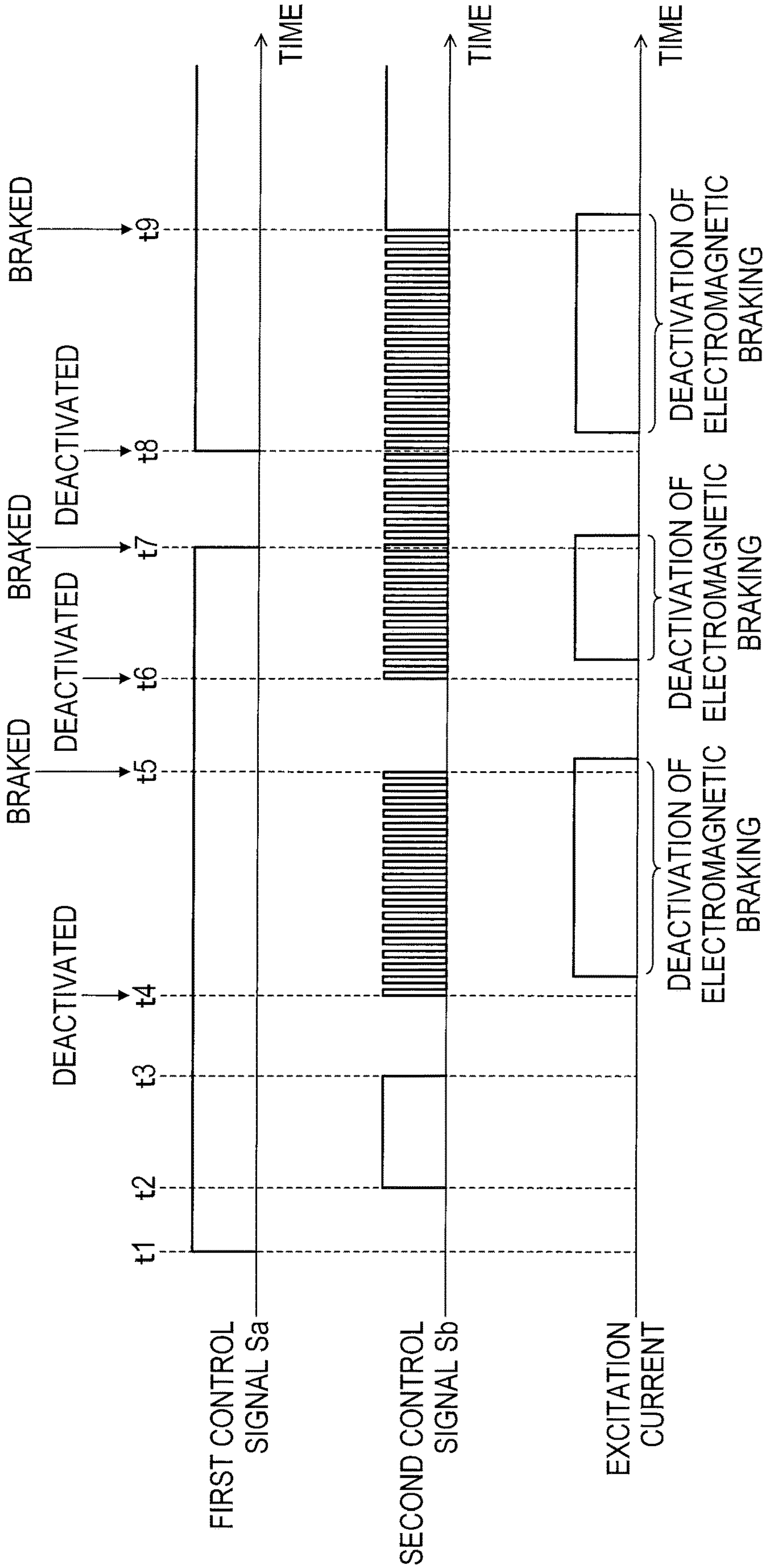
FIRST CONTROL SIGNAL Sa
SECOND CONTROL SIGNAL Sb
EXCITATION CURRENT
TIME
TIME
TIME
t1
t2
t3
t4
t5
t6
t7
t8
t9
DEACTIVATED
BRAKED
DEACTIVATED
BRAKED
DEACTIVATED
BRAKED
DEACTIVATION OF ELECTROMAGNETIC BRAKING
DEACTIVATION OF ELECTROMAGNETIC BRAKING
DEACTIVATION OF ELECTROMAGNETIC BRAKING

FIG. 6

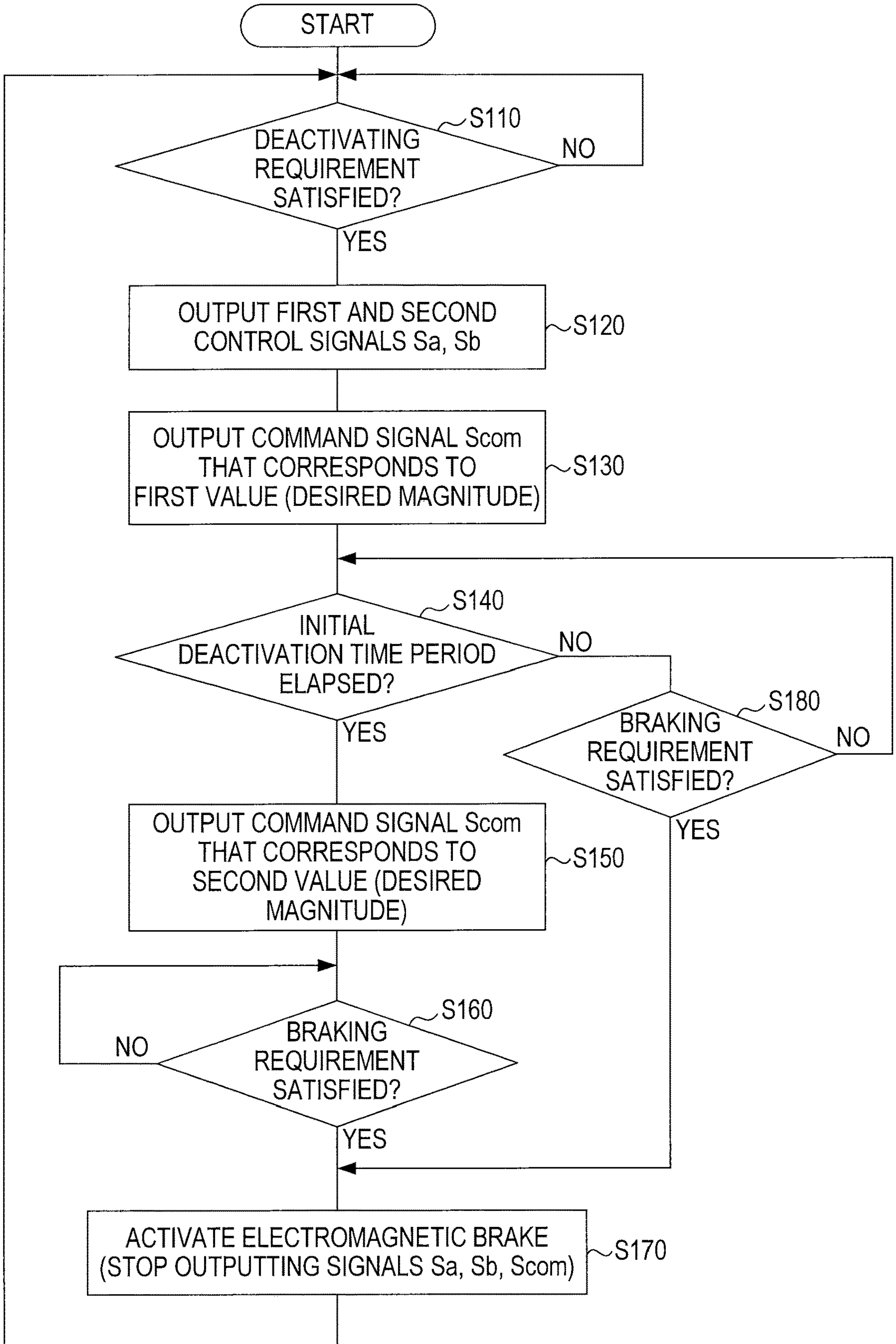
START
DEACTIVATING REQUIREMENT SATISFIED?
S110
NO
YES
OUTPUT FIRST AND SECOND CONTROL SIGNALS Sa, Sb
S120
OUTPUT COMMAND SIGNAL Scom THAT CORRESPONDS TO FIRST VALUE (DESIRED MAGNITUDE)
S130
INITIAL DEACTIVATION TIME PERIOD ELAPSED?
S140
NO
YES
BRAKING REQUIREMENT SATISFIED?
S180
NO
YES
OUTPUT COMMAND SIGNAL Scom THAT CORRESPONDS TO SECOND VALUE (DESIRED MAGNITUDE)
S150
BRAKING REQUIREMENT SATISFIED?
S160
NO
YES
ACTIVATE ELECTROMAGNETIC BRAKE (STOP OUTPUTTING SIGNALS Sa, Sb, Scom)
S170

FIG. 7

ELECTRIC-POWERED WHEELBARROW

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of Japanese Patent Application No. 2021-148767 filed on Sep. 13, 2021 with the Japan Patent Office, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

The present disclosure relates to an electric-powered wheelbarrow.

Japanese Patent Publication No. 6865512 discloses a wheel hand truck including an electromagnetic brake. The electromagnetic brake (i) brakes wheels during the electromagnetic brake receiving an electric power and (ii) deactivates braking during the electromagnetic brake not receiving the electric power.

SUMMARY

There may be a case where the wheel hand truck utilizes an electromagnetic power-off brake in place of the aforementioned electromagnetic brake. The electromagnetic power-off brake (i) brakes a wheel during an electric power being not supplied thereto and (ii) deactivates braking during the electric power being supplied thereto.

When there is an improper control on a supply of the electric power to the electromagnetic power-off brake, the electromagnetic power-off brake may be unintentionally deactivated.

It is desirable that one aspect of the present disclosure can properly control an electromagnetic power-off brake of an electric-powered wheelbarrow.

One aspect of the present disclosure provides an electric-powered wheelbarrow (or an electric-powered dolly). The electric-powered wheelbarrow includes a motor. The electric-powered wheelbarrow includes a motor driver. The motor driver delivers an electric power to the motor to thereby rotate the motor. The electric-powered wheelbarrow includes a wheel. The wheel is driven by the motor. The electric-powered wheelbarrow may include a grip. The grip may be gripped by a user of the electric-powered wheelbarrow who stands on a surface of a travel path for the electric-powered wheelbarrow.

The electric-powered wheelbarrow includes an electromagnetic brake. The electromagnetic brake includes an electromagnetic coil. The electromagnetic coil receives an excitation current to thereby be energized. The electromagnetic brake is in the form of an electromagnetic power-off brake. That is, the electromagnetic brake is activated to apply a braking force to the wheel in response to the electromagnetic coil being de-energized (or degaussed). The electromagnetic brake is deactivated to release the braking force from the wheel in response to the electromagnetic coil being energized (or excited).

The electric-powered wheelbarrow includes a control circuit. The control circuit outputs a first control signal and a second control signal. The control circuit may output the first and second control signals in response to a deactivating requirement being satisfied or having been satisfied. The deactivating requirement is required to deactivate the electromagnetic brake.

The electric-powered wheelbarrow includes a signal-processing circuit. The signal-processing circuit (i) receives the first and second control signals and (ii) to thereby output a deactivating signal.

The electric-powered wheelbarrow includes a drive circuit. The drive circuit receives the deactivating signal to thereby deliver (or supply) the excitation current (or an exciting current or an energizing current) to the electromagnetic coil.

In the electric-powered wheelbarrow described above, the electromagnetic brake is not deactivated even when a certain malfunction (for example, a faulty state of the control circuit) causes output of the first or second control signal despite a situation to activate the electromagnetic brake. In other words, the electromagnetic brake is not deactivated when only one of the first or second control signal is output. Accordingly, such an electric-powered wheelbarrow enables proper control of the electromagnetic brake. More specifically, it is possible to inhibit or reduce unintentional deactivation of the electromagnetic brake.

Another aspect of the present disclosure provides a method of controlling an electromagnetic brake of an electric-powered wheelbarrow. The method includes receiving a first control signal and a second control signal. Each of the first and second control signals permits deactivation of the electromagnetic brake. The method includes deactivating the electromagnetic brake in response to receipt of the first and second control signals.

This method can exhibit the same effect as the effect of the above-described electric-powered wheelbarrow.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the present disclosure will be described hereinafter by way of example with reference to the accompanying drawings, in which:

FIG. **1** is a perspective view of an electric-powered wheelbarrow according to an embodiment;

FIG. **2** is a bottom view of the electric-powered wheelbarrow without a platform;

FIG. **3** is a cross-sectional view along a line in FIG. **2**;

FIG. **4** is a block diagram showing a configuration of an electric system of the electric-powered wheelbarrow;

FIG. **5** is an electric circuit diagram showing a detailed configuration of a signal-processing circuit and a drive circuit;

FIG. **6** is a time chart showing an operation example of an electromagnetic brake; and

FIG. **7** is a flow chart of an electromagnetic braking process.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Overview of Embodiments

There is provided an electric-powered wheelbarrow according to an embodiment. The electric-powered wheelbarrow may include a motor. The electric-powered wheelbarrow may include a motor driver. The motor driver may deliver an electric power to the motor to thereby rotate the motor. Additionally/alternatively, the electric-powered wheelbarrow may include a wheel configured to be driven by the motor. Additionally/alternatively, the electric-powered wheelbarrow may include a grip. The grip may be gripped by a user of the electric-powered wheelbarrow. The grip may be gripped by the user who stands on a surface of a travel path for the electric-powered wheelbarrow.

Additionally/alternatively, the electric-powered wheelbarrow may include an electromagnetic brake. The electromagnetic brake may include an electromagnetic coil. The electromagnetic coil may receive an excitation current to thereby be energized. The electromagnetic brake is configured to apply a braking force to the wheel (or to brake the wheel, or to brake the electric-powered wheelbarrow). The electromagnetic brake may be activated in response to the electromagnetic coil being de-energized (or degaussed). That is, the electromagnetic brake may apply the braking force to the wheel in response to the electromagnetic coil being de-energized. The electromagnetic coil may be de-energized by interruption of a path of the excitation current thereto. The electromagnetic brake may be deactivated in response to the electromagnetic coil being energized. That is, in response to the electromagnetic coil being energized, the electromagnetic brake may release the braking force from the wheel (or deactivate braking of the wheel, or deactivate braking of the electric-powered wheelbarrow). The electromagnetic coil may be energized with supply (or delivery) of the excitation current thereto.

The electromagnetic brake may directly or indirectly apply the braking force to the wheel. For example, the electromagnetic brake may directly apply the braking force to the motor, to thereby indirectly (that is, resultantly) brake the wheel. Furthermore, the wheel may be indirectly applied with the braking force by, for example, the electromagnetic brake directly applying the braking force to a transmission path to transmit a rotational force of the motor to the wheel.

Additionally/alternatively, the electric-powered wheelbarrow may include a control circuit (or a brake control circuit). The control circuit may output a first control signal and a second control signal. The control circuit may output the first and second control signals in response to a deactivating requirement being satisfied or having been satisfied. The deactivating requirement may correspond to (or be related to) a requirement to deactivate the electromagnetic brake (that is, deactivate braking by the electromagnetic brake). That is, the deactivating requirement may be required to deactivate the electromagnetic brake.

Additionally/alternatively, the electric-powered wheelbarrow may include a signal-processing circuit. The signal-processing circuit may output a deactivating signal in response to receiving both the first and second control signals.

Additionally/alternatively, the electric-powered wheelbarrow may include a drive circuit. The drive circuit may deliver (or supply) the excitation current to the electromagnetic coil in response to receiving the deactivating signal.

In a case where an electric-powered wheelbarrow according to an embodiment includes the motor, the motor driver, the wheel, the grip, the electromagnetic brake, the control circuit, the signal-processing circuit, and the drive circuit, which are mentioned above, such an electric-powered wheelbarrow can properly control the electromagnetic brake. More specifically, it is possible to inhibit or reduce unintentional deactivation of the electromagnetic brake.

Additionally/alternatively, the first and second control signals may have forms different from each other. Specifically, the first control signal may have a fixed voltage greater than zero. A state where the first control signal has the fixed voltage may correspond to the first control signal being in a first proper state. Alternatively, a state where the first control signal has the fixed voltage of a specific value or more may correspond to the first control signal being in the first proper state. That the first control signal has the fixed voltage may mean that (i) the first control signal has a direct current (DC) voltage and (ii) the DC voltage has the fixed voltage. In this case, the DC voltage may have only the fixed voltage. Alternatively, the DC voltage may include multiple voltage components and one of the multiple voltage components may be the fixed voltage. The second control signal may have two or more pulse voltages. The two or more pulse voltages may be periodically or non-periodically output. A state where the second control signal has the two or more pulse voltages may correspond to the second control signal being in a second proper state.

The signal-processing circuit may output the deactivating signal in response to (i) the first control signal received being in a first proper state and (ii) the second control signal received being in a second proper state. In a case where an electric-powered wheelbarrow according to an embodiment includes the signal-processing circuit with the aforementioned features, the electromagnetic brake is deactivated when both the first and second control signals are properly output. Thus, it is possible to improve reliability of the electromagnetic brake.

Additionally/alternatively, the signal-processing circuit may include a first circuit. The first circuit may enable the second control signal in response to the first control signal received being in the first proper state. Additionally/alternatively, the signal-processing circuit may include a second circuit. The second circuit may detect the second control signal enabled. The second circuit may detect the second control signal (i) having been enabled by the first circuit and (ii) being in the second proper state. That is, the second circuit may not detect the second control signal (i) having been enabled by the first circuit and (ii) not being in the second proper state. Additionally/alternatively, the signal-processing circuit may include a third circuit. The third circuit may output the deactivating signal during the second circuit detecting the second control signal enabled. In a case where an electric-powered wheelbarrow according to an embodiment includes the signal-processing circuit with the aforementioned features, such an electric-powered wheelbarrow can output a deactivating signal with high reliability. Accordingly, it is possible to improve reliability of the electromagnetic brake.

Additionally/alternatively, the drive circuit may (i) receive the excitation current from the first battery and (ii) deliver the excitation current to the electromagnetic coil.

Additionally/alternatively, the motor driver may receive, from a first battery or a second battery, the electric power to be delivered to the motor. Additionally/alternatively, the drive circuit may receive, from a first battery or a second battery, the excitation current to be delivered to the electromagnetic coil. In a case where an electric-powered wheelbarrow according to an embodiment includes the motor driver and the drive circuit with the aforementioned feature, such an electric-powered wheelbarrow can provide the user with various ways to use the first and second batteries. For example, the user may mount both the first and second batteries on the electric-powered wheelbarrow. In this case, the user can make the electric-powered wheelbarrow keep travelling for a long time. Alternatively, the user may mount only one of the first or second battery on the electric-powered wheelbarrow, to thereby make the electric-powered wheelbarrow travel.

Additionally/alternatively, the first battery may include a first positive electrode, and the second battery may include a second positive electrode. Additionally/alternatively, the electric-powered wheelbarrow may include a selector circuit. The selector circuit may be connected to the first and second positive electrodes. The selector circuit may (i) receive a first current from the first battery and a second current from the second battery and (ii) output the excitation current including the first or second current. In other words, the selector circuit may output the first or second current as the excitation current. Additionally/alternatively, the drive circuit may receive the excitation current from the selector circuit and deliver, to the electromagnetic coil, the excitation current received.

Additionally/alternatively, the selector circuit may include a first rectifier circuit. The first rectifier circuit may include a first input terminal to receive the first current from the first battery. The first rectifier circuit may include a first output terminal to output the first current received from the first input terminal. The first rectifier circuit may inhibit the second current from flowing from the first output terminal to the first input terminal. Additionally/alternatively, the selector circuit may include a second rectifier circuit. The second rectifier circuit may include a second input terminal to receive the second current from the second battery. The second rectifier circuit may include a second output terminal connected to the first output terminal. The second output terminal may output the second current received from the second input terminal. The second rectifier circuit may inhibit the first current from flowing from the second output terminal to the second input terminal. In a case where an electric-powered wheelbarrow according to an embodiment includes the selector circuit and the drive circuit with the aforementioned features, such an electric-powered wheelbarrow can easily deliver, to the electromagnetic coil, the electric power of the first battery or the electric power of the second battery.

Additionally/alternatively, the electric-powered wheelbarrow may include a voltage adjustment circuit (or a voltage control circuit). The voltage adjustment circuit may adjust (or control) an excitation voltage to be applied to the electromagnetic coil. In a case where an electric-powered wheelbarrow according to an embodiment includes the voltage adjustment circuit with the aforementioned features, such an electric-powered wheelbarrow can control the electromagnetic brake efficiently.

Additionally/alternatively, the control circuit may output a voltage command signal to the voltage adjustment circuit. The voltage command signal designates (or commands) a desired magnitude (or a target value or a desired value) of the excitation voltage. Additionally/alternatively, the voltage adjustment circuit may receive the voltage command signal. The voltage adjustment circuit may adjust the excitation voltage so as to maintain an actual magnitude of the excitation voltage at the desired magnitude designated by the voltage command signal received. In a case where an electric-powered wheelbarrow according to an embodiment includes the control circuit and the voltage adjustment circuit with the aforementioned features, such an electric-powered wheelbarrow can control the electromagnetic brake more efficiently.

Additionally/alternatively, the control circuit may keep outputting, for a specific length of time, the voltage command signal designating a first value as the desired magnitude in response to a deactivating requirement being satisfied. The deactivating requirement is required to deactivate the electromagnetic brake.

Additionally/alternatively, the control circuit may, in response to having output, for the specific length of time, the voltage command signal to designate the first value, output the voltage command signal designating a second value as the desired magnitude. The second value is smaller than the first value. In a case where an electric-powered wheelbarrow according to an embodiment includes the control circuit with the aforementioned features, such an electric-powered wheelbarrow can maintain deactivation of the electromagnetic brake while reducing a power consumption of the electromagnetic brake.

Additionally/alternatively, the electric-powered wheelbarrow may further include a voltage detection circuit. The voltage detection circuit may (i) receive the excitation voltage applied to the electromagnetic coil and (ii) generate an actual voltage signal. The actual voltage signal indicates a mean value of the excitation voltage received. Additionally/alternatively, the voltage adjustment circuit may adjust the excitation voltage so as to maintain the mean value indicated by the actual voltage signal at the desired magnitude (for example, the first or second value).

Additionally/alternatively, the voltage adjustment circuit may, during the drive circuit receiving the deactivating signal, operate the drive circuit so as to deliver the excitation current to the electromagnetic coil in response to the mean value indicated by the actual voltage signal being smaller than the desired magnitude indicated by the voltage command signal. The voltage adjustment circuit may, during the drive circuit receiving the deactivating signal, operate the drive circuit so as to stop the excitation current in response to the mean value indicated by the actual voltage signal being equal to or greater than the desired magnitude indicated by the voltage command signal.

There is provided a method of controlling an electromagnetic brake according to an embodiment. The method may be employed in an electric-powered wheelbarrow. The method may include receiving a first control signal and a second control signal. Each of the first and second control signals permits deactivation of the electromagnetic brake. Additionally/alternatively, the method may include, in response to receipt of the first and second control signals, deactivating the electromagnetic brake.

In a case where a method of controlling an electromagnetic brake according to an embodiment includes all the processes mentioned above, such a method enables proper control of the electromagnetic brake.

In one embodiment, the features above may be combined in any manner. In one embodiment, at least one of the features above may be omitted (or eliminated).

2. Specific Exemplary Embodiment

(1) Overview of Electric-Powered Wheelbarrow

As shown in FIGS. **1** and **2**, there is provided an electric-powered wheelbarrow **1** in the present embodiment. The electric-powered wheelbarrow **1** includes a main body **2** and two or more wheels. The two or more wheels include one or more front wheels and one or more rear wheels. In the present embodiment, the one or more front wheels include, for example, two front wheels **8**, **9**, and the one or more rear wheels are, for example, two rear wheels **10**, **11**. In other words, the electric-powered wheelbarrow **1** in the present embodiment is in the form of a four-wheeled vehicle.

In the present embodiment, for example, each of the front wheels **8**, **9** corresponds to a drive wheel, and each of the rear wheels **10**, **11** corresponds to a driven wheel. The front wheels **8**, **9** are driven (that is, rotated) by a motor **25**, which will be described below (see, FIGS. **3** and **4**).

The main body **2** includes a platform **3** fixed thereto. The platform **3** is detachable from the main body **2**. The platform **3** can be loaded with various material. A user of the electric-powered wheelbarrow **1** operates the electric-powered wheelbarrow **1** with the material loaded on the platform **3** to carry the material. The user can selectively fix, to the main body **2**, any one of two or more types of the platform **3**.

As shown in FIGS. **2** and **3**, the electric-powered wheelbarrow **1** further includes a motor device **20**. As shown in FIG. **3**, the motor device **20** houses the motor **25**. As shown in FIGS. **3** and **4**, the electric-powered wheelbarrow **1** further includes an electromagnetic brake **30**. In the present embodiment, the electromagnetic brake **30** is housed in, for example, the motor device **20**.

As shown in FIG. **3**, the motor **25** includes a motor stator **26**, a motor rotor **27**, and a motor shaft **28**. The motor rotor **27** includes, for example, a permanent magnet. The motor shaft **28** is fixed to the motor rotor **27**. In accordance with rotation of the motor rotor **27**, the motor shaft **28** is rotated. In the present embodiment, the term "rotation" of the motor **25** specifically means that the motor shaft **28** rotates.

The motor **25** in the present embodiment is in the form of, for example, a three-phase brushless DC motor (or a brushless motor, or a three-phase brushless motor, or a brushless DC motor). As shown in FIG. **4**, the motor **25** includes a first terminal **25***u*, a second terminal **25***v*, and a third terminal **25***w*. The motor stator **26** includes, for example, three windings (not shown). Each of the three windings is connected to one or two of the first through third terminals **25***u* through **25***w*. The three windings may be connected to one another in any manner. The three windings may be connected to one another, for example, in a delta connection, or in a star (or wye) connection. An electric power is delivered, via the first through third terminals **25***u* through **25***w*, to the three windings, and thereby the motor rotor **27** (and thus the motor shaft **28**) rotates.

As shown in FIGS. **1** and **2**, the electric-powered wheelbarrow **1** further includes a transmission mechanism **21**. The transmission mechanism **21** is mechanically coupled to the motor **25** and the drive wheels (that is, the front wheels **8**, **9**). The transmission mechanism **21** transmits a rotational force of the motor **25** (that is, a rotational force of the motor shaft **28**) to the drive wheels. More specifically, the transmission mechanism **21** transmits the rotational force of the motor **25** to the front wheel **8** via a right drive shaft **22**, and also to the front wheel **9** via a left drive shaft **23**. The transmission mechanism **21** may include, for example, a differential gear.

As shown in FIG. **2**, the electric-powered wheelbarrow **1** further includes a mechanical brake **24**. The mechanical brake **24** brakes the front wheels **8**, **9** (that is, controls rotation of the front wheels **8**, **9**) with a friction force. In the present embodiment, the mechanical brake **24** includes, for example, a right disc brake **24***a* and a left disc brake **24***b*. The right disc brake **24***a* brakes the front wheel **8**. That is, the right disc brake **24***a* includes two brake pads and a brake disc that rotates integrally with the front wheel **8**. The left disc brake **24***b* includes two brake pads and a brake disc that rotates integrally with the front wheel **9**. In response to being manually operated by the user, the mechanical brake **24** is activated. When the mechanical brake **24** is activated, each brake disc is pressed (or squeezed) by its corresponding two brake pads, and thereby the front wheels **8**, **9** are braked.

As shown in FIG. **1**, the main body **2** includes a right handle bar **12** and a left handle bar **13**. Each of the right handle bar **12** and the left handle bar **13** has a bar-shape with, for example, a curve like an L-shape. As shown in FIGS. **1** and **2**, the right handle bar **12** is provided with a right grip **12***a* at its first end. The left handle bar **13** is provided with a left grip **13***a* at its first end. For example, the right grip **12***a* is gripped by the right hand of the user, and the left grip **13***a* is gripped by the left hand of the user.

As shown in FIG. **2**, the main body **2** includes a brake lever **13***b*. The brake lever **13***b* is provided, for example, on the left handle bar **13** near the left grip **13***a*. For example, the user can manually move (or manually operate) (for example, pull) the brake lever **13***b* with the left hand while gripping the left grip **13***a* with the left hand. The brake lever **13***b* is manually moved to activate the mechanical brake **24**, thereby applying a braking force of the mechanical brake **24** to the front wheels **8**, **9**. The braking force of the mechanical brake **24** has a magnitude that varies depending on a position (or a pulled distance) of the brake lever **13***b*.

The electromagnetic brake **30** in the present embodiment applies the braking force to the drive wheels (or brakes the drive wheels or brakes the electric-powered wheelbarrow **1**). More specifically, the electromagnetic brake **30** in the present embodiment directly applies the braking force to the motor **25**, to thereby indirectly apply the braking force to the drive wheel. The electromagnetic brake **30** in the present embodiment is in the form of an electromagnetic power-off brake. As shown in FIG. **3**, the electromagnetic brake **30** includes, for example, a brake stator **31**, a brake plate **32**, an armature **33**, and a brake rotor **34**. The brake stator **31** includes an electromagnetic coil **31***a* therein. The brake stator **31** and the brake plate **32** are fixed inside the motor device **20**.

The brake rotor **34** is fixed to the motor shaft **28**. As the motor shaft **28** rotates, the brake rotor **34** also rotates. The armature **33** is elastically supported to be movable along a direction perpendicular to a rotational surface of the brake rotor **34** (that is, a direction parallel to an axial direction of the motor shaft **28**). The armature **33** is subjected to an elastic force in a direction toward the brake plate **32**.

When the electric power (that is, an excitation current) is not delivered (or supplied) to the electromagnetic coil **31***a*, the electromagnetic coil **31***a* is de-energized (or degaussed). During the electromagnetic coil **31***a* being de-energized, the electromagnetic brake **30** is turned ON (that is, activated). That is, the electromagnetic brake **30** brakes the motor **25** (specifically, the rotation of the motor shaft **28**), to thereby brake the drive wheels. Specifically, when the excitation current is not delivered to the electromagnetic coil **31***a*, the armature **33** moves toward the brake plate **32** due to the elastic force described above. This causes the brake rotor **34** to be squeezed by the armature **33** and the brake plate **32**, thereby braking rotation of the brake rotor **34**. When the brake rotor **34** is braked, the motor **25** and thus the drive wheels are braked.

On the other hand, when receiving the excitation current, the electromagnetic coil **31***a* is energized (or activated) and acts as an electromagnet. This turns OFF (that is, deactivates or releases) the electromagnetic brake **30**, that is, deactivates braking of the motor **25** (and thus the drive wheels) by the electromagnetic brake **30**. Specifically, when the excitation current is delivered to the electromagnetic coil **31***a*, the armature **33** moves away from the brake plate **32** and the brake rotor **34** due to a magnetic force of the electromagnetic coil **31***a*. Consequently, the brake rotor **34** does not contact the armature **33** and the brake plate **32**, resulting in the electromagnetic brake **30** not applying the braking force to the motor shaft **28**. Accordingly, the braking force on the drive wheels (specifically, an indirect braking force) is deactivated.

The electric-powered wheelbarrow **1** in the present embodiment may be braked by the above-described mechanical brake **24** and/or the electromagnetic brake **30**.

The electric-powered wheelbarrow **1** in the present embodiment may be further braked by dynamic braking. The dynamic braking in the present embodiment includes, for example, three-phase dynamic braking and/or two-phase dynamic braking. The three-phase dynamic braking corresponds to short-circuiting the first through third terminals **25***u* through **25***w* of the motor **25** to one another. The two-phase dynamic braking corresponds to short-circuiting any two terminals of the first through third terminals **25***u* through **25***w* to one another.

As shown in FIG. **1**, the main body **2** includes a manipulation switch **14**. The manipulation switch **14** is provided, for example, on the right handle bar **12** near the right grip **12***a*. The manipulation switch **14** in the present embodiment is in the form of, for example, a lever. For example, the user can manually operate (for example, pull) the manipulation switch **14** with the right hand while gripping the right grip **12***a* with the right hand.

As shown in FIGS. **1** and **2**, the main body **2** includes a battery box **15**. The battery box **15** is arranged, for example, between the right handle bar **12** and the left handle bar **13**. Two or more battery packs are detachably attached to the battery box **15**. For example, a first battery pack **41** and a second battery pack **42** (see, FIG. **4**) are individually attached to the battery box **15** in the present embodiment.

The user can use the electric-powered wheelbarrow **1** while standing on a ground. Specifically, the user can move or stop the electric-powered wheelbarrow **1** on the ground while gripping the right grip **12***a* and/or the left grip **13***a*. The user can manually operate the manipulation switch **14** while gripping the right grip **12***a* and/or the left grip **13***a*. Upon the manipulation switch **14** being manually operated, the motor **25** is driven, to thereby drive the front wheels **8**, **9**. Upon the front wheels **8**, **9** being driven, the electric-powered wheelbarrow **1** travels. While gripping the right grip **12***a* and/or the left grip **13***a*, the user can walk or run as the electric-powered wheelbarrow **1** travels. Accordingly, the user can easily use the electric-powered wheelbarrow **1** while having a less physical burden. The user may push or pull the electric-powered wheelbarrow **1** by himself/herself, thereby allowing the electric-powered wheelbarrow **1** to travel.

(2) Electrical Configuration of Electric-Powered Wheelbarrow

As shown in FIG. **4**, the electric-powered wheelbarrow **1** includes a first controller **50**. The first controller **50** controls the motor **25** and the electromagnetic brake **30**. The electric-powered wheelbarrow **1** further includes a second controller **60**. The second controller **60** drives the electromagnetic brake **30**. The second controller **60** in the present embodiment drives the electromagnetic brake **30** based on various signals from the first controller **50**. The various signals include a first control signal Sa, a second control signal Sb, and a command signal Scorn, which will be described later.

The first controller **50** includes a control circuit **51**. The first and second control signals Sa, Sb and the command signal Scorn are output from the control circuit **51**. The control circuit **51** in the present embodiment is in the form of, for example, a microcomputer including a central processing unit (CPU) **51***a* and a memory **51***b*. The memory **51***b* may include, for example, a semiconductor memory such as a Read-Only Memory (ROM), a Random-Access Memory (RAM), a Nonvolatile RAM (NVRAM), or a flash memory.

The control circuit **51** achieves various functions by executing a program stored in a non-transitory tangible storage medium. In the present embodiment, the memory **51***b* corresponds to the non-transitory tangible storage medium storing the program. The memory **51***b* stores a program for an electromagnetic braking process (see, FIG. **7**), which will be described below.

Some or all of the various functions implemented by the control circuit **51** may be achieved by executing a program (that is, by software processing), or may be achieved by one or some hardware. For example, the control circuit **51** may include a logic circuit including two or more electronic components, in place of or in addition to the microcomputer. The control circuit **51** may include an integrated circuit (IC) for a particular use, such as an Application Specific Integrated Circuit (ASIC) and/or an Application Specific Standard Product (ASSP), or include a programmable logic device that can be programmed to create a logic circuit, for example, a Field Programmable Gate Array (FPGA).

The control circuit **51** directly or indirectly receives an operation signal from the manipulation switch **14**. The operation signal indicates whether the manipulation switch **14** is turned ON. When the user manually operates the manipulation switch **14**, the manipulation switch **14** is turned ON. The control circuit **51** can identify whether the manipulation switch **14** is turned ON based on the operation signal. The manipulation switch **14** may be turned ON during the manipulation switch **14** being manually operated, and may be turned OFF upon manual operation of the manual switch **14** being deactivated. The control circuit **51** drives the motor **25** during the manipulation switch **14** being turned ON.

The control circuit **51** outputs the first and second control signals Sa, Sb and the command signal Scom in response to a deactivating requirement being satisfied or having been satisfied. The deactivating requirement corresponds to a requirement to deactivate the electromagnetic brake **30** (that is, deactivate the braking by (or the braking force of) the electromagnetic brake **30**). That is, the deactivating requirement is required to deactivate the electromagnetic brake **30**. When the control circuit **51** outputs the first and second control signals Sa, Sb, the electromagnetic brake **30** is turned OFF, and thereby the electromagnetic brake **30** is deactivated. When a braking requirement is satisfied after the deactivating requirement is satisfied, the control circuit **51** stops the first and second control signals Sa, Sb and the command signal Scom. As a result, the electromagnetic brake **30** is turned ON and the motor **25** is braked. The braking requirement corresponds to a requirement to activate the electromagnetic brake **30**. That is, the braking requirement is required to activate the electromagnetic brake **30**.

The deactivating requirement may be determined in any manner. For example, the deactivating requirement may be satisfied with the manipulation switch **14** having been manually operated. During the manipulation switch **14** being manually operated, the deactivating requirement may continue to be satisfied. The braking requirement may be determined in any manner. For example, the braking requirement may be satisfied with the manual operation of the manipulation switch **14** having been deactivated.

FIG. **4** shows an example state where both the first and second battery packs **41**, **42**, which are described above, are attached to the battery box **15**. The first battery pack **41** includes a first battery **41***a*. The second battery pack **42** includes a second battery **42***a*. Each of the first and second batteries **41***a*, **42***a* functions as a power source for the electric-powered wheelbarrow **1**. The motor **25** rotates with an electric power from the first or second battery **41***a*, **42***a*. The first battery **41***a* and/or the second battery **42***a* may be, for example, a rechargeable battery.

The first battery **41***a* has a first battery voltage Vb**1**. The second battery **42***a* has a second battery voltage Vb**2**. A rated value (hereinafter, referred to as "first rated value") of the first battery voltage Vb**1** and a rated value (hereinafter, referred to as "second rated value") of the second battery voltage Vb**2** may be any values. In the present embodiment, the first and second rated values are equal (or approximately equal) to each other. In the present embodiment, the first and second rated values are, for example, 36V.

The first and second batteries **41***a*, **42***a* may be configured in any manner. In the present embodiment, the first battery **41***a* includes two batteries connected to each other in series. A rated voltage of each of the two batteries may be any value. In the present embodiment, the rated voltage of each of the two batteries is one-half of the first rated value (for example, 18V). The second battery **42***a* in the present embodiment is configured in the same manner as the first battery **41***a*.

Each of the first and second battery packs **41**, **42** is attachable to various electric apparatuses different from the electric-powered wheelbarrow **1**. That is, each of the first and second battery packs **41**, **42** can function as a power source for the various electric apparatuses. Examples of the various electric apparatuses include various job-site electric apparatuses used at job-sites, such as home carpentry, manufacturing, gardening, construction. Examples of the various job-site electric apparatuses include an electric drill, an electric screwdriver, an electric grinder, an electric circular saw, an electric bush/grass cutter, an electric cleaner, an electric blower, and an electric dust collector.

The electric-powered wheelbarrow **1** includes a first power-supply line **43**, a second power-supply line **44**, and a ground line **45**. When the first battery pack **41** is attached to the battery box **15**, a first end of the first power-supply line **43** is electrically connected to a positive electrode of the first battery **41***a*. Furthermore, a negative electrode of the first battery **41***a* is electrically connected to the ground line **45**. When the second battery pack **42** is attached to the battery box **15**, a first end of the second power-supply line **44** is electrically connected to a positive electrode of the second battery **42***a*. Furthermore, a negative electrode of the second battery **42***a* is electrically connected to the ground line **45**. Each of the first and second power-supply lines **43**, **44** includes a second end connected to the second controller **60**.

The electric-powered wheelbarrow **1** includes a battery selector switch **70**. In the present embodiment, the battery selector switch **70** is disposed, for example, on the battery box **15**. The battery selector switch **70** includes a first terminal connected to the first power-supply line **43**. The battery selector switch **70** includes a second terminal connected to the second power-supply line **44**. The battery selector switch **70** includes a common terminal connected to the first controller **50**.

In response to being manually operated by the user, the battery selector switch **70** sets one of the first or second battery pack **41**, **42** as a power source for the motor **25**. That is, the electric power of either one of the first or second battery **41***a*, **42***a* selected is delivered to the first controller **50**. Hereinafter, the electric power to be input to the first controller **50** via the battery selector switch **70** is referred to as "motor drive electric power".

The first controller **50** includes a first gate circuit **53** and a motor driver **52**. The control circuit **51** outputs two or more motor control signals to the first gate circuit **53**. The two or more motor control signals are used for controlling rotation of the motor **25**. The two or more motor control signals in the present embodiment include, for example, a pulse-width modulation signal (PWM signal). The first gate circuit **53** generates two or more drive signals corresponding to (or related to, or associated with) the respective two or more motor control signals. The first gate circuit **53** outputs, to the motor driver **52**, the two or more drive signals generated.

The motor driver **52** receives the motor drive electric power. The motor driver **52** is connected to the first through third terminals **25***u* through **25***w* of the motor **25**. The motor driver **52** includes, for example, a three-phase full-bridge circuit (not shown). Based on the two or more drive signals generated, the motor driver **52** converts the motor drive electric power into a three-phase drive power. The motor driver **52** delivers the three-phase drive power to the motor **25**. The motor **25** rotates with the three-phase drive power.

The first controller **50** includes a first regulator **54**. The first regulator **54** receives the first battery voltage Vb**1** through diodes D**1**, D**2**. Furthermore, the first regulator **54** receives the second battery voltage Vb**2** through diodes D**3**, D**4**.

The first regulator **54** generates a first control voltage Vc**1** based on the first or second battery voltage Vb**1**, Vb**2**. The first control voltage Vc**1** is delivered to the control circuit **51** and nearby circuit(s). The control circuit **51** is activated with the first control voltage Vc**1**.

The second controller **60** receives the first battery voltage Vb**1** through the first power-supply line **43**. Furthermore, the second controller **60** receives the second battery voltage Vb**2** through the second power-supply line **44**. The second controller **60** is connected to the electromagnetic brake **30**. More specifically, the second controller **60** is connected to the electromagnetic coil **31***a*.

The second controller **60** includes a selector circuit **85**. The selector circuit **85** includes a first rectifier circuit **81** and a second rectifier circuit **82**. The first rectifier circuit **81** includes a first input terminal **81***a* and a first output terminal **81***b*. The second rectifier circuit **82** includes a second input terminal **82***a* and a second output terminal **82***b*. The first input terminal **81***a* is connected to the second end of the first power-supply line **43**. The second input terminal **82***a* is connected to the second end of the second power-supply line **44**. The first output terminal **81***b* is connected to the second output terminal **82***b*.

The second controller **60** includes a drive circuit **61**. The drive circuit **61** includes a switch **65** and a second gate circuit **66**. The switch **65** in the present embodiment includes, for example, an N-channel metal oxide semiconductor field-effect transistor (MOSFET). The switch **65** includes a gate connected to the second gate circuit **66**.

The switch **65** includes a drain connected to the first and second output terminals **81***b*, **82***b*. More specifically, the second controller **60** includes a fuse **80**. The first and second output terminals **81***b*, **82***b* are connected to the drain of the switch **65** via the fuse **80**.

Each of the first and second rectifier circuits **81**, **82** includes one or more rectifiers (or rectifier elements). In the present embodiment, each of the first and second rectifier circuits **81**, **82** includes, for example, two diodes connected to each other in series as illustrated in FIG. **4**. The first rectifier circuit **81** allows a current to flow from the first input terminal **81***a* through the first output terminal **81***b*, and prevents or inhibits the current from flowing from the first output terminal **81***b* through the first input terminal **81***a*. The second rectifier circuit **82** allows the current to flow from the second input terminal **82***a* through the second output terminal **82***b*, and prevents or inhibits the current from flowing from the second output terminal **82***b* through the second input terminal **82***a*.

The switch **65** includes a source connected to the electromagnetic brake **30**. More specifically, the source of the switch **65** is connected to a first end of the electromagnetic coil **31***a*. The electromagnetic coil **31***a* includes a second end connected to the ground line **45**. The second controller **60** further includes a diode D**10**. The diode D**10** includes an anode connected to the ground line **45**. The diode D**10** includes a cathode connected to the source of the switch **65**.

When the switch **65** is ON, the electric power of the first battery **41***a* or the electric power of the second battery **42***a* is delivered to the electromagnetic brake **30** via the switch **65**. This turns OFF the electromagnetic brake **30**, resulting in deactivation of the braking of the motor **25** by the electromagnetic brake **30**. When the switch **65** is OFF, neither the electric power of the first battery **41***a* nor the electric power of the second battery **42***a* is delivered to the electromagnetic brake **30**. In this case, the electromagnetic brake **30** is turned ON, to thereby brake the motor **25**.

The selector circuit **85** selectively outputs the first or second battery voltage Vb**1**, Vb**2** to the drive circuit **61**. For example, when the first battery voltage Vb**1** is higher than the second battery voltage Vb**2**, the first battery voltage Vb**1** is input to the drive circuit **61** via the first rectifier circuit **81**. In this case, upon the switch **65** being turned ON, the electric power of the first battery **41***a* is delivered to the electromagnetic coil **31***a*. That is, the electromagnetic coil **31***a* receives the excitation current from the first battery **41***a*.

On the other hand, when the second battery voltage Vb**2** is higher than the first battery voltage Vb**1**, the second battery voltage Vb**2** is input to the drive circuit **61** via the second rectifier circuit **82**. In this case, upon the switch **65** being turned ON, the electric power of the second battery **42***a* is delivered to the electromagnetic coil **31***a*. That is, the electromagnetic coil **31***a* receives the excitation current from the second battery **42***a*. Hereinafter, the first or second battery voltage Vb**1**, Vb**2** to be output to the drive circuit **61** is referred to as "brake voltage".

The second controller **60** includes a second regulator **64**. The second regulator **64** receives the brake voltage. The second regulator **64** generates a second control voltage Vc**2** based on the brake voltage. The second control voltage Vc**2** is delivered to the drive circuit **61**, a signal-processing circuit **62**, and a voltage adjustment circuit (or a voltage control circuit) **63**.

The second controller **60** includes the signal-processing circuit **62**. The signal-processing circuit **62** receives the first and second control signals Sa, Sb from the control circuit **51**. More specifically, the control circuit **51** in the present embodiment outputs the first and second control signals Sa, Sb in response to the deactivating requirement being satisfied or having been satisfied. The control circuit **51** outputs the first and second control signals Sa, Sb, to thereby deactivate the electromagnetic brake **30**. Upon the braking requirement being satisfied while the electromagnetic brake **30** is deactivated, the control circuit **51** stops the first and second control signals Sa, Sb.

The first control signal Sa has a direct-current (DC) voltage. The DC voltage has a voltage value that is fixed. The voltage value of the DC voltage is equal to or greater than a first specific voltage value. That is, the DC voltage in the present embodiment is a fixed voltage. The first control signal Sa functions as a power source for a first buffer **71**, which will be described later. When the first control signal Sa is properly output, the first buffer **71** properly operates. When the first control signal Sa is not output or not properly output, the first buffer **71** does not operate or does not properly operate. In this case, the switch **65** is turned OFF, resulting in the electromagnetic coil **31***a* being not energized. That is, the motor **25** is braked by the electromagnetic brake **30**. The first control signal Sa being not properly output may mean that the voltage value of the first control signal Sa is equal to or less than a specific minimum value. The specific minimum value may be lower than the first specific voltage value.

The second control signal Sb has two or more pulse voltages (for example, two or more square-wave voltages). The two or more pulse voltages may be generated periodically or non-periodically. The second control signal Sb in the present embodiment has two or more pulse voltages that are periodically generated at a fixed cycle.

When receiving both the first and second control signals Sa, Sb, the signal-processing circuit **62** outputs a deactivating signal. In a precise sense, the first and second control signals Sa, Sb are those that are proper (i.e., the proper first and second control signals Sa, Sb). The proper first control signal Sa has the DC voltage described above, and the proper second control signal Sb has the two or more pulse voltages described above. Hereinafter, "the first control signal Sa" means the proper first control signal Sa unless otherwise specified. The same applies to the second control signal Sb.

The signal-processing circuit **62** is connected to the second gate circuit **66** via a resistor R**1**. The deactivating signal is input from the signal-processing circuit **62** to the drive circuit **61** via the resistor R**1**. In response to receiving the deactivating signal, the drive circuit **61** delivers the excitation current to the electromagnetic coil **31***a*. As a result, the electromagnetic brake **30** is turned OFF (that is, the braking is deactivated).

The signal-processing circuit **62** does not output the deactivating signal when not receiving the first control signal Sa and/or the second control signal Sb. When not receiving the deactivating signal, the drive circuit **61** interrupts a path of the excitation current to the electromagnetic coil **31***a*, to thereby turn ON the electromagnetic brake **30**. In other words, in the present embodiment, the electromagnetic brake **30** is turned OFF when the signal-processing circuit **62** receives both the first and second control signals Sa, Sb. The electromagnetic brake **30** is turned ON when the signal-processing circuit **62** does not receive the first control signal Sa and/or the second control signal Sb.

The deactivating signal has, for example, a second specific voltage value. Specifically, the deactivating signal is also referred to as a High-level signal. The deactivating signal is input to the second gate circuit **66**. As shown in FIG. **5**, the second gate circuit **66** includes a second buffer **66***a*. The second gate circuit **66** turns OFF the switch **65** during the second gate circuit **66** not receiving the deactivating signal. Consequently, the excitation current is not delivered to the electromagnetic coil **31***a* during the second gate circuit **66** not receiving the deactivating signal. In response to receiving the deactivating signal, the second gate circuit **66** turns ON the switch **65**. Consequently, the excitation current is delivered to the electromagnetic coil **31***a* during the second gate circuit **66** receiving the deactivating signal.

When receiving the deactivating signal, the second gate circuit **66** applies a gate drive voltage to a gate of the switch **65**, to thereby turn ON the switch **65**. A value of the gate drive voltage is, for example, a value of a specific minimum ON-voltage or greater. The value of the minimum ON-voltage corresponds to, for example, a voltage value obtained by adding a ON-state maintaining voltage to a voltage to be applied to the source of the switch **65** that has been turned ON. The ON-state maintaining voltage corresponds to a gate-source voltage required to keep the switch **65** ON. When the switch **65** is ON, a source of the switch **65** is applied with a voltage close to or approximately equal to the brake voltage. The second gate circuit **66** may include any configuration that can generate the gate drive voltage. The second gate circuit **66** may include, for example, a not-shown booster circuit (for example, a charge pump circuit) to boost (or raise) an output voltage of the second buffer **66***a*. In this case, the gate drive voltage may include an output voltage from the booster circuit. That is, the output voltage from the booster circuit may be applied to the gate of the switch **65**. Furthermore, for example, the second buffer **66***a* may be configured to generate the gate drive voltage. Still further, for example, the deactivating signal from the signal-processing circuit **62** may have a voltage value equal to or approximately equal to the value of the gate drive voltage.

With reference to FIG. **5**, a description is given to a specific configuration of the signal-processing circuit **62**. The signal-processing circuit **62** includes the first buffer **71** described above, a charge pump circuit **72**, a resistor R**2**, a first comparator **73**, and an inverter circuit **74**.

The first control signal Sa is input to a power-supply input terminal of the first buffer **71**. The first control signal Sa functions as a power source for the first buffer **71**. That is, the first buffer **71** operates with the first control signal Sa. The second control signal Sb is input to a signal input terminal of the first buffer **71**. Upon receiving the second control signal Sb, the first buffer **71** outputs an output signal corresponding to the second control signal Sb. In other words, the first buffer **71** enables the second control signal Sb to output the same. For example, when the second control signal Sb is a High-level signal, the first buffer **71** outputs an output signal of a High level. When the second control signal Sb is a Low-level signal, the first buffer **71** outputs an output signal of a Low level. As discussed above, the second control signal Sb in the present embodiment has the two or more pulse voltages. Accordingly, the first buffer **71**, which has received the second control signal Sb, outputs a pulse voltage (hereinafter, referred to as "charging pulse") corresponding to the second control signal Sb. The charging pulse from the first buffer **71** is input to the charge pump circuit **72**.

The charge pump circuit **72** includes a first capacitor C**1**, a second capacitor C**2**, a first diode D**11**, and a second diode D**12**. The first capacitor C**1** includes a first end connected to an output terminal of the first buffer **71**. In other words, the charging pulse is input to the first end of the first capacitor C**1**. The first capacitor C**1** includes a second end connected to a cathode of the first diode D**11** and an anode of the second diode D**12**.

The anode of the first diode D**11** receives the second control voltage Vc**2**. The cathode of the second diode D**12** is connected to a first end of the second capacitor C**2**. A second end of the capacitor C**2** is connected to the ground line **45**. A voltage at the first end of the second capacitor C**2** corresponds to an output voltage of the charge pump circuit **72** (hereinafter, referred to as "charging voltage"). The charging voltage is input to an inverting input terminal of the first comparator **73**. That is, the first end of the second capacitor C**2** is connected to the inverting input terminal of the first comparator **73**. The first end of the second capacitor C**2** is connected to the ground line **45** via the resistor R**2**.

The charge pump circuit **72** outputs the charging voltage by receiving the charging pulse. A value of the charging voltage is higher than a value of a voltage (that is, the second control voltage Vc**2**) input to the first diode D**11**. The value of the charging voltage may be, for example, twice, or approximately twice as much as the second control voltage Vc**2**. In this case, a magnitude (or an amplitude) of the charging pulse may be, for example, equal to or approximately equal to a magnitude (or an amplitude) of the second control voltage Vc**2**. As the operation principle of the charge pump circuit **72** has been well known, a detailed description thereof will be omitted here.

When not properly receiving the charging pulse, the charge pump circuit **72** does not output the charging voltage. For example, when receiving, from the first buffer **71**, a voltage distinctive from the pulse voltage, the charge pump circuit **72** does not output a proper charging voltage. Thus, it can be said that the charge pump circuit **72** has a function to detect that the charging pulse is properly output from the first buffer **71**, in other words, a function to detect that the second control signal Sb is enabled by the first buffer **71**. That is, a state where the charging voltage is being output from the charge pump circuit **72** means that (i) the second control signal Sb has been enabled by the first buffer **71** and (ii) the second control signal Sb enabled has been detected by the charge pump circuit **72**.

The first comparator **73** includes a non-inverting input terminal to receive the second control voltage Vc**2**. The first comparator **73** includes an output terminal connected to the inverter circuit **74**. The inverter circuit **74** receives an output signal of the first comparator **73**. The inverter circuit **74** inverts logic levels of the signal input from the first comparator **73** (input signal) and then outputs the signal input (also referred to as "output signal"). The output signal of the inverter circuit **74** corresponds to an output signal (that is, the deactivating signal) of the signal-processing circuit **62**. That is, the output signal of the inverter circuit **74** is input to the drive circuit **61** as the deactivating signal via the resistor R**1**.

When the first control signal Sa and/or the second control signal Sb are/is not input to the first buffer **71**, the first buffer **71** does not output the charging pulse. In this case, the charge pump circuit **72** does not generate the charging voltage. Consequently, the first comparator **73** outputs a High-level signal. When the High-level signal is output from the first comparator **73**, the inverter circuit **74** outputs a Low-level signal, in other words, the signal-processing circuit **62** does not output the deactivating signal. Accordingly, the switch **65** is turned OFF and thus, the electromagnetic brake **30** is not deactivated.

When the first and second control signals Sa, Sb are input to the first buffer **71**, the first buffer **71** outputs the charging pulse. In this case, the charge pump circuit **72** generates the charging voltage. Consequently, the first comparator **73** outputs a Low-level signal. When the Low-level signal is output from the first comparator **73**, the inverter circuit **74** outputs the High-level signal. In other words, the signal-processing circuit **62** outputs the deactivating signal. Accordingly, the switch **65** is turned ON and thus, the electromagnetic brake **30** is deactivated.

For example, assume that the first or second control signal Sa, Sb is output despite a failure occurring in the first controller **50** discourages fulfillment of the deactivating requirement. In this case, the electromagnetic brake **30** is not deactivated.

More specifically, assume that, for example, where the first control signal Sa is not output, but the second control signal Sb is output. In this case, the first buffer **71** does not operate. That is, the first buffer **71** does not output the charging pulse despite receipt of the second control signal

Sb. Thus, the switch **65** remains OFF, and thereby the braking by the electromagnetic brake **30** is maintained.

Furthermore, assume that, for example, where the second control signal Sb is not output, but the first control signal Sa is output. In this case, the second control signal Sb is not input to the first buffer **71** despite the first buffer **71** operating. That is, the first buffer **71** does not output the charging pulse. Accordingly, the switch **65** remains OFF, and thereby the braking by the electromagnetic brake **30** is also maintained in this case.

Next, a description will be given to a voltage adjustment circuit **63**. The voltage adjustment circuit **63** receives the command signal Scom from the control circuit **51**. The voltage adjustment circuit **63** adjusts (or controls) a magnitude of a voltage to be applied to the electromagnetic coil **31***a* in accordance with the command signal Scorn. More specifically, the voltage adjustment circuit **63** in the present embodiment adjusts a mean value of the voltage to be applied to the electromagnetic coil **31***a* (in other words, a mean value of the excitation current or the electric power to be delivered to the electromagnetic coil **31***a*). Hereinafter, the mean value of the voltage to be applied to the electromagnetic coil **31***a* is referred to as "mean applied voltage".

As shown in FIGS. **4** and **5**, the voltage adjustment circuit **63** includes a second comparator **67**, a filter circuit **68**, an attenuator **69**, and a diode D**13**. The attenuator **69** is connected to the first end of the electromagnetic coil **31***a*. The attenuator **69** receives an actual voltage of the electromagnetic coil **31***a* at the first end (hereinafter, referred to as "actual coil voltage"). The attenuator **69** outputs the actual coil voltage (output voltage) by attenuating the same at a specific attenuation rate. The output voltage of the attenuator **69** is input to the filter circuit **68**.

The filter circuit **68** includes a resistor R**3** and a capacitor C**3**. The resistor R**3** includes a first end to receive the output voltage from the attenuator **69**. The resistor R**3** includes a second end connected to a first end of the capacitor C**3** and an inverting input terminal of the second comparator **67**. The second end of the capacitor C**3** is connected to the ground line **45**. The filter circuit **68** smooths (that is, averages) the output voltage from the attenuator **69**, and outputs a voltage smoothed (hereinafter, referred to as "smoothed voltage") to the second comparator **67**. The smoothed voltage corresponds to one example of the actual voltage signal in the present disclosure.

In the voltage adjustment circuit **63**, the command signal Scom is input to a non-inverting input terminal of the second comparator **67**. The command signal Scorn indicates a desired value of an average applied voltage. In the present embodiment, the desired value of the average applied voltage can be set to a first value or a second value.

The first value is lower than the first rated value of the first battery **41***a* (or the second rated value of the second battery **42***a*). The first value is equal to or greater than a first minimum excitation voltage value. The first minimum excitation voltage value corresponds to a minimum value of the average applied voltage necessary to energize the electromagnetic coil **31***a* (that is, deactivate the electromagnetic brake **30**). The first value may be, for example, a rated voltage of the electromagnetic coil **31***a*. The first value may be, for example, two thirds of the first rated value of the first battery **41***a*. The rated voltage value of the electromagnetic coil **31***a* in the present embodiment is, for example, 24V.

The second value is smaller than the first value. The second value is equal to or greater than a second minimum excitation voltage value. The second minimum excitation voltage value corresponds to a minimum value of the average applied voltage necessary to maintain an energized state of the electromagnetic coil **31***a* (that is, maintain a deactivated state of the electromagnetic brake **30**). The second value may be, for example, one thirds of the first rated value of the first battery **41***a* (or the second rated value of the second battery **42***a*). The second value may be, for example, one half of the first value. In the present embodiment, the second value is, for example, 12V.

When the deactivating requirement is satisfied, the control circuit **51** sets, during a specific initial deactivation time period, the desired value of the average applied voltage to the first value. In other words, the control circuit **51** outputs the command signal Scom indicating the first value. The initial deactivation time period is a time period to enable energization of the electromagnetic coil **31***a* with the average applied voltage having the first value. In other words, the initial deactivation time period is a time period to enable deactivation of the electromagnetic brake **30** with the average applied voltage having the first value. The initial deactivation time period may be, for example, one second.

The second comparator **67** outputs the High-level or the Low-level signal based on a voltage value of the command signal Scorn and a value of the smoothed voltage from the filter circuit **68**. The second comparator **67** outputs the High-level signal when the value of the smoothed voltage is less than (or equal to or less than) the voltage value of the command signal Scorn, in other words, when the value of the average applied voltage is less than (or equal to or less than) the desired value.

The second comparator **67** outputs the Low-level signal when the value of the smoothed voltage is greater than (or equal to or greater than) the voltage value of the command signal Scorn, in other words, when the value of the average applied voltage is greater than (or equal to or greater than) the desired value. The second comparator **67** includes an output terminal connected to a cathode of the diode D**13**. The diode D**13** includes an anode connected to an output terminal of the signal-processing circuit **62** via the resistor R**1**. In other words, the deactivating signal from the signal-processing circuit **62** is also input to the diode D**13** as well as to the drive circuit **61**.

When the High-level signal is output from the second comparator **67**, the deactivating signal is enabled. That is, the deactivating signal is input to the drive circuit **61**. Consequently, the switch **65** is turned ON, resulting in the electromagnetic brake **30** being deactivated. On the other hand, when the Low-level signal is output from the second comparator **67**, the output terminal of the signal-processing circuit **62** is connected to the ground line **45** via the diode D**13** and the output terminal of the second comparator **67**. In this case, the deactivating signal is disabled, resulting in the deactivating signal not being input to the drive circuit **61**. Thus, the switch **65** is turned OFF, and thereby the electromagnetic brake **30** is resultantly activated.

During receipt of the command signal Scom corresponding to (or related to) the first value (hereinafter, referred to as "first command signal"), the voltage adjustment circuit **63** adjusts the value of the average applied voltage to the first value. Specifically, when the value of the average applied voltage exceeds (or is equal to or greater than) the first value, the switch **65** is turned OFF. When the switch **65** is turned OFF, the value of the average applied voltage is equal to or less than (or less than) the first value. When the value of the average applied voltage is equal to or less than (or less than) the first value, the switch **65** is turned ON. That is, the switch **65** is turned ON or OFF in accordance with a difference between the value of the average applied voltage and the first value. Accordingly, the value of the average applied voltage is adjusted to the first value.

In response to elapse of the initial deactivation time period since the desired value of the average applied voltage has been set to the first value, the control circuit **51** sets the desired value of the average applied voltage to the second value. In other words, after energizing the electromagnetic coil **31***a* with the average applied voltage having the first value, the control circuit **51** decreases the value of the average applied voltage. Accordingly, the control circuit **51** can maintain the energized state of the electromagnetic coil **31***a* while reducing a power consumption to energize the electromagnetic coil **31***a*.

(3) Operation Example of Electromagnetic Brake

With reference to FIG. **6**, a description is given to an operation example of the electromagnetic brake **30** in the present embodiment. In FIG. **6**, the term "DEACTIVATED" at times t**4**, t**6**, t**8** indicates that the deactivating requirement has been satisfied. Furthermore, the term "BRAKED" at times t**5**, t**7**, t**9** indicates that the braking requirement has been satisfied. Still further, a period from the time t**1** through the time t**4**, a period between the times t**5** and t**6**, and a period after the time t**9** illustrate that, due to some malfunction (that is, the first control signal Sa is not properly output), the first control signal Sa is output despite the deactivating requirement not being satisfied. The first control signal Sa is properly output during periods from the time t**4** through the time t**5**, from the time t**6** through the time t**7**, and from the time t**8** through the time t**9**.

Furthermore, FIG. **6** illustrates that, during a period from the time t**2** through the times t**3** and a period after the time t**9**, an abnormal second control signal Sb is output due to some malfunction. The abnormal second control signal Sb is distinctive from a proper pulse voltage. Still further, a period from the time t**7** through the time t**8** illustrates that, due to some malfunction (that is, the second control signal Sb is not properly output), the second control signal Sb is output despite the deactivating requirement not being satisfied. The second control signal Sb is properly output during periods from the time t**4** through the time t**5**, from the time t**6** through the time t**7**, and from the time t**8** through the time t**9**.

In the above example in FIG. **6**, despite the deactivating requirement not being satisfied, the first control signal Sa is improperly (that is, unintentionally) output during the periods from the time t**1** through the time t**4**, from the time t**5** through the time t**6**, and after the time t**9**. However, the second control signal Sb is not output in any of these periods (that is, the second control signal Sb is properly controlled). Thus, the excitation current is not delivered to the electromagnetic brake **30**. Accordingly, the braking by the electromagnetic brake **30** is maintained. Furthermore, during the period from the time t**7** through the time t**8**, the second control signal Sb is improperly (that is, unintentionally) output despite the deactivating requirement not being satisfied. However, as the first control signal Sa is not output during this period (that is, the first control signal Sa is properly controlled), the excitation current is not supplied to the electromagnetic brake **30**. Accordingly, the braking by the electromagnetic brake **30** is maintained. Due to the deactivating requirement being satisfied during the periods from the time t**4** through the time t**5**, from the time t**6** through the time t**7**, and from the time t**8** through the time t**9**, both the first and second control signals Sa, Sb are properly output. Thus, the excitation current is delivered to the electromagnetic brake **30**, resulting in deactivation of the electromagnetic brake **30**.

(4) Electromagnetic Braking Process

The above-described operation of the electromagnetic brake **30** is achieved by the control circuit **51** (specifically, a CPU **51***a*) executing the electromagnetic braking process shown in FIG. **7**. Upon being activated, the CPU **51***a* executes the electromagnetic braking process (hereinafter, referred to as "present process").

Upon starting the electromagnetic braking process, the CPU **51***a* determines whether the braking requirement is satisfied in S**110**. If the braking requirement is not satisfied, then the CPU **51***a* repeats a process of S**110**. If the braking requirement is satisfied, then the present process proceeds to S**120**.

In S**120**, the CPU **51***a* outputs the first and second control signals Sa, Sb. In S**130**, the CPU **51***a* sets the desired value of the average applied voltage to the first value. Specifically, the CPU **51***a* outputs the command signal Scom corresponding to the first value. This applies a voltage having the first value on average to the electromagnetic coil **31***a*, which is thereby energized. Upon the electromagnetic coil **31***a* being energized, the electromagnetic brake **30** is deactivated.

In S**140**, the CPU **51***a* determines whether the initial deactivation time period has elapsed since the output of the command signal Scom in S**130**. If the initial deactivation time period has not elapsed, then the present process proceeds to S**180**. In S**180**, the CPU **51***a* determines whether the braking requirement has been satisfied. If the braking requirement has not been satisfied, then the present process proceeds to S**140**. If the braking requirement has been satisfied, then the present process proceeds to S**170**.

If the initial deactivation time period has elapsed in S**140**, then the present process proceeds to S**150**. In S**150**, the CPU **51***a* sets the desired value of the average applied voltage to the second value. Specifically, the CPU **51***a* outputs the command signal Scorn corresponding to (or related to) the second value. This applies a voltage having the second value on average to the electromagnetic coil **31***a*, which thereby remains energized. That is, the braking by the electromagnetic brake **30** is maintained.

In S**160**, the CPU **51***a* determines whether the braking requirement has been satisfied. If the braking requirement has not been satisfied, then the CPU **51***a* repeats a process of S**160**. If the braking requirement has been satisfied, then the present process proceeds to S**170**.

In S**170**, the CPU **51***a* activates the electromagnetic brake **30**. Specifically, the CPU **51***a* stops outputting the first and second control signals Sa, Sb and the command signal Scorn. This stops power delivery to the electromagnetic coil **31***a*. As a result, the electromagnetic coil **31***a* is de-energized, and thereby the electromagnetic brake **30** is activated. That is, the drive wheels are braked by the electromagnetic brake **30**.

(5) Correspondence between Terms

In the present embodiment, the first buffer **71** corresponds to one example of the first circuit in the overview. The charge pump circuit **72** corresponds to one example of the second circuit in the overview. The first comparator **73** and the inverter circuit **74** correspond to one example of the third circuit in the overview. The first rectifier circuit **81** and the second rectifier circuit **82** correspond to one example of the selector circuit in the overview. The command signal Scorn corresponds to one example of the voltage command signal in the overview. The filter circuit **68** corresponds to one example of the voltage detection circuit in the overview.

3. Other Embodiments

Although one embodiment to implement the overview has been described above, the overview is not limited to the above-described embodiment, but may be implemented in various forms.

(3-1) Each of the first and second control signals Sa, Sb may be any signal. The signal-processing circuit **62** may include any configuration to enable proper output of the deactivating signal based on the first and second control signals Sa, Sb.

(3-2) The second control signal Sb may be in the form of a signal distinctive from the pulse voltage. In this case, the signal-processing circuit **62** may be configured to enable output of a proper deactivating signal based on the second control signal Sb.

The second control signal Sb in the form of the pulse voltage exhibits an effect to be described as follows. When a malfunction occurs in the control circuit **51** (specifically, the microcomputer), there is a possibility that a faulty signal is output from an output port of the second control signal Sb in the control circuit **51**. The faulty signal is a signal different from the proper second control signal Sb. The faulty signal may be, for example, a signal maintained at a High or Low level. Alternatively, when the malfunction occurs in the control circuit **51**, there is a possibility that the output port is opened. Assume that the proper second control signal Sb is the signal maintained at the High level. In this case, the malfunction described above may cause output of such a High-level signal from the output port despite a failure to satisfy the deactivating requirement. That is, when the High-level signal is erroneously output despite the failure to satisfy the deactivating requirement, the electromagnetic brake **30** may be deactivated. On the other hand, the malfunction in the control circuit **51** does not cause or is not likely to cause output of the pulse voltage from the output port. For this reason, it is possible to improve reliability of the electromagnetic brake **30** by utilizing a signal having the pulse voltage as the second control signal Sb in the above-described embodiment.

(3-3) The signal-processing circuit **62** may include a microcomputer to detect the second control signal Sb in place of the charge pump circuit **72**, the first comparator **73**, and the inverter circuit **74**. This microcomputer may output the High-level signal to the first buffer **71** in response to detection of the second control signal Sb. Furthermore, the output signal of the first buffer **71** may be output as the deactivating signal from the signal-processing circuit **62**.

(3-4) The voltage adjustment circuit **63** may be configured in any manner that can adjust the desired value of the average applied voltage. For example, the attenuator **69** may be omitted (or eliminated), such that the second comparator **67** receives the command signal Scorn having the same voltage value as the desired value. In this case, for example, the command signal Scorn output from the control circuit **51** may have the same voltage value as the desired value. Furthermore, there may be provided, for example, an amplifier circuit to amplify the command signal Scom output from the control circuit **51**, and thereby the command signal Scorn amplified by the amplifier circuit may be input to the second comparator **67**.

(3-5) The electromagnetic coil **31***a* may be disposed in the upstream of the switch **65**.

(3-6) The electromagnetic brake **30** may be disposed at any position that enables braking of the electric-powered wheelbarrow **1**. The electromagnetic brake **30** may be provided to, for example, a transmission path for the rotational force of the motor **25**. The transmission path starts from the motor **25** to the drive wheels through the transmission mechanism **21**. In other words, the electromagnetic brake **30** may directly or indirectly apply the braking force to the drive wheels to brake the same. In the above-described embodiment, the electromagnetic brake **30** directly applies the braking force to the motor **25**, to thereby indirectly apply the same to the drive wheels. However, the electromagnetic brake **30** may directly apply the braking force to the drive wheels. More specifically, the electromagnetic brake **30** may be disposed, for example, inside or in the vicinity of the transmission mechanism **21**. Furthermore, the electromagnetic brake **30** may be provided to, for example, the transmission path between the motor **25** and the transmission mechanism **21**. Still further, there may be the electromagnetic brake **30**, for example, between the transmission mechanism **21** and each of the front wheels **8**, **9**. Still further, the electromagnetic brake **30** may brake any wheel(s) of the electric-powered wheelbarrow **1**. The electromagnetic brake **30** may apply the braking force to, for example, the driven wheels. The electromagnetic brake **30** may apply the braking force to any number of wheels.

(3-7) The electric-powered wheelbarrow **1** may be embodied distinctively from the four-wheeled vehicle. For example, the electric-powered wheelbarrow **1** may include two wheels or less, or five wheels or more. Furthermore, any wheel can be a drive wheel.

(3-8) The first battery **41***a* and/or the second battery **42***a* may be built into the electric-powered wheelbarrow **1**. The electric-powered wheelbarrow **1** may include only one battery (for example, the first battery **41***a*) detachably mounted therewith or built therein.

(3-9) Two or more functions performed by a single element in the above-described embodiments may be achieved by two or more elements, or a function performed by a single element may be achieved by two or more elements. Furthermore, two or more functions performed by two or more elements may be achieved by a single element, and a function performed by two or more elements may be achieved by a single element. Furthermore, a part of a configuration in the above-described embodiments may be omitted. Still further, at least a part of a configuration in the above-described embodiments may be added to, or may replace, another configuration in the above-described embodiments.

What is claimed is:

1. An electric-powered wheelbarrow comprising:
- a motor;
- a motor driver configured to deliver an electric power to the motor to thereby rotate the motor;
- a wheel configured to be driven by the motor;
- an electromagnetic brake including an electromagnetic coil, the electromagnetic coil being configured to receive an excitation current to thereby be energized, the electromagnetic brake being configured (i) to be activated to apply a braking force to the wheel in response to the electromagnetic coil being de-energized and (ii) to be deactivated to release the braking force from the wheel in response to the electromagnetic coil being energized;
- a control circuit configured to output a first control signal and a second control signal;
- a signal-processing circuit configured (i) to receive the first control signal and the second control signal and (ii) to thereby output a deactivating signal; and

a drive circuit configured to receive the deactivating signal to thereby deliver the excitation current to the electromagnetic coil.

2. The electric-powered wheelbarrow according to claim 1, wherein the control circuit is configured to output the first control signal and the second control signal in response to a deactivating requirement being satisfied or having been satisfied, the deactivating requirement being required to deactivate the electromagnetic brake.

3. The electric-powered wheelbarrow according to claim 1,

wherein the first control signal has a fixed voltage greater than zero, and

wherein the second control signal has two or more pulse voltages.

4. The electric-powered wheelbarrow according to claim 3, wherein the signal-processing circuit is configured to output the deactivating signal in response to (i) the first control signal received being in a first proper state and (ii) the second control signal received being in a second proper state, the first control signal in the first proper state having the fixed voltage, and the second control signal in the second proper state having the two or more pulse voltages.

5. The electric-powered wheelbarrow according to claim 4, wherein the signal-processing circuit includes:

a first circuit configured to enable the second control signal in response to the first control signal received being in the first proper state;

a second circuit configured to detect the second control signal enabled; and

a third circuit configured to output the deactivating signal during the second circuit detecting the second control signal enabled.

6. The electric-powered wheelbarrow according to claim 5, wherein the second circuit is configured to detect the second control signal (i) having been enabled and (ii) being in the second proper state.

7. The electric-powered wheelbarrow according to claim 1, wherein the motor driver is configured to receive, from a first battery or a second battery, the electric power to be delivered to the motor.

8. The electric-powered wheelbarrow according to claim 1, wherein the drive circuit is configured to receive, from a first battery or a second battery, the excitation current to be delivered to the electromagnetic coil.

9. The electric-powered wheelbarrow according to claim 8,

wherein the first battery includes a first positive electrode;

wherein the second battery includes a second positive electrode;

wherein the electric-powered wheelbarrow further includes a selector circuit connected to the first positive electrode and the second positive electrode, the selector circuit being configured to (i) receive a first current from the first battery and a second current from the second battery and (ii) output the excitation current including the first current or the second current, and

wherein the drive circuit is configured to receive the excitation current from the selector circuit and deliver, to the electromagnetic coil, the excitation current received.

10. The electric-powered wheelbarrow according to claim 9, wherein the selector circuit includes:

a first rectifier circuit including (i) a first input terminal configured to receive the first current from the first battery and (ii) a first output terminal configured to output the first current received from the first input terminal, the first rectifier circuit being configured to inhibit the second current from flowing from the first output terminal to the first input terminal; and

a second rectifier circuit including (i) a second input terminal configured to receive the second current from the second battery and (ii) a second output terminal connected to the first output terminal, the second output terminal being configured to output the second current received from the second input terminal, and the second rectifier circuit being configured to inhibit the first current from flowing from the second output terminal to the second input terminal.

11. The electric-powered wheelbarrow according to claim 1, further comprising a voltage adjustment circuit configured to adjust an excitation voltage to be applied to the electromagnetic coil.

12. The electric-powered wheelbarrow according to claim 11,

wherein the control circuit is further configured to output a voltage command signal to the voltage adjustment circuit, the voltage command signal designating a desired magnitude of the excitation voltage, and

wherein the voltage adjustment circuit is configured to (i) receive the voltage command signal and (ii) adjust the excitation voltage so as to maintain an actual magnitude of the excitation voltage at the desired magnitude designated by the voltage command signal received.

13. The electric-powered wheelbarrow according to claim 12, wherein the control circuit is configured to keep outputting, for a specific length of time, the voltage command signal designating a first value as the desired magnitude in response to a deactivating requirement being satisfied, the deactivating requirement being required to deactivate the electromagnetic brake.

14. The electric-powered wheelbarrow according to claim 13, wherein the control circuit is configured to, in response to having output, for the specific length of time, the voltage command signal to designate the first value, output the voltage command signal designating a second value as the desired magnitude, the second value being smaller than the first value.

15. The electric-powered wheelbarrow according to claim 12, further comprising a voltage detection circuit configured to (i) receive the excitation voltage applied to the electromagnetic coil and (ii) generate an actual voltage signal, the actual voltage signal indicating a mean value of the excitation voltage received, and

wherein the voltage adjustment circuit is configured to adjust the excitation voltage so as to maintain the mean value indicated by the actual voltage signal at the desired magnitude.

16. The electric-powered wheelbarrow according to claim 15, wherein the voltage adjustment circuit is configured to, during the drive circuit receiving the deactivating signal, (i) operate the drive circuit so as to deliver the excitation current to the electromagnetic coil in response to the mean value indicated by the actual voltage signal being smaller than the desired magnitude indicated by the voltage command signal and (ii) operate the drive circuit so as to stop the excitation current in response to the mean value indicated by the actual voltage signal being equal to or greater than the desired magnitude indicated by the voltage command signal.

17. A method of controlling an electromagnetic brake of an electric-powered wheelbarrow, the method comprising:

receiving a first control signal and a second control signal, each of the first control signal and the second control signal being required for deactivation of the electromagnetic brake;

in response to simultaneous receipt of both the first control signal and the second control signal, outputting a deactivating signal for deactivating the electromagnetic brake; and

in response to receipt of only one of the first and second control signals, not outputting the deactivating signal for deactivating the electromagnetic brake.

18. The method according to claim **17**, wherein the second control signal has two or more pulse voltages.

19. The method according to claim **18**, wherein the first control signal has a fixed voltage greater than zero.

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