United States Patent

[11] **3,600,659**

[72] Inventor **Alex Danchuk**
Livingston, N.J.

[21] Appl. No. **862,208**
[22] Filed **Sept. 30, 1969**
[45] Patented **Aug. 17, 1971**
[73] Assignee **The Bendix Corporation**

[54] **SOLID-STATE COMPACT SERVOSYSTEM**
2 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** **318/608,** 318/614, 318/615
[51] **Int. Cl.** **G05b 5/01**
[50] **Field of Search** 318/20.415, 20.411, 20.400, 20.440, 20.420, 20.370

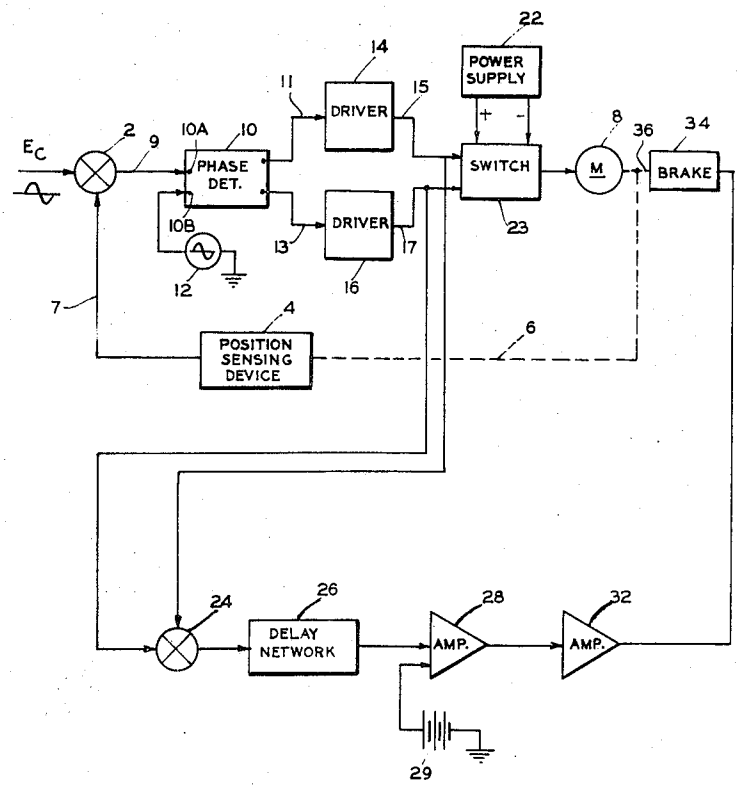
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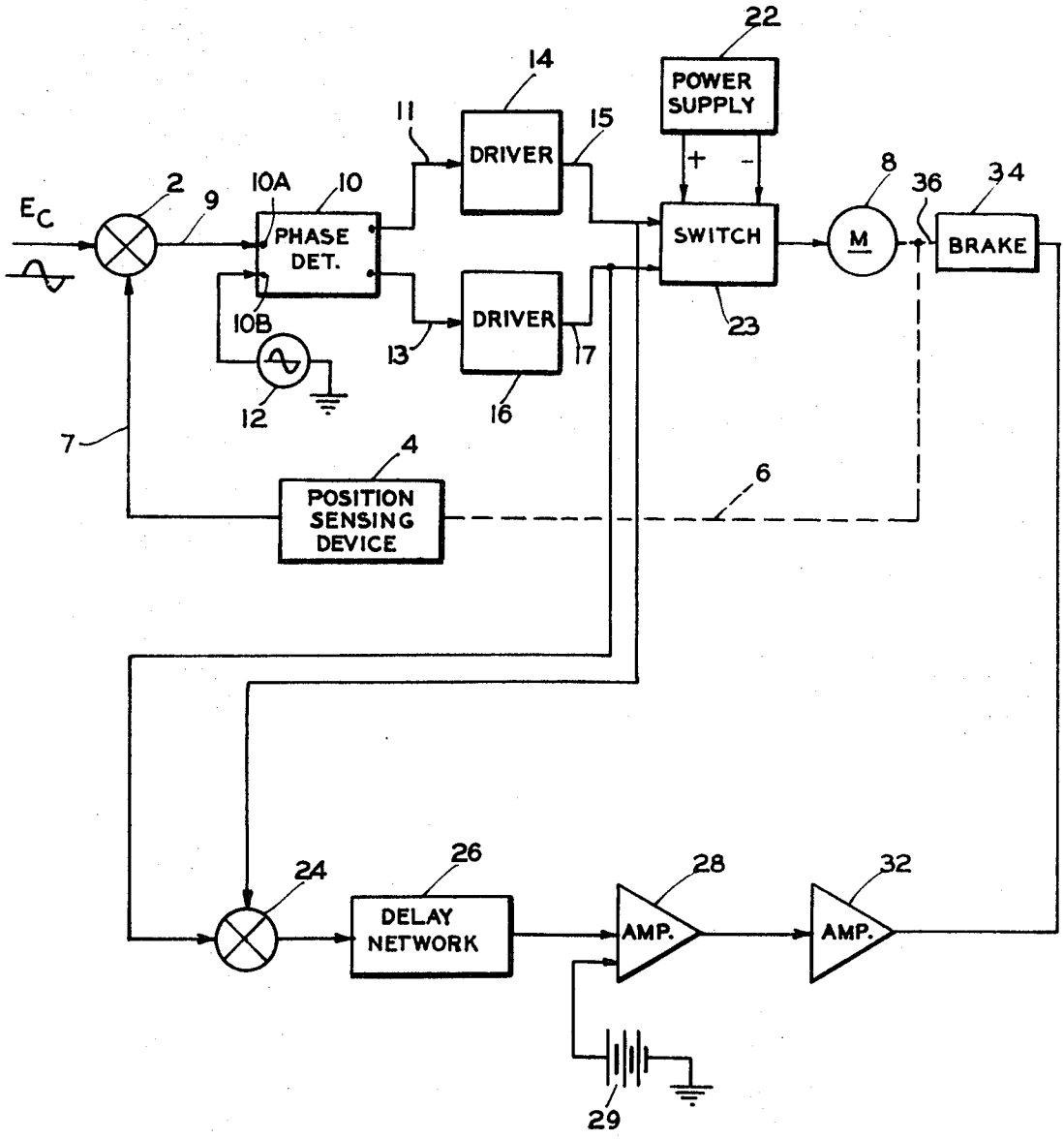
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Primary Examiner—Benjamin Dobeck
Attorneys—Anthony F. Cuoco and Plante, Arens, Hartz, Smith and Thompson

ABSTRACT: A servosystem having solid-state components includes means for summing an alternating command signal with a motor shaft position signal and when the resulting difference signal exceeds a predetermined threshold drivers are actuated for applying to the motor a voltage having a polarity in accordance with the phase of the difference signal relative to a reference. The voltage is cut off when the motor is at null, whereupon inertia drives the motor past null to provide a difference signal of opposite polarity so that the motor is driven in the opposite direction until it again passes through null, reversing the voltage thereto with the result being that full voltage is applied to the motor until the null is reached.





INVENTOR.
ALEX DANCHUK
BY
ATTORNEY

SOLID-STATE COMPACT SERVOSYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to servosystems and, more particularly, to servosystems having solid state components, and having reduced size and weight and minimal power losses.

2. Description of the Prior Art

Servosystems now known in the art use servoamplifiers which, for high power applications, are large in size and incur considerable power losses. Modern requirements call for smaller and lighter systems and systems which operate with increased accuracy.

SUMMARY OF THE INVENTION

This invention contemplates a servosystem of solid-state construction and having means for summing an AC command signal with a servomotor shaft position signal for providing a difference signal. The phase of the difference signal relative to a reference signal is detected, and when the difference signal exceeds a predetermined threshold clockwise or counterclockwise drivers, depending on said detected phase, are actuated. The drivers operate a switch for applying a voltage of appropriate polarity to the servomotor. When the servomotor is at null the voltage is cutoff, but inertia drivers the motor past null so that a difference signal of opposite polarity is detected. The voltage to the motor is thereupon reversed to initially slow the motor and to ultimately drive the motor in the opposite direction until the motor again drives through null reversing the voltage to the motor. In this manner full voltage is applied to the motor until null is reached to provide a servosystem having improved accuracy. Improved null stability is achieved by applying braking action to the motor at null conditions.

One object of this invention is to provide a servosystem of solid state construction having reduced size, minimal power losses and increased accuracy.

Another object of this invention is to provide a servosystem of the type described having improved null stability.

Another object of this invention is to provide a servosystem having small power consumption components for minimizing power losses and for substantially reducing the cost of the system.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein one embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustration purposes only and are not to be construed as defining the limits of the invention.

DESCRIPTION OF THE DRAWINGS

The single figure in the drawing is a block diagram of a servosystem according to the invention.

An AC command signal E_c which may correspond, for purposes of example, to an aircraft flight condition signal is applied to a summing means **2**. Signal E_c has a phase in accordance with the direction of the command. A position sensing device **4** is connected by suitable mechanical means **6** to a torquer motor **8** and is connected by a conductor **7** to summing means **2**. Position sensor **4** may be a linear potentiometer for sensing the angular position of the motor shaft and for providing at conductor **7** a corresponding electrical signal. Summing means **2**, which may be a simple resistance, transformer or operational amplifier in differential amplifier configuration sums signal E_c and the signal from position sensing device **4** and provides at an output conductor **9** an AC signal corresponding to the difference therebetween. Solid state differential amplifiers suitable for purposes of the invention are described at pages 111—120, *Transistor Manual* published in 1964 by the General Electric Company.

Summing means **2** is connected through conductor **9** to an input terminal **10A** of a phase detector **10**. Phase detector **10** has another input terminal **10B** connected to a suitable AC reference source **12**. When the signal from summing means **2** exceeds a predetermined threshold, phase detector **10** provides an output at either an output conductor **11** or at an output conductor **13**, depending on the phase of the signal from summing means **2**. Phase detector **10** is of the type which includes an operational amplifier used as a threshold device for comparing the signal from summing means **2** to a fixed level reference voltage and further includes a pair of operational amplifiers for phase detection whereby AC signal proportional to the phase difference between the signal from summing means **2** and the reference voltage from source **12** is provided at one of the conductors **11** or **13**, depending on the phase of the signal from summing means **2**. A solid-state device suitable for the purposes of phase detector **10** is shown in FIG. **7—26**, *Pulse, Digital and Switching Waveforms*, Milman and Taub, McGraw-Hill 1965, modified as will be understood by those skilled in the art and as indicated at page 260.

Conductors **11** and **13** are connected to corresponding drivers **14** and **16**, and which drivers include high input impedance amplifiers which may be described at page **102**, FIG. **4.7**, **4.8**, *Transistor Manual*, supra, for protecting the signal channel from loading effects. Drivers **14** and **16** further include demodulators or converters for providing DC voltages at respective output conductors **15** and **17**. A device employing semiconductors and suitable for the purposes of drivers **14** and **16** is described in U.S. Pat. No. 3,525,921 issued Aug. 25, 1970 to H. B. Wattson and assigned to The Bendix Corporation, assignee of the present invention. It will be understood that driver **14** will provide a voltage at output conductor **15** if phase detector **10** provides an output at conductor **11** and driver **16** will provide a voltage at conductor **17** if phase detector **10** provides an output at conductor **13**. The effect of drivers **14** and **16** is to drive motor **8** in either clockwise or counterclockwise directions as will hereinafter become evident.

Conductors **15** and **17** are connected to a switch **23**, and which switch **23** is connected to a power supply **22** providing suitable positive and negative DC motor driving voltages. Switch **23** may be an electrical mechanical relay or transistorized switch such as described at Chapter 6, *Transistor Manual*, supra, responsive to the voltages at conductors **15** or **17** to apply voltage of proper polarity from power supply **22** to motor **8** to drive the motor. It will be understood that when voltage of one polarity is applied to motor **8**, the motor is driven clockwise and when voltage of the opposite polarity is applied, the motor is driven counterclockwise.

Drivers **14** and **16**, are also connected through output conductors **15** and **17** to a summing means **24**, and which summing means **24** may be an operational amplifier such as described with reference to summing means **2** for summing the signals from the drivers and for providing a signal corresponding to the difference therebetween.

Summing means **24** is connected to a delay network **26**, and which delay network **26** is connected to a voltage level detector **28**. Delay network **26** is a low pass filter such as described at pages 42—47, *Pulse, Switching and Digital Waveforms*, supra for smoothing and delaying the signal from summing means **24** before applying said signal to the level detector. Level detector **28** is an operational amplifier connected as described in copending U.S. application Ser. No. 691,376, filed Dec. 18, 1967 by Steven D. Stolman and assigned to The Bendix Corporation, assignee of the present invention, which compares the signal from delay network **26** to a preselected reference signal provided by a battery **29**, and provides a triggering output when the difference between said signals exceeds a predetermined level. The driver **32**, which may be a high input impedance amplifier such as described with reference to drives **15** and **17**, is connected to level detector **28** and is connected to a brake **34**. Brake **34** is coupled by suitable mechanical means **36** to the shaft of Motor **8**. The

triggering output from level detector **28** is applied through driver **32** to brake **34**, and which brake **34** imparts a holding action to motor **18** for better null stability, and during intervals when power to the system is cut off.

OPERATION

As command signal E_c is received, it is compared by summing means **2** with the signal from position sensing device **4** to determine the difference between the two signals. The difference signal is applied to phase detector **10** which, in accordance with phase of the difference signal, applies a signal to either clockwise driver **14** or counterclockwise **16**. The drivers, in turn, actuate switch **23** which delivers full voltage of appropriate polarity directly to motor **8** for driving said motor clockwise or counterclockwise. Motor **8** receives full voltage as long as an input signal is provided at input **10A** of phase detector **10**, and as soon as the motor drives through a null, power is cut off. However, inertia carries the motor load past null for providing at the output of summing device **2** an opposing signal which reverses the polarity of the motor driving voltage. This first slows down the motor and finally drivers the motor in the opposite direction until null is again achieved. In contrast to servosystems now shown in the art, the system of the invention thus provides full voltage to the motor until null is reached and thereby imparts greater accuracy to the system.

At the same time, clockwise and counterclockwise drivers **14** and **16** apply signals to summing device **24** and which device **24** sums the signals and applies the resulting difference signal to delay network **26** and therefrom to level detector **28**. When the delayed difference signal exceeds a predetermined threshold established by level detector **28**, driver **32** actuates brake **34** for better null stability, and also for holding the system at time when power is off.

Although only one embodiment of the invention has been illustrated and described, various changes in the form and relative arrangements of the parts, which will now appear obvious to those skilled in the art may be made without departing from the scope of the invention. Reference is, therefore, to be had to the appended claims for a definition of the limits of the invention.

What I claim is:

1. A servosystem, comprising:

a servomotor;

means connected to the servomotor for providing a motor shaft position signal;

means for providing a command signal;

means connected to the shaft position signal means and to the command signal means for summing the signals therefrom and providing a difference signal;

a voltage source;

switching means connecting the voltage source to the servomotor;

driving means connected to the switching means;

means for connecting the driving means to the difference signal means, with the driving means responsive to the difference signal above a predetermined level in one sense for rendering the switching means effective to apply voltage from the voltage source to the motor;

means for providing an AC reference signal;

the means for connecting the difference signal means to the driving means being connected to the reference signal means for providing a first signal when the difference signal is of one phase relative to the reference signal and for providing a second signal when said difference signal is of another phase;

the driving means including means responsive to the first signal for providing a signal for driving the motor in one direction and responsive to the second signal for providing a signal for driving the motor in an opposite direction;

means connected to the means for providing the motor driving signals for summing the signals therefrom and for providing a signal corresponding to the difference therebetween;

means connected to the difference signal for filtering said signal;

means for providing a reference signal;

means for comparing the reference signal and the filtered signal to provide a triggering signal when the difference between the compared signals exceeds a predetermined level; and

braking means connected to the triggering signal means and to the motor for braking the motor in response to the triggering signal.

2. A system as described by claim **1**, wherein:

the voltage source provides voltages of opposite polarities; and

the switching means is affected by the signal for driving the motor in the one direction for applying voltage of one polarity to the motor, and is affected by the signal for driving the motor in the opposite direction for applying voltage of opposite polarity to the motor.