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CA 2351201 A1 2002/05/21

(21) 2 351 201

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2001/06/21

(41) Mise à la disp. pub./Open to Public Insp.: 2002/05/21

(30) Priorité/Priority: 2000/11/21 (09/718,862) US

(51) Cl.Int.[7]/Int.Cl.[7] H02P 5/16

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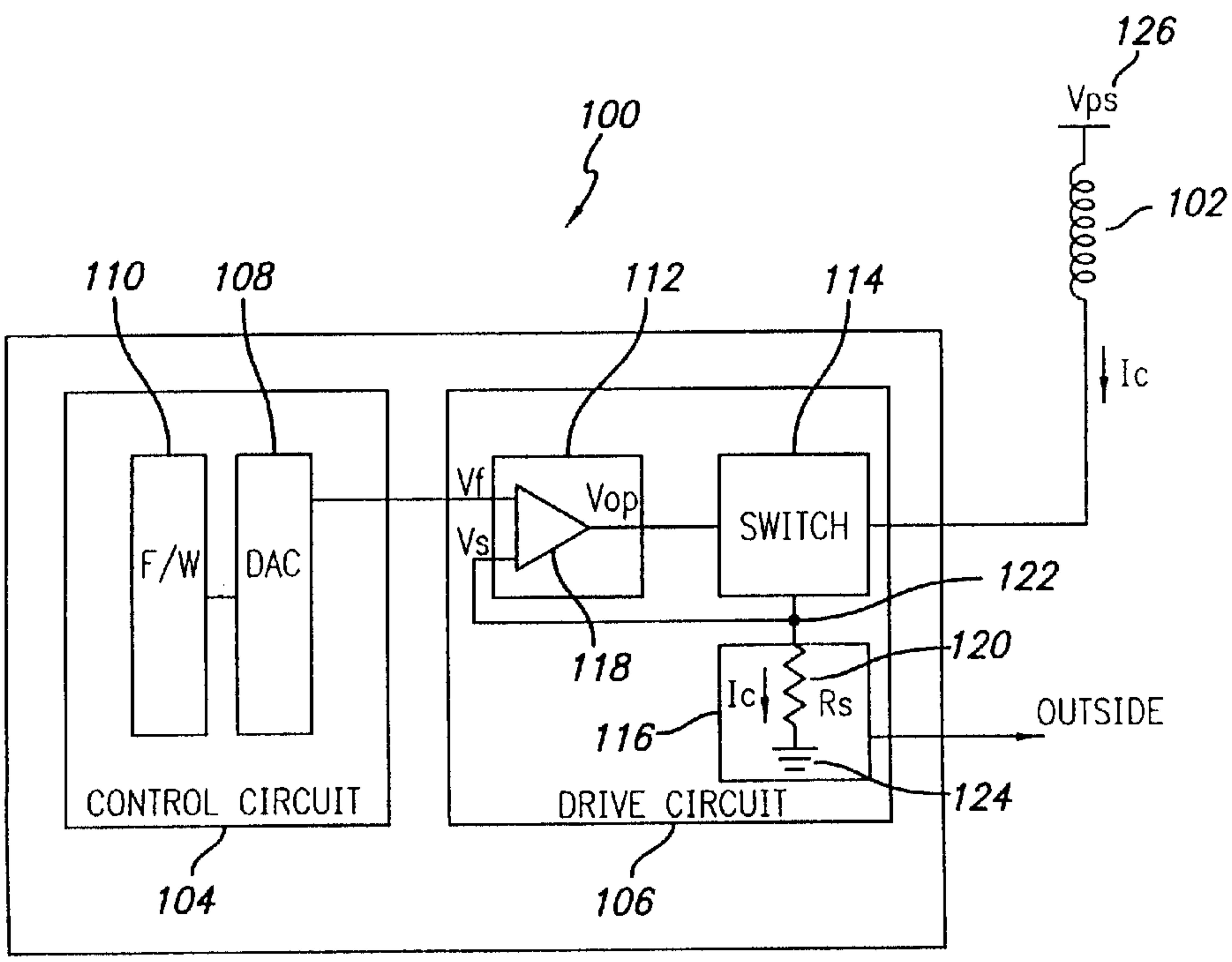
(54) Titre : CIRCUIT DE COMMANDE DE MOTEUR AMELIORE
(54) Title: AN IMPROVED MOTOR DRIVER CIRCUIT



(57) Abrégé/Abstract:
An improved motor driver circuit comprises a firmware adapted to provide digital control signals, a digital-to-analog converter coupled to said firmware to receive the digital control signals for generating a reference voltage at an output, a compare circuit having a first input coupled to the output of said digital-to-analog converter, a second input coupled to a sense circuit for receiving a sense voltage and an output, and a switch circuit coupled in series to said sense circuit wherein said compare circuit compares the reference voltage and the sense to generate a compare voltage at the output to be fed into said switch circuit for directing the switch circuit to conduct or not to conduct a drive current flowing through said switch circuit and said sense circuit.

Abstract

An improved motor driver circuit comprises a firmware adapted to provide digital control signals, a digital-to-analog converter coupled to said firmware to receive the digital control signals for generating a reference voltage at an output, a compare circuit having a first input coupled to the output of said digital-to-analog converter, a second input coupled to a sense circuit for receiving a sense voltage and an output, and a switch circuit coupled in series to said sense circuit wherein said compare circuit compares the reference voltage and the sense to generate a compare voltage at the output to be fed into said switch circuit for directing the switch circuit to conduct or not to conduct a drive current flowing through said switch circuit and said sense circuit.

AN IMPROVED MOTOR DRIVER CIRCUIT

Field of the Invention

The present invention relates generally to a driver circuit and, more particularly, to a motor driver adapted to provide selectable current levels of a drive current for driving a motor externally coupled to the motor driver.

Background of the Invention

A conventional motor driver, such as a chopper motor driver, is generally designed to limit the amount of current that a motor can draw from a power supply. As a result, the motor will not draw more current than necessary for operation, thereby increasing the power efficiency of the motor and the motor driver. More importantly, by limiting the current supplied to the motor, the conventional motor driver prevents too much current from flowing through the motor than the motor could handle so that the motor will not burn up.

A conventional arrangement of the motor driver 10 and the motor 30 is shown in Figure 1. The conventional motor driver 10 includes a driver circuit 12 coupled to a reference circuit 14. The reference circuit 14 typically includes a voltage divider 22 for generating a predetermined reference voltage V_f to the motor driver 10. Ordinarily, the voltage divider 22 has first R1 and second R2 resistors 24, 26 connected in series between power supply V_{cc} 32 and ground node 38. The reference voltage V_f is defined as the voltage at node 28, where the first R1 and second R2 resistors 24, 26 join. As a result, the reference voltage V_f is defined as

$$V_f = V_{cc} \times R2/(R1+R2)$$

where the V_{cc} is a predetermined stable voltage. By selecting the first R1 and second R2 resistors 24, 26, a user of the motor driver 10 can provide a fixed reference voltage V_f for determining how much current could flow through the motor 30, as will be further explained in the following paragraphs.

The drive circuit 12 of the conventional motor driver 10 includes a compare circuit 20, as shown in Figure 1. Normally, the node 28 is coupled to one terminal 42 of the compare circuit 20 for receiving the reference voltage V_f. In addition, the other terminal 44 of the compare circuit 20 receives a sense voltage from an output 40 of a sense circuit 18. Therefore, the compare circuit 20 compares the reference voltage V_f with the sense voltage V_s to generate a compare voltage V_{op} at its output. As shown in Figure 1, the compare circuit 20 often includes an op-amp 36 to compare the reference voltage V_f with the sense voltage V_s for generating the compare voltage V_{op} at the output of the op-amp 36 based on the relative difference of the V_f and V_s.

As shown in Figure 1, the drive circuit 12 also includes the switch circuit 16 coupled in series between the motor 30 and the sense circuit 18 of the drive circuit 12. The sense circuit 18 generally includes a sense resistor R_s 34 coupled in series between the switch circuit 18 and the ground node 38. As a result, a current I_c flowing through the motor 30 will also flow through the sense resistor R_s 34 by way of the sense circuit 18.

Figure 1 shows the sense resistor R_s 34 being coupled to the compare circuit 20 at the output node 40. Thus, the sense voltage V_s, which is the voltage at the output node 40, is defined as

$$V_s = I_c \times R_s$$

where the current I_c is the same current flowing through the motor 30, the switch circuit 16, and the sense resistor R_s 34.

As mentioned, the sense voltage V_s is fed into the other terminal 44 of the comparator 36 to be compared with the reference voltage V_f fed into one input terminal 42 of the op-amp 36. If the V_s is larger than the V_f, the output voltage V_{op} of the op-amp 36 will force the switch circuit 16 to open, i.e., to stop conducting the current I_c from the motor 30. As a result, the motor 30 will not draw any current from power supply V_{ps} 46. Simultaneously, the sense voltage V_s will start to drop since no current is now flowing through the sense resistor R_s 34 due to the open circuit of the switch circuit 16. After the sense voltage V_s has dropped to a level lower than the reference voltage V_f, the output voltage V_{op} of the op-amp 36 will then cause the switch circuit 16 to close, i.e., to start conducting the current I_c from the motor 30, and the sense voltage V_s will then start to rise. In short, the configuration of the conventional motor driver 10 provides a feedback loop between the drive circuit 12 and the reference circuit 14, whereby a feedback voltage, i.e., the sense voltage V_s, is compared to the reference voltage V_f for determining the status (open or close) of the switch circuit 16. Therefore, the sense voltage V_s will be confined within a range approximately equal to the reference voltage V_f and the current flowing through the motor 30 will be defined approximately as

$$I_c = V_f / R_s.$$

Comparing the sense voltage V_s with the predetermined reference voltage V_f effectively allows the conventional motor driver 10 to control how much current current I_c will flow through the motor 30. Therefore, the motor 30 will be protected from burning up due to the excessive heat generated by the excessive current. Also, a specific torque characteristic can be achieved. The conventional motor driver 10, however, has several disadvantages.

Generally, the motor 30 needs a relatively large current to start the motor's rotor during an initial operating stage. In contrast, the motor 30 needs only a much lower current level to maintain rotation once it passes the initial operating stage. For example, a larger initial torque Γ_i is needed to overcome the static friction f_s so as to initially start the motor 30 from rest. When the motor's rotor starts to rotate, a smaller torque Γ_r is required to overcome a dynamic friction f_d for maintaining rotation. The dynamic friction F_d usually is smaller than the static friction f_s. As a result, the initial torque Γ_i has to be larger than the rotating torque Γ_r. Since only one reference voltage V_f is provided to the conventional motor driver 10, the reference voltage V_f has to be set at a value that is sufficient to drive the motor 30 during the initial stage. As a result, the current I_c, which is determined by the V_f, is defined sufficiently large to drive the conventional motor 30 during the initial stage but is often larger than necessary after the motor 30 starts running. Consequently, the conventional motor driver 10 consumes more electrical power than necessary for operation and is less efficient.

Moreover, since a larger than necessary current I_c flows through the motor 30, the motor driver 30 often generates excessive heat during operation. The excessive heat will have an adverse effect on the reliability of the motor 30, or conventional motor driver 10. A heat sink may be added to the conventional motor driver 10 to eliminate the excessive heat problem. However, adding the heat sink will inevitably increase the complexity and manufacturing costs and size of the conventional motor driver 10. An improved motor driver solution is thus needed to resolve the above-mentioned difficulties.

Summary of the Invention

The present invention is directed to an improved motor driver circuit having a select circuit for controlling a current level flowing through a motor coupled to the improved motor driver. In a preferred embodiment of the present invention, the select circuit includes a DAC (Digital-to-Analog Converter) for determining the current level of the motor. The DAC is coupled to a drive circuit of the improved motor driver circuit to provide the drive circuit a reference voltage that is selectable from a plurality of voltage levels. The drive circuit then, in response to the selected reference voltage supplied by the DAC, controls the current level of the motor to its appropriate level during different stages of operation. In another embodiment, the present invention further comprises a firmware program for controlling the DAC to output the reference voltage. The firmware may be pre-programmed according to the needs of the motor during various stages of operation.

The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Brief Description of the Drawings

Figure 1 shows a conventional motor drive circuit coupled to a motor and a power supply.

Figure 2 shows a preferred embodiment of an improved motor drive circuit according to the present invention.

Detailed Description of the Invention

The present invention is directed to an improved motor drive circuit 100 which provides a selectable current level for a motor 102 during different stages of motor operation. The motor 102 is coupled to the motor driver 100 and is not part of the present invention. The motor driver 100 includes a control circuit 104 coupled to a first input of a drive circuit 106. In the preferred embodiment, the control circuit 104 includes a DAC (Digital-to Analog Converter) 108 having an output coupled to the first input of the drive circuit 106. The output of the DAC 108 supplies a selectable reference voltage V_f to be fed into the first input of the drive circuit 106.

The drive circuit 106 includes a compare circuit 112 coupled to a switch circuit 114 at the output. The compare circuit 112 has a first and a second input respectively coupled to the output of the DAC 108 through the first input of the drive circuit 106 and to a sense circuit 116, as shown in Figure 2. The switch circuit 114 is coupled to the sense circuit 116 in series, whereby the node 122 is positioned directly between the switch circuit 114 and the sense circuit 116. Moreover, the switch circuit 114 is further coupled to the motor 102 in series, as shown in Figure 2.

The compare circuit 112 also has an output terminal coupled to the switch circuit 114. Thus, an output voltage V_{op} of the op-amp 118 is provided to the switch circuit 114 for controlling the status (open or close) of the switch circuit 114. For instance, when the output voltage V_{op} is at one level, the switch circuit 114 will be closed (i.e., conducting) and is adapted to conduct an electric current I_c flowing through the motor 102. When the output voltage V_{op} is the opposite, the switch circuit 114 will be open and will not conduct the electric current I_c from the motor 102.

The sense circuit 116 defines a sense voltage V_s at the node 122 to be fed back to the comparator or op-amp 118. Basically, the sense circuit 116 uses a resistive load for determining the sense voltage V_s at the node 122. In the preferred embodiment, the sense circuit 116 includes a sense resistor R_s coupled in series between the node 122 and the ground node 124, as shown in Figure 2, so that the I_c will flow from the switch circuit 114 through the sense resistor R_s into the ground node 124. The sense voltage V_s at the node 122 is, therefore, defined as

$$V_s = I_c \times R_s$$

where I_c is the electric current flowing through the motor 102 and the sense resistor R_s and the R_s is the resistance of the sense resistor R_s. In an alternative embodiment, the sense resistor R_s may be replaced by a load circuit or by other electrical components adapted to provide the suitable means for determining the sense voltage V_s.

As mentioned, the output of the DAC 108 generates the selectable reference voltage V_f which is fed into the compare circuit 112, as shown in Figure 2. The reference voltage V_f functions to control the switch circuit 114 for determining the current level of the I_c flowing through the motor 102. Moreover, when the V_{op} is at one level, the switch circuit 114 will be closed to conduct the I_c from the motor 102. When the V_{op} is at the other level, the switch circuit 114 will open to disconnect the sense circuit 116 from the motor 102. Therefore, the sense voltage V_s will start to drop due to the decreasing current flow of I_c. Once the sense voltage V_s has dropped to a level lower than the reference voltage V_f, the V_{op} of the op-amp 118 will switch to the first level again and the switch circuit 114 will start conducting the I_c and start raising the sense voltage V_s. By providing this dynamic feedback loop of the drive circuit 106, the present invention can, thus, control the I_c in the motor 102 approximately at a level corresponding to a selected voltage level of the reference voltage V_f.

As noted, the reference voltage V_f provided by the DAC 108 is selectable, i.e., the DAC 108 may choose the voltage level of the reference voltage V_f within a predetermined range. The voltage range of the V_f should be sufficiently large to provide enough voltage for rotating the motor rotor during an initial operation stage of the motor 102. Moreover, the reference voltage V_f should provide sufficient sustaining voltage for continuing to rotate the motor rotor after the initial operation state. The DAC 108 works to convert pre-selected digital bit information into analog voltage levels for outputing the reference voltage V_f. In the preferred embodiment, the DAC 108 has an eight-bit configuration. As a result, the DAC 108 is capable of providing 256 voltage levels for the reference voltage V_f. In other alternative embodiments, the DAC may have any suitable numbers of digital bit configuration adapted for various applications.

In the preferred embodiment, the control circuit 104 of the present invention further comprises a firmware 110 coupled to the DAC 108 for controlling the same. The firmware 110 is pre-programmed to generate digital bit information, 8 bits in the case of the preferred embodiment, according to the operation stage of the motor 102. The digital bit information of the firmware 110 is then fed into the DAC 108 for generating reference voltage V_f corresponding to the digital bit information.

By having the firmware 110 and the DAC 108 of the control circuit 104, the present invention is adapted to provide different voltage levels of the reference voltage V_f to provide adequate current levels of the motor 102 during different stages of the motor operation. For example, during the initial operation stage, the reference voltage V_f is set to a high value in order to allow sufficiently large I_c in the motor 102 to provide a large initial torque Γ_i for rotating the motor rotor. Once the motor 102 starts rotating, the firmware 110 causes the DAC 108 to generate a lower reference voltage V_f, and thus lower Ic, sufficient to maintain rotation of the motor 102. Because the motor 102 runs on a higher I_c only during the short period of the initial operation stage, the present invention has a better power efficiency as compared the conventional motor driver. Moreover, since the DAC 108 has an 8-bit configuration to provide 256 levels of reference voltage V_f, the present invention may dynamically adjust the reference voltage V_f according to various stages of the motor operation. This may further save substantial power consumption, and improve power efficiency, of the motor driver 100. As a result, the present invention needs no heat sink to dissipate heat generated by the motor 102, as many conventional motor drivers do to prevent thermal damages of the motor and/or the motor driver.

From the foregoing, it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made by persons skilled in the art without deviating from the spirit and/or scope of the invention. Specifically, the switch circuit can be any standard switch circuit in the industry that is suitable to control the I_c at the current levels within the range of the present invention. Also, a digital analog converter is not required. It could be a series of resistors that form a low current digital analog converter function. The improved motor driver can also be utilized to regulate current levels of other electrical elements.

Claims:

1. An improved motor driver circuit coupled to an external motor, comprising:

a digital-to-analog converter for generating selectable voltage levels of a reference voltage at an output; and

a drive circuit coupled to the output of said digital-to-analog converter, said drive circuit being adapted to receive the reference voltage from the digital-to-analog converter for regulating a drive current flowing through said drive circuit and the motor.

2. The improved motor driver circuit of claim 1, wherein said drive circuit comprises:

a sense circuit, said sense circuit being adapted to provide a sense voltage;

a compare circuit coupled to said digital-to-analog converter and said sense circuit, said compare circuit being adapted to compare the reference voltage and the sense voltage to generate a compare voltage at an output; and

a switch circuit coupled to said sense circuit in series, said switch circuit being further coupled to the output of said compare circuit wherein the compare voltage direct the switch circuit to conduct or not to conduct the drive current flowing through said switch circuit and said sense circuit.

3. The improved motor driver circuit of claim 2, wherein said sense circuit comprises a sense resistor coupled in series between said switch circuit and a ground terminal, said sense resistor having the drive current

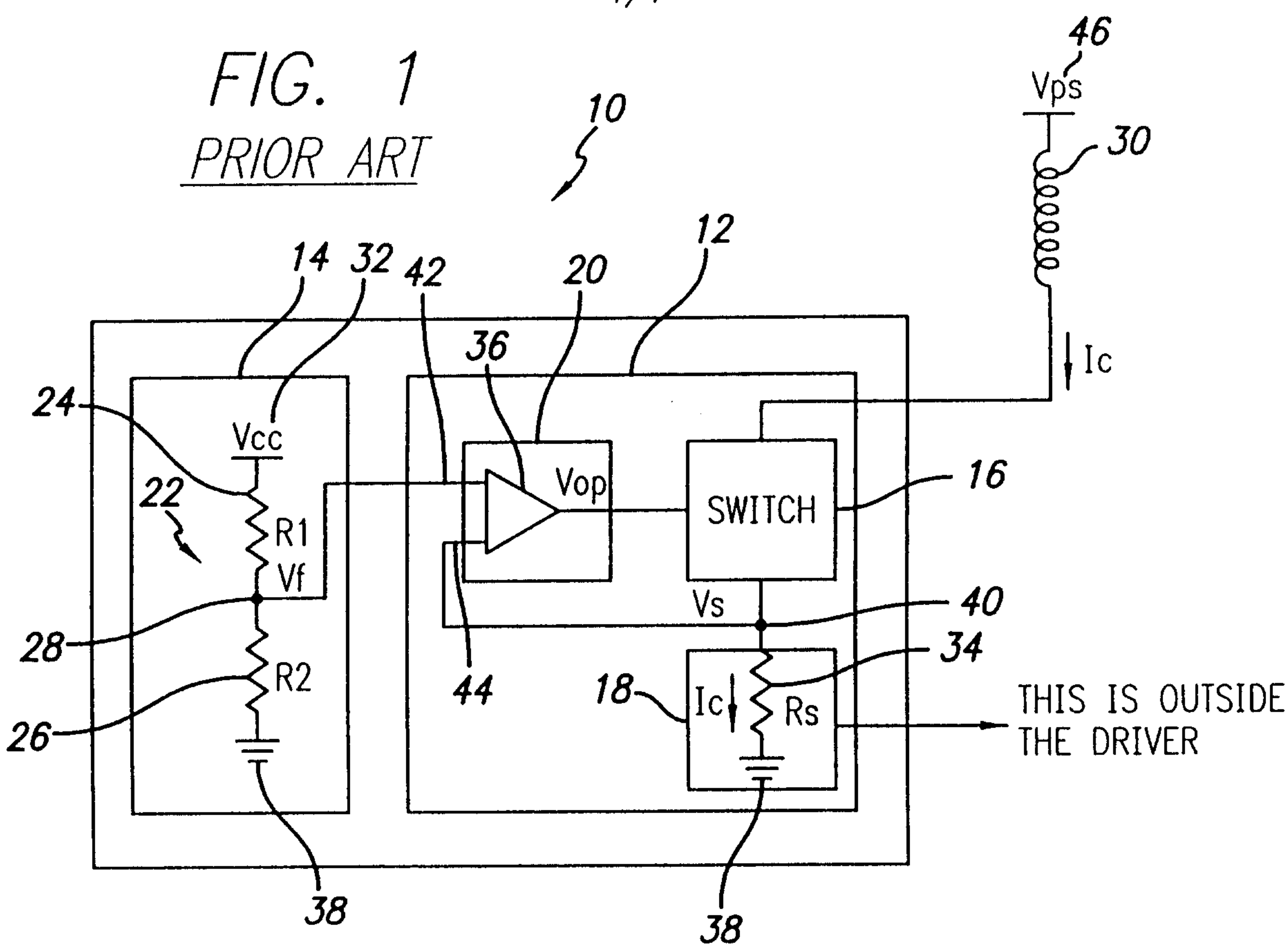
flowing through therein to provide the sense voltage to be fed into the compare circuit.

4. The improved motor driver circuit of claim 2, wherein said switch circuit is coupled in series to the motor allowing the drive current to flow from the motor through said switch circuit into said sense circuit, said switch circuit being controlled by the compare voltage for opening or closing said switch circuit.

5. The improved motor driver circuit of claim 1, further comprising a firmware coupled to said digital-to-analog converter, said firmware being configured to provide digital control signals to said digital-to-analog converter for generating the reference voltage.

6. The improved motor driver circuit of claim 1, wherein said digital-to-analog converter is an eight-bit digital-to-analog converter adapted to provide 256 voltage levels of the reference voltage.

FIG. 1
PRIOR ART



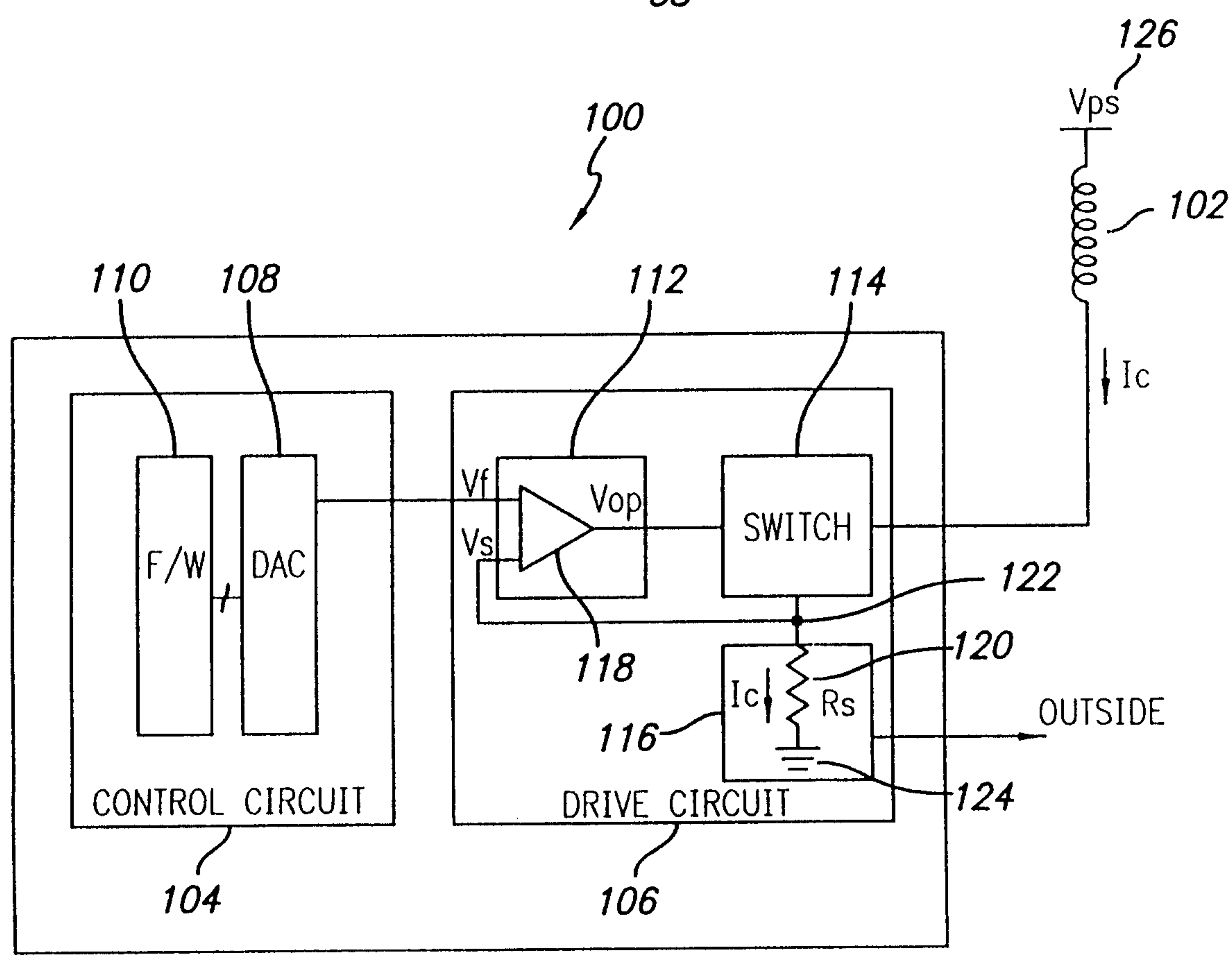
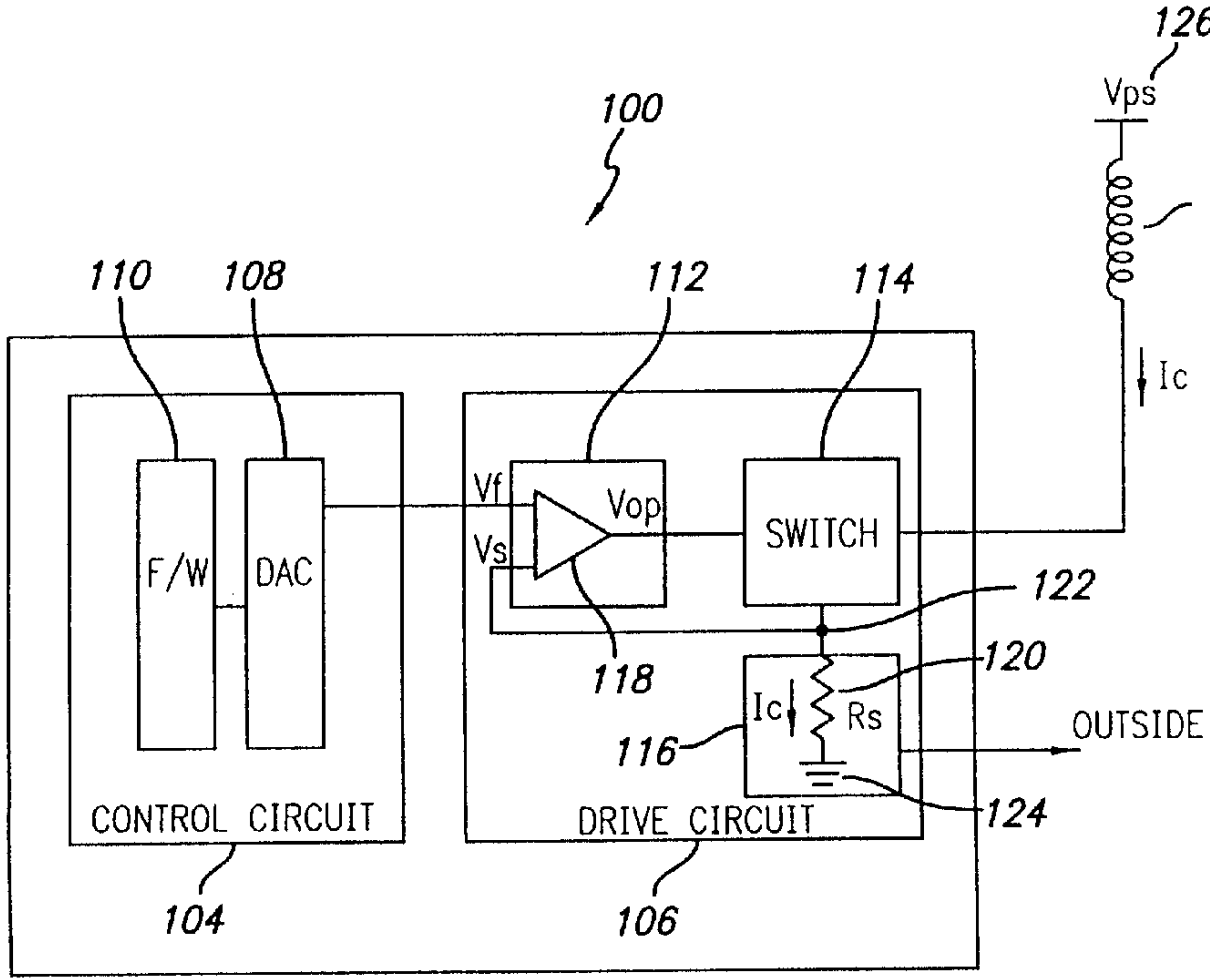


FIG. 2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Rs
OUTSIDE
116
124
CONTROL CIRCUIT
DRIVE CIRCUIT
104
106