# AN8235S

## 3.5-inch FDD Spindle Motor Controller

### ■ Overview

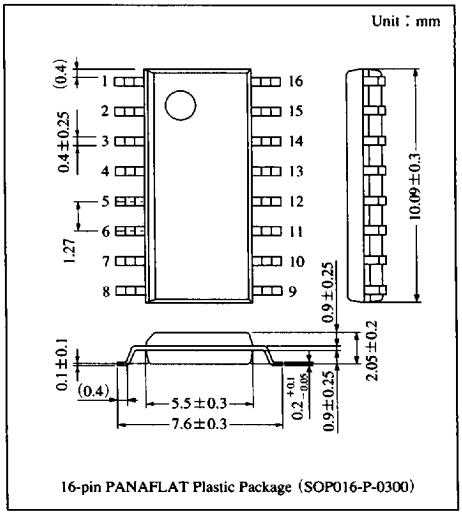
The AN8235S is an IC developed for controlling the 3.5-inch FDDs' belt type spindle motors. Using the digital FG servo system, it can easilly realize adjustment-free low drift. It is also available as a DC motor speed control IC.

### ■ Features

- Operating supply voltage range : $V_{CC}$ = 4.4 to 6V
- Digital F/V conversion system
- Current feedback system
- Built-in speed changeover function
  - 1/1.2 : Correspond to 300/360 r.p.m.
  - 1/1.2 : Corresponds to 300/600 r.p.m.
- Built-in FG and EA amplifiers
- Built-in protective circuit (current limiter) function

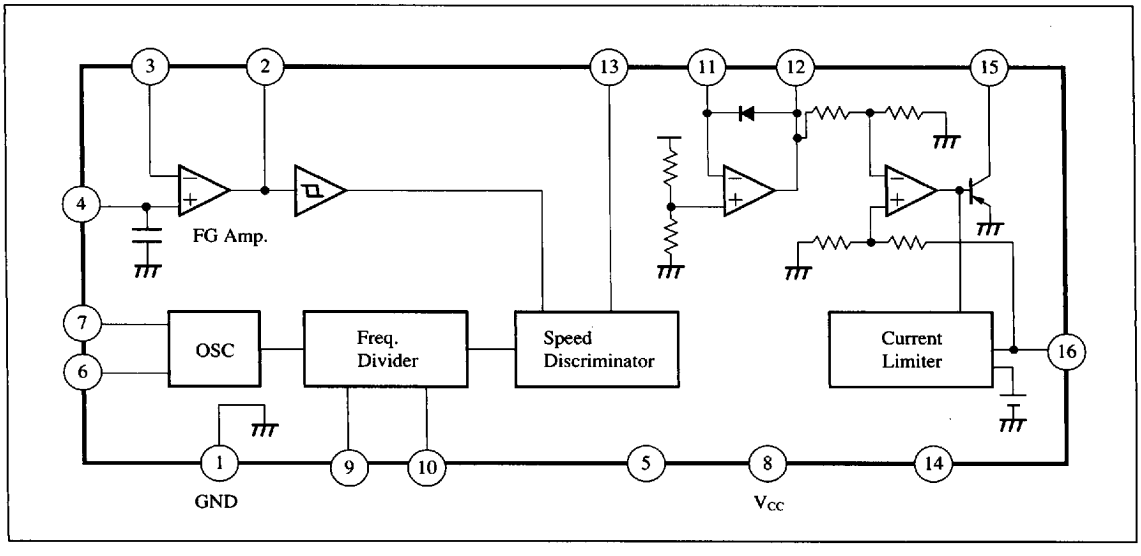
### ■ Applications

Control of the FDD spindle motors and DC motors




ICs for Motor

### ■ Block Diagram



## ■ Absolute Maximum Ratings (Ta=25℃)

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Supply voltage | $V_{CC}$ | 7 | V |
| Supply current | $I_{CC}$ | 20 | mA |
| Power dissipation | $P_D$ | 380 | mW |
| Operating ambient temperature | $T_{opr}$ | −20 to +75 | ℃ |
| Storage temperature | $T_{stg}$ | −55 to +125 | ℃ |

## ■ Recommended Operating Range (Ta=25℃)

| Parameter | Symbol | Range |
|---|---|---|
| Operating supply voltage range | $V_{CC}$ | 4.4V to 6V |

## ■ Electrical Characteristics (Ta=25℃)

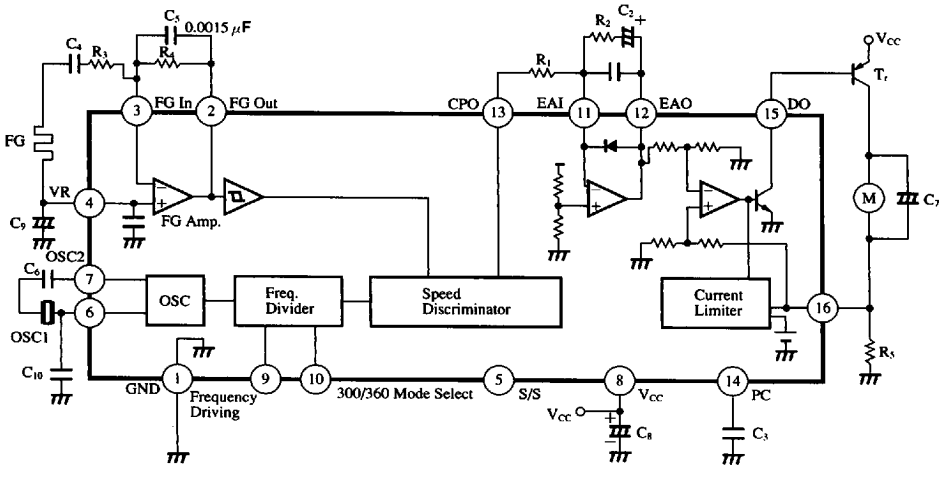
| Parameter | Symbol | Condition | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Quiescent current at standby | $I_{QS}$ | $V_{CC}$=5V, $V_S$=4.2V or OPEN | — | 0.01 | 0.5 | mA |
| Quiescent current at no load | $I_{QN}$ | $V_{CC}$=5V, $V_S$=0V | 6 | 11 | 18 | mA |
| **Reference Voltage Block** | | | | | | |
| Reference voltage | $V_{OR}$ | $V_{CC}$=5V | 2.15 | 2.4 | 2.65 | V |
| Output sink current | $I_{OR}^+$ | $V_{CC}$=5V | 0.02 | 0.08 | — | mA |
| Output source current | $I_{OR}^-$ | $V_{CC}$=5V | — | −1.6 | −0.8 | mA |
| Output impedance | $Z_{OR}$ | $V_{CC}$=5V, $I_{OR}^-$=0mA to −0.8mA | — | 110 | 200 | Ω |
| **FG Amp./Schmidt Block** | | | | | | |
| Offset block | $V_{OFS}$ | $V_{CC}$=5V | −20 | — | 20 | mV |
| Output sink current | $I_{OF}^+$ | $V_{CC}$=5V | 1 | 3 | — | mA |
| Output source current | $I_{OF}^-$ | $V_{CC}$=5V | — | −3 | −1 | mA |
| Open loop gain | $A_{FGG}$ | $V_{CC}$=5V | — | 78 | — | dB |
| Schmidt width | $V_S$ | $V_{CC}$=5V | — | 50 | — | mV |
| **Speed Discriminator Block** | | | | | | |
| Discriminator count 1 | $N_{CT}$ | $V_{CC}$=5V, $V_{CT1}$=0V, $V_{CT2}$=0V | — | 1390 | — | — |
| Speed discriminator error 1 | $\Delta T1$ | $V_{CC}$=5V CLK=100kHz $V_{CT1}$=0V, $V_{CT2}$=0V | 6 | 10 | 14 | μs |
| Speed discriminator error 2 | $\Delta T2$ | | 6 | 10 | 14 | μs |
| Max. clock frequency | $f_{max.}$ | $V_{CC}$=5V | 1 | 2.2 | — | MHz |
| 1/1.2 select voltage | $V_{CT1}$ | $V_{CC}$=5V | 0.8 | — | 2 | V |
| 1/2 frequency-dividing select voltage | $V_{CT2}$ | $V_{CC}$=5V | 0.8 | — | 2 | V |
| Speed discriminator output H | $\Delta V_{DH}$ | $V_{CC}$=5V | — | 0.1 | 0.3 | V |
| Speed discriminator output L | $\Delta V_{DL}$ | $V_{CC}$=5V | — | 0.1 | 0.3 | V |
| Output sink current | $I_{DL}$ | $V_{CC}$=5V | 1 | 3 | — | mA |
| Output source current | $I_{DH}$ | $V_{CC}$=5V | — | −3 | −1 | mA |
| Equivalent count 1 | $R_{C1}$ | $V_{CC}$=5V, 720rpm, $V_{CT1}$=LOW, $V_{CT2}$=LOW | — | 1390 | — | — |
| Equivalent count 2 | $R_{C2}$ | $V_{CC}$=5V, 600rpm, $V_{CT1}$=HIGH, $V_{CT2}$=LOW | — | 1668 | — | — |
| Equivalent count 3 | $R_{C3}$ | $V_{CC}$=5V, 360rpm, $V_{CT1}$=LOW, $V_{CT2}$=HIGH | — | 2780 | — | — |
| Equivalent count 4 | $R_{C4}$ | $V_{CC}$=5V, 300rpm, $V_{CT1}$=HIGH, $V_{CT2}$=HIGH | — | 3336 | — | — |

Note) Equivalent count=CLK÷FG frequency (FG frequency when the motor is installed)

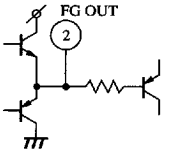
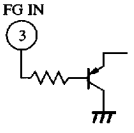
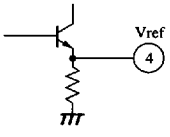
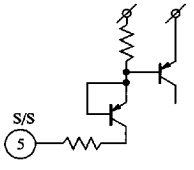
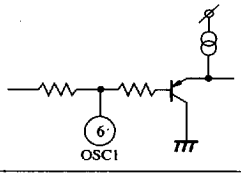
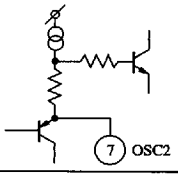
## ■ Electrical Characteristics (Cont.) (Ta=25℃)

| Parameter | Symbol | Condition | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| **Error Amp. Block** | | | | | | |
| Integrating amp. error output 1 | $\Delta V_{ERO1}$ | $V_{CC}$=5V Acceleration mode | 0.3 | 0.7 | 1.1 | V |
| Integrating amp. error output 2 | $\Delta V_{ERO2}$ | $V_{CC}$=5V Acceleration mode | — | — | −0.3 | V |
| Output sink current | $I_{OE}^+$ | $V_{CC}$=5V | 1 | 3 | — | mA |
| Output source current | $I_{OE}^-$ | $V_{CC}$=5V | — | −3 | −1 | mA |
| Open loop gain | $A_{EAG}$ | $V_{CC}$=5V | — | 73 | — | dB |
| Input bias current | $I_{EA}$ | $V_{CC}$=5V | — | 20 | — | nA |
| Gain bandwisth product | $f_T$ | $V_{CC}$=5V | — | 800 | — | kHz |
| **Predrive Output Block** | | | | | | |
| Drive output current | $I_{OD}$ | $V_{CC}$=5V | 16 | 33 | — | mA |
| Limitter voltage | $V_{LC}$ | $V_{CC}$=5V | 0.225 | 0.25 | 0.275 | V |
| Drive gain | $G_D$ | $V_{CC}$=5V | 0.54 | 0.67 | 0.8 | time |
| **Start/Stop Control Block** | | | | | | |
| Input voltage H (stop) | $V_{OSH}$ | $V_{CC}$=5V | 4.2 | — | — | V |
| Input voltage L (start) | $V_{OSL}$ | $V_{CC}$=5V | — | — | 0.8 | V |
| Input current H | $I_{OSH}$ | $V_{CC}$=5V | −20 | — | 3 | μA |
| Input current L | $I_{OSL}$ | $V_{CC}$=5V | −500 | −180 | — | μA |
| **Oscillation Circuit Block** | | | | | | |
| Ceramic oscillation frequency | $f_S$ | $V_{CC}$=5V, Ceramic oscillator : 800kHz | — | 800 | — | kHz |

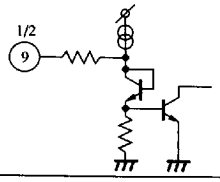
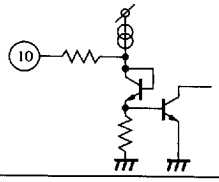
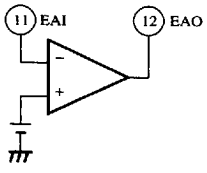
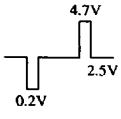
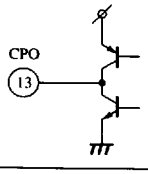
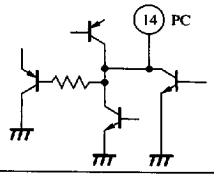
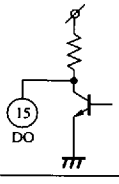
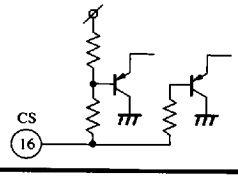
## ■ Application Circuit



## ■ Pin Descriptions

| Pin No. | Pin name | Typical waveform | Description | I/O impedance | Pin equivalent circuit |
|---|---|---|---|---|---|
| 1 | Ground (GND) | DC 0V | Ground pin | — |  |
| 2 | FG amp. inverting output (FG IN) | — | Output pin of the FG amplifier | — |  |
| 3 | FG amp. inverting input (FG IN) | — | Inverting input pin of the FG amplifier | — |  |
| 4 | FG amp. non-inverting input (Vref) | DC 2.4V | Reference voltage source of the main circuit | — |  |
| 5 | Start/Stop select (S/S) | — | Start/stop selector pin | — |  |
| 6 | Oscillation circuit 1 (OSC 1) | — | Oscillation circuit input pin | — |  |
| 7 | Oscillation circuit 2 (OSC 2) | — | Oscillation circuit output pin | — |  |
| 8 | Power supply | — | Power pin | — |  |

## ■ Pin Descriptions (Cont.)

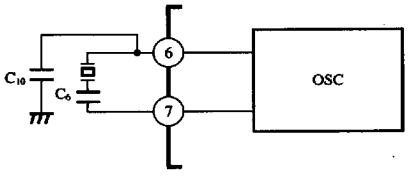
| Pin No. | Pin name | Typical waveform | Description | I/O impedance | Pin equivalent circuit |
|---|---|---|---|---|---|
| 9 | 1/2 frequency-dividing select (1/2) | — | 300/600 r.p.m. selector pin | — |   |
| 10 | 1/1.2 speed select (1/1.2) | — | 300/360 r.p.m. selector pin | — |   |
| 11 | Error amp. inverting input (EAI) | — | Inverting input pin and amplifier output pin of the error amplifier | — |   |
| 12 | Error amp. output (EAO) | | | | |
| 13 | Speed error output (CPO) |   | Output pin of the speed discriminator circuit | — |   |
| 14 | Phase compensation (PC) | — | Phase compensation pin for current feedback | — |   |
| 15 | Predrive (DO) | — | Predrive pin of the external power PNP transistor | — |   |
| 16 | Current detection (CS) | — | Current detection pin | — |   |

## ■ Supplementary Explanation

### ● Application

(1) Reference oscillator block

Set the motor speed according to the oscillation frequency of the oscillator block.




①Use a ceramic oscillator so that oscillations from 200kHz to 1MHz may be available.

②Some pF of capacitance is normally used for the capacitor $C_6$.

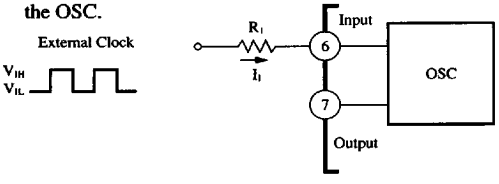
The oscillation frequency can finely adjusted according to a capacitance value.

③The capacitor $C_{10}$ is a spurious measure for parasitic oscillation.

④When using the external clock

(input an external clock without oscillating the OSC block)

The external clock can be input from the input Pin⑥ of the OSC.




If an excessive input is applied, the OSC block may not function. In this case, connect the current limiting resistor $R_I$.

The input currents $I_{IH}$ and $I_{IL}$ flowing through the resistor $R_I$ are expressed as follows.

$$1_{IH}=\frac{V_{IH}-1.4}{R_I+R_{OSC}} \quad (\mu A)$$

$$1_{IL}=-\frac{1.4-V_{IL}}{R_I+R_{OSC}} \quad (\mu A)$$

(The $V_{IH}$ and $V_{IL}$ threshold levels inside the IC are calculated at 1.4V.)

However, $R_{OSC}$ is an IC internal resistance and designed to be 2kΩ.

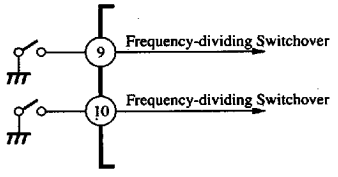
Design at about some 10μF as an IC drive capability.

A recommended $R_I$ value is 10kΩ.

(conditions of $V_{IH}$=2.36V, $V_{IL}$=0.44V, $I_I$=80μA)

(2) Frequency-dividing selector block

Frequency-dividing can be switched over to "Low" or "High (Open)", using the Pins⑨ and ⑩.




| Pin⑩ | Pin⑨ | Motor Speed (rpm) | Equivalent Counts |
|---|---|---|---|
| Low | Low | 720 | 1390 |
| Open (High) | Low | 600 | 1668 |
| Low | Open (High) | 360 | 2780 |
| Open (High) | Open (High) | 300 | 3336 |

The motor speed N is obtained by the following expressin.

$$N \simeq 60 \cdot \frac{f_{OSC}}{N_C \cdot Z} (rpm)$$

$f_{OSC}$ : Oscillation frequency (Hz)

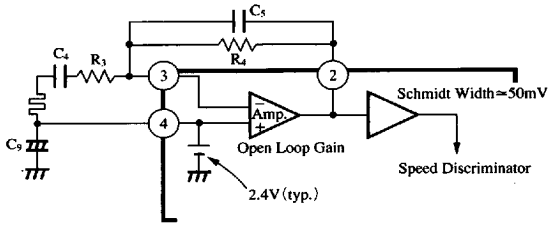
$N_C$ : Equivalent counts $N_C=\frac{f_{OSC}}{f_{FG}}$

Z : No. of the FG teeth

$f_{FG}$ : FG frequency (Hz)

(3) FG amplifier and Schmidt circuit

The motor speed is detected and amplified, and then, a waveform is shaped by the Schmidt circuit.




①Use as an inverting amplifier as shown in the figure above.

The closed loop gain G is as follows.

$$G \simeq -\frac{R_4}{R_3}$$

Set the gain so that the output swing of the amplifier will be within a range of 1 to 3 $V_{P-P}$.

The voltage at the Pin④ has been set inside the IC to about 2.4V.

## ■ Supplementary Explanation (Cont.)

②Elimination of noise components

The high-pass filter is configured with $C_4$ and $R_3$, and the low-pass filter with $C_5$ and $R_4$. Noise components are eliminated by these filters. The cut-off frequencies $f_{CH}$ and $f_{CL}$ are as follows.

$$f_{CH} \simeq \frac{1}{2\pi \cdot C_4 \cdot R_3}$$

$$f_{CL} \simeq \frac{1}{2\pi \cdot C_5 \cdot R_4}$$

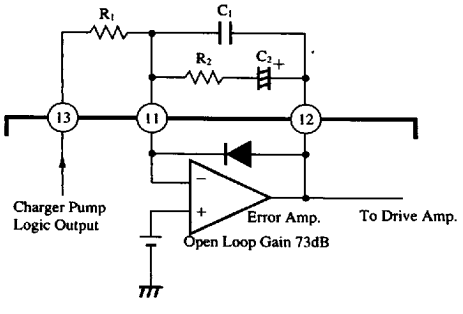
Suppose the FG frequency is $f_{FG}$, make setting so that the following condition will be satisfied.

$$f_{CH} < f_{FG} < f_{CL}$$

### (4) Error Amplifier Block

The error amplifier smoothes and amplifiers a speed detection error.

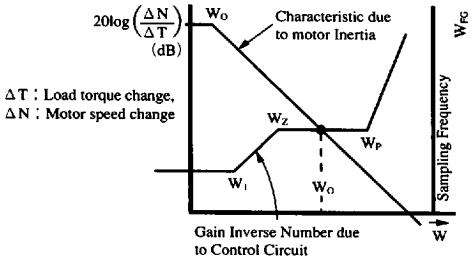
Main characteristics such as control system stability, transient characteristics, etc. are determined in this block.




①Obtaining the constants C and R

The body chart of the control system is shown below. Phase advance/delay compensation is combined by Miller integral in order to improve the characteristics in the low frequency range.

The frequencies at the respective pole and zero points are as follows




$W_O$ : 1/ (motor's time constant)

$W_1$ : 1/ (Miller intergral time constant)

$W_Z$ : $1/C_2R_2$

$W_P$ : $1/ (C1//C_2)\ R_2$

②An important point to set the constants is to set the frequency $W_0$dB at the gain intersection so that the condition of $W_Z < W_O < W_P$ will be satisfied. This assures stability of the control system.

Normally, set as follows.

$K_1 = W_P/W_Z$ = approx.10 $K_P = W_{FG}/W_O > 20$

ICs for Motor

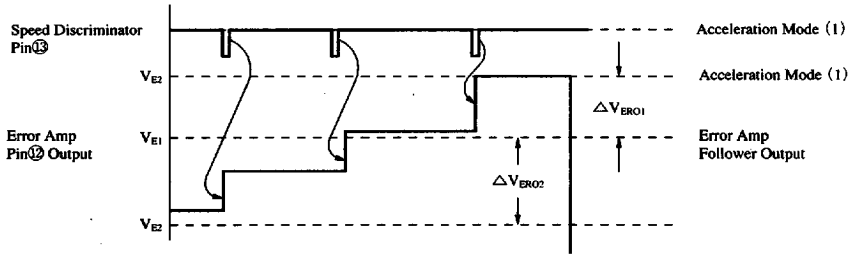
## ■ Supplementary Explanation (Cont.)

(5) Speed discriminator and error amplifier block

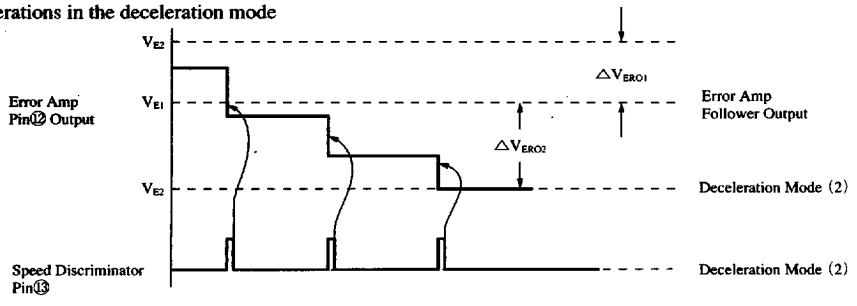
A waveform shaped FG signal and the reference frequency oscillated from the OSC block are compared by the speed discriminator, and a signal is output to the error amplifier.

An output change of the error amplifier changes motor drive current and keeps the motor speed constantly.

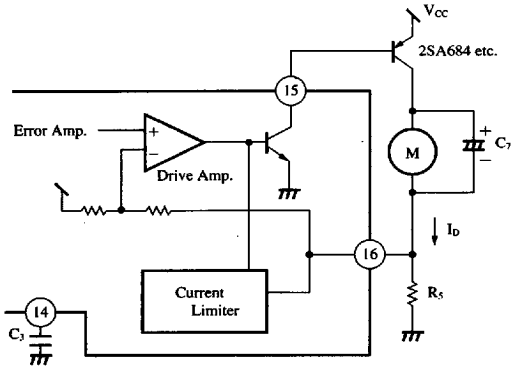
①Operations in the acceleration mode




②Operations in the deceleration mode




(6) Predrive block



## ■ Supplementary Explanation (Cont.)

Connect the motor drive power PNP transistor to the predrive output Pin⑮. Adjust the wattage of the power PNP transistor to the motor working condition.

The resistor $R_5$ is used to detect a current flowing to the motor and works as a current limiter. The reference voltage of the current limiter has been designed at 0.25V±10%.

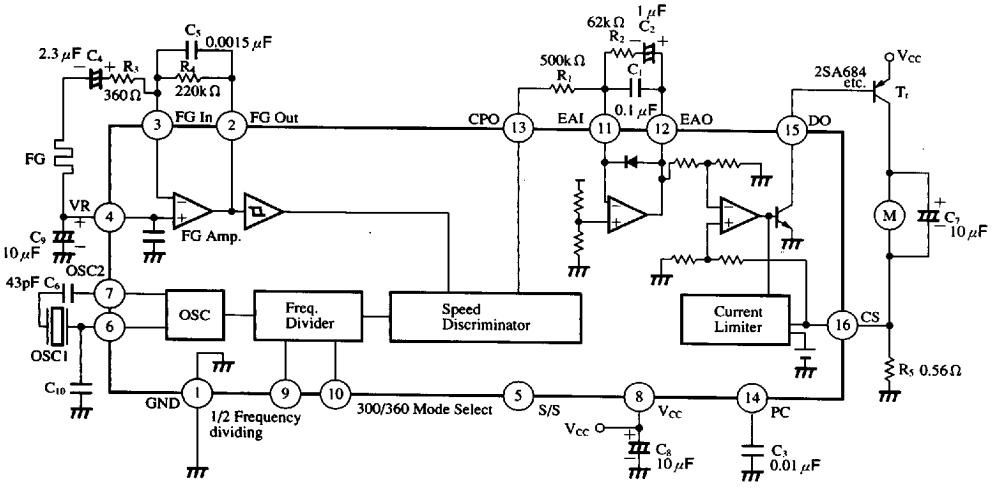
The capacitor $C_3$ is for phase compensation. When parasitic oscillation may occur depending on a type of motor, connect the capacitor $C_7$ to prevent parasitic oscillation.

(7) Start/stop

Motor rotation can be started/stopped with the Pin⑤.

The logic level starts at Low and stops at High. At the stop mode, current consumption can be reduced very much to as low as 500 μA or less.

(8) External parts




| External Part No. | | Recommended value | Function |
|---|---|---|---|
| $R_1$, $R_2$ | $C_1$, $C_2$ Note 1) | — | Integration constant |
| $R_3$, $R_4$ | $C_4$, $C_5$ Note 2) | — | FD amp. filter constant |
| | $C_3$ Note 3) | 0.01 μF to 0.1 μF | Filter constant |
| $R_5$ Note 4) | | 0.56Ω | Current detection |
| | $V_6$, $C_{10}$ Note 5) | — | OSC/AC conpling |
| | $C_7$ Note 6) | 0.1 μF to 10 μF | For stablization |
| | $C_8$ Note 7) | 0.1 μF to 10 μF | Power supply noise measure |
| | $C_9$ Note 8) | 0.1 μF to 10 μF | For stabilization |

Note 1) For $C_1$ and $C_2$, use the types which are less affected by a leak current. If you use those having a leak current, the motor speed will deviate.
(Example) When $C_1$=0.1 μF and $C_2$=1 μF and $R_1$=20Ω, a leak current of 125nA corresponds to 0.1% rotational deviation.

Note 2) When setting the closed loop gain of the FG amplifier to about 60dB, use the types less affected by a leak current for $C_4$, $C_5$.
In this case, note that the leak current will be the DC offset of an output voltage.
(Example) When $R_1$=100Ω and $R_2$=100kΩ, if the leak current of the capacitor is 1 μA, it will be a 100mV offset.

Note 3) It is for phase compensation of the current feedback loop and current limiter loop.

Note 4) It works as a current limiter when $R_5$ is not equal to 0.

Note 5) They are for fine adjustment of the oscillation frequency $f_{OSC}$.
Use those with low temperature dependency.

Note 6) When oscillation occurs depending on a type of motor, use this part for prevention of oscillation.

Note 7) Attach this part when operations become unstable due to noises coming from the power supply.

Note 8) Attach this part when the FD amplifier output becomes unstable due to noises.