

# HA13426

## Three-Phase Motor Driver with Speed Discriminator

### Description

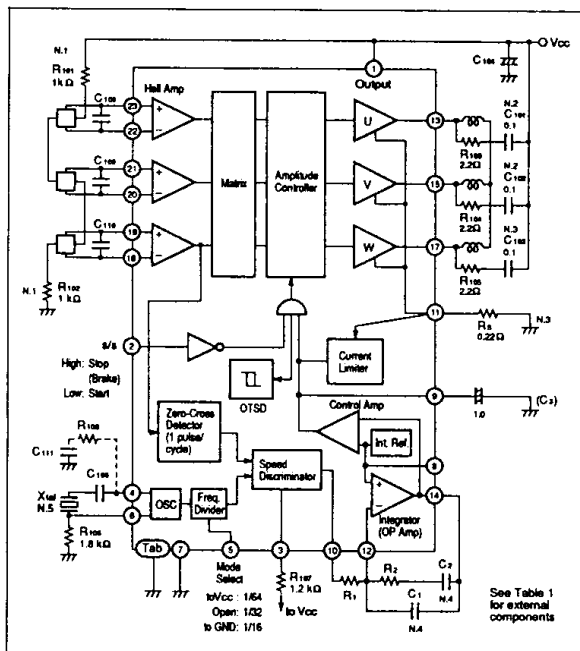
The HA13426 power IC for driving the three-phase brushless motor of 5.25 inch-HDD (hard disk drive) includes a speed discriminator. It is possible to construct a servo system with by adding a quartz resonator and few external components.

Because it uses a voltage drive system, it controls EMI (electro magnetic interference) noise from the motor driver.

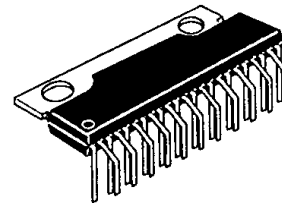
### Features

- Single-chip servo system
- Large output current (3A)
- Digital servo system requires no adjustment.
- The voltage drive system (not supply voltage control) causes almost no spike voltage at commutation which causes EMI in conventional systems
- TTL-level START/STOP terminal
- Load-short brake at STOP mode
- Built-in current limiter depresses maximum current at starting.
- Frequency divide permits wide selection for quartz resonator.

### Block Diagram

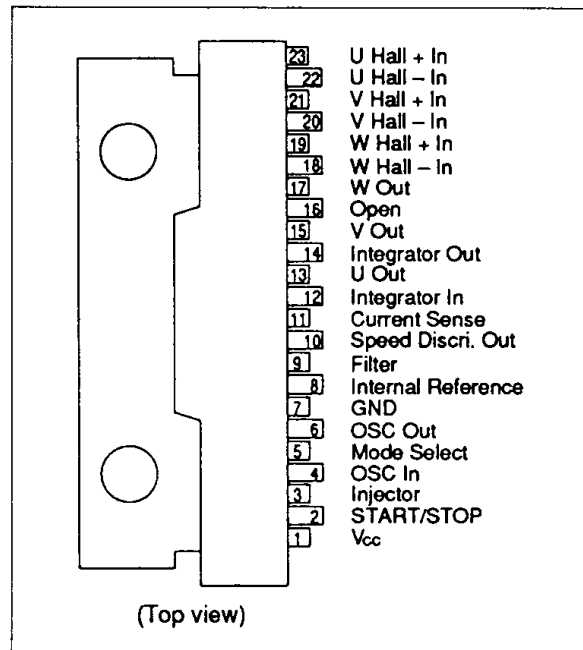


HA13426



(SP-23TA)

### Pin Arrangement



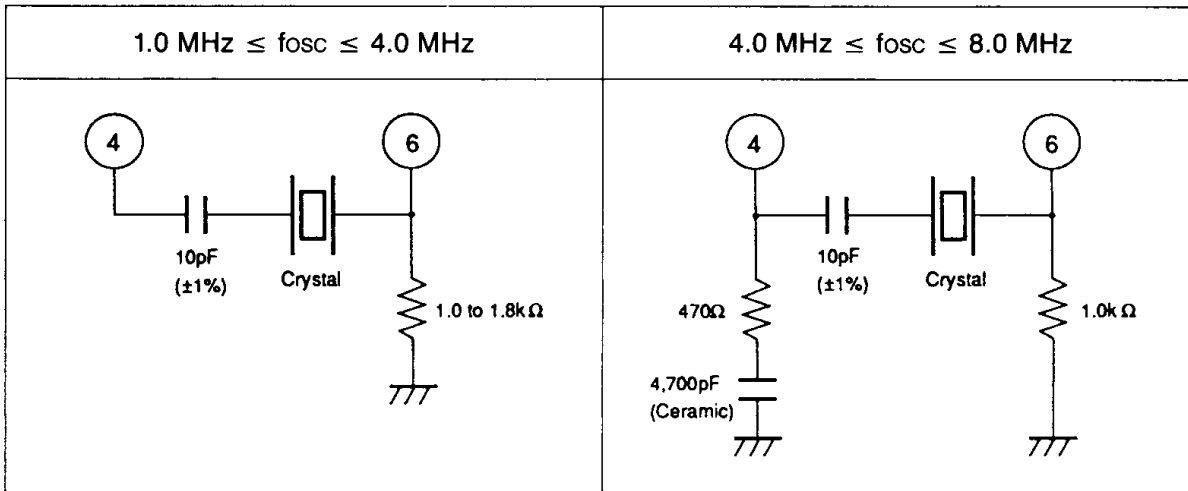
### Ordering Information

Type No.	Package
HA13426	SP-23TA

**Table 1 External Components**

Part No.	Recommended Value	Function	Note
R101, R102	1 kΩ	Hall effect element bias	1
R103, R104, R105	2.2 Ω (0.5 W)	Stability	
R106	1.8 kΩ	OSC bias	6
R107	1.2 kΩ	Speed descrim. bias	
R108	470 Ω	Stability	6
R1,R2	See functional description	Integration constant	
Rs	—	Current sense	3
C101, C102, C103	0.1 μF	Stability	2
C104	≥0.1 μF	Vcc bypassing	
C106	10 pF	AC coupling OSC	
C108, C109, C110	≥0.01 μF	Stability	
C111	4700 pF	Stability	5
C1,C2	See functional description	Integration constant	4
C3	See functional description	Filter constant	
Xtal	See functional description	Resonator	

- Notes:
- Set R101 and R102 so that output voltage of more than 50 mVpp is applied to hall-effect elements.
  - Use capacitors for C101 to C103 which cause no 2nd resonance. Connect the common points of C101, C102, and C103 to the most stable of Vcc, GND, on the middle point of the coil (use non-polar capacitor when connecting them to the middle point of the coil).
  - Output current is limited as shown below by Rs value.
 
$$I_{\text{limit}} = \frac{0.56 \text{ V} \pm 10 \%}{R_s(\Omega)}$$
 For example, output current is limited to 2.55 A ± 10 % at Rs=0.22 Ω
  - C1 and C2 must be nonpolar.
  - Determine external components of Oscillator as shown below in accordance with the frequency range.



**Functional Description**

**Resonator Selection**

HA13426: The synchronous oscillating frequency,  $f_{osc}$ , and the motor rotation speed  $N$  have the relationship;

$$N = \frac{60}{512} \cdot \frac{m \cdot f_{osc}}{p} \text{ (rpm)} \dots\dots\dots (1)$$

where  $p$  is the number of motor poles and  $m$  is the dividing ratio of the divider. The mode select pin determines  $m$  (Table 2).

**Table 2 Dividing Ratio**

Mode Select	$m$
GND	1/16
Open	1/32
Vcc	1/64

Table 3 shows sample values of  $f_{osc}$  to rotate a 4-poles motor at 3600 rpm.

**Table 3  $f_{osc}$  Examples**

Mode Select	$f_{osc}$ (MHz)
GND	1.96608
Open	3.93216
Vcc	7.86432

HA13431/432/432MP: The synchronous oscillating frequency  $f_{osc}$ , and the FG frequency,  $f_{FG}$ , have the relationship;

$$f_{FG} = \frac{m \cdot f_{osc}}{1024} \dots\dots\dots (2)$$

where  $m$  is the dividing ratio of the divider, and determined by one of the mode select pin (Table 4).

**Table 4 Dividing Ratio**

Mode Select	$m$
GND	1
Open	1/2
Vcc	1/4

**Determining Integration Constants  $R_1$ ,  $R_2$ ,  $C_1$ , and  $C_2$ , and Filter Constant  $C_3$**

Figure 1 is the block diagram showing motor speed control by the HA13426/431/432/432MP. The part enclosed by dotted lines denotes the IC, and  $G_1$  (S) and  $G_2$  (S) indicate an integrator transfer function and the transfer function from control amp to output, respectively. Since these ICs are driven by voltage, the motor coil impedance and the kick-back voltage are contained in the loop.

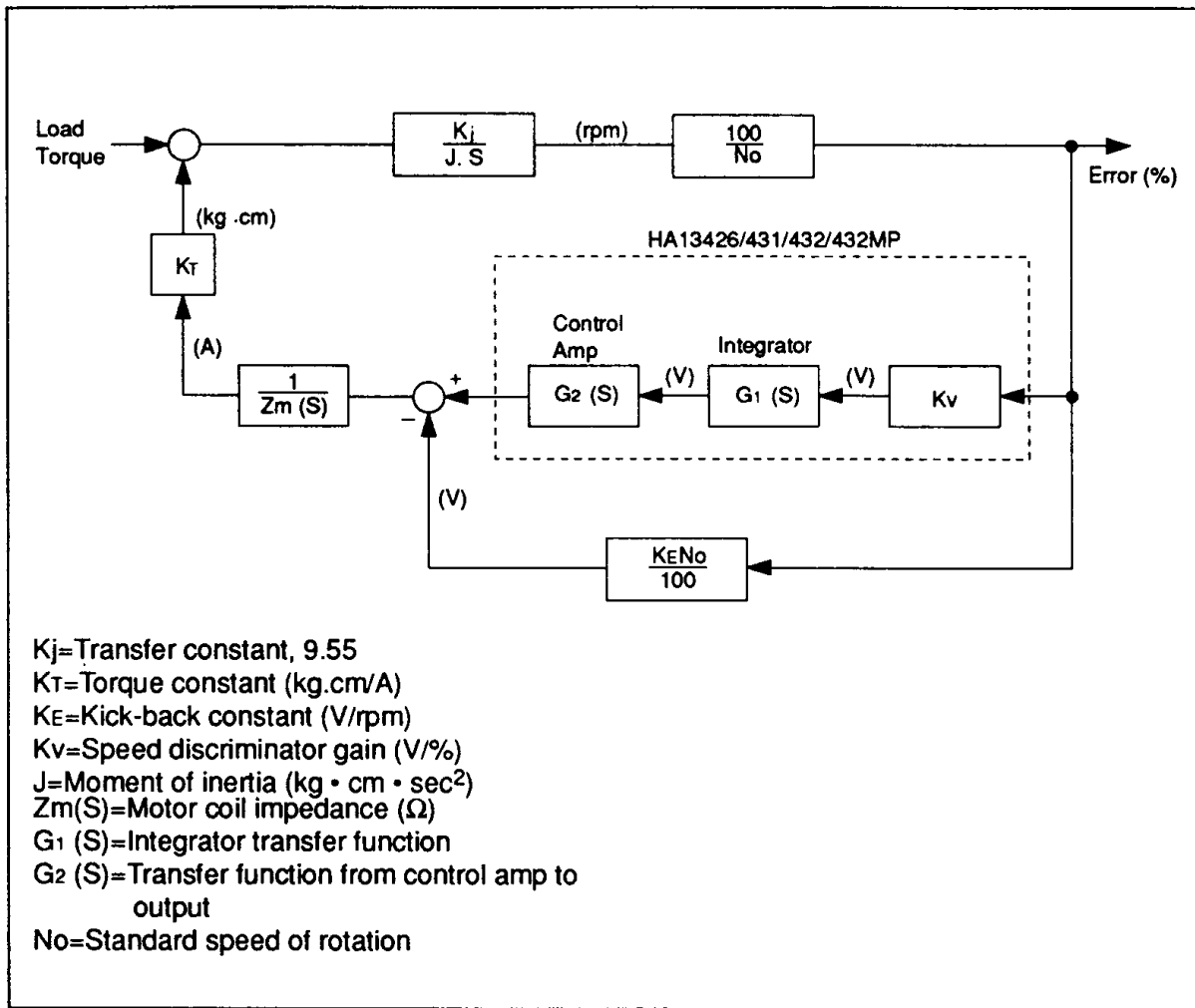


Figure 1 Block Diagram

In Figure 1, when

$$A(S) = \frac{K_j}{J \cdot S} \cdot \frac{100}{N_o} \dots\dots\dots(3)$$

$$\beta(S) = \frac{K_T}{Z_m(S)} (K_v \cdot G_1(S) \cdot G_2(S) - \frac{K_e \cdot N_o}{100}) \dots\dots(4)$$

Then Figure 1 can be shown in Figure 2.

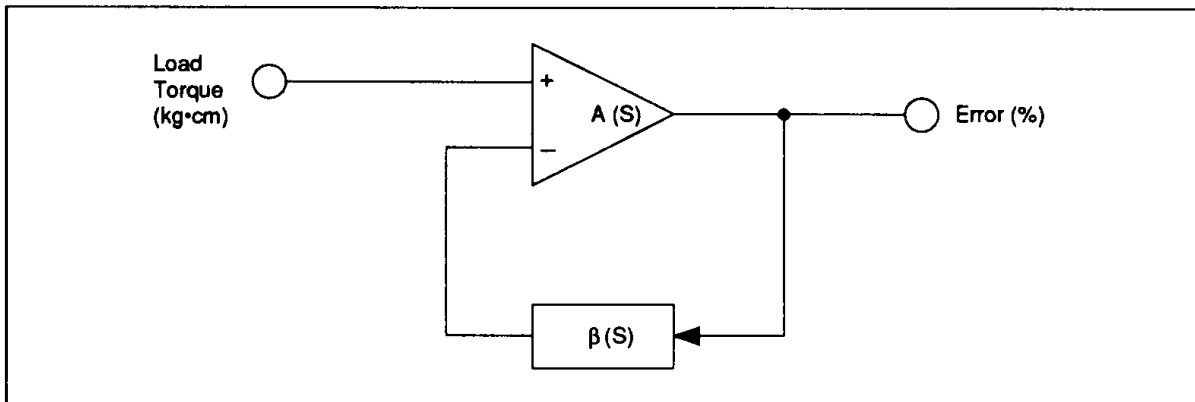


Figure 2 Simplified Block Diagram



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On the other hand,  $Z_m(S)$ ,  $G_1(S)$ , and  $G_2(S)$  are expressed as follows;

$$Z_m(S) = R_m(1+S/\omega_m) \dots\dots\dots (5)$$

$$G_1(S) = \frac{R_2}{R_1} \frac{1+\omega_2/S}{1+S/\omega_1} \dots\dots\dots (6)$$

$$G_2(S) = \frac{G_{CTL}}{1+S/\omega_3} \dots\dots\dots (7)$$

Then,

$$\omega_m = \frac{R_m}{L_m} \dots\dots\dots (8)$$

$$\omega_1 = \frac{1}{C_1 R_2} \dots\dots\dots (9)$$

$$\omega_2 = \frac{1}{C_2 R_2} \dots\dots\dots (10)$$

$$\omega_3 = \frac{1}{C_3 R_3} \dots\dots\dots (11)$$

$G_{CTL}$  and  $R_3$  are the internal constant of the IC. Substituting equations (5) to (11) into equation (4),  $\beta(S)$ , gives

$$\beta(S) = \frac{K_T}{R_m(1+S/\omega_m)} \left( \frac{R_2 K_v G_{CTL} (1+\omega_2/S)}{R_1 (1+S/\omega_1) (1+S/\omega_3)} \frac{K_E N_o}{100} \right) \\ = \frac{R_2 K_T K_v G_{CTL}}{R_1 R_m} \frac{1+\omega_2/S}{(1+S/\omega_m) (1+S/\omega_1) (1+S/\omega_3)} \dots\dots\dots (12)$$

assuming  $\left( \frac{R_2 K_v G_{CTL}}{R_1} \gg \frac{K_E N_o}{100} \right)$

To control speed within a stable fashion,  $A(S)$  and  $\beta(S)$  must have the relationship shown in Figure 3. That is, the angular frequency of the crosspoint of  $A(S)$  and  $\beta(S)$ ,  $\omega_o$ , should be between the angular frequency of the integrator,  $\omega_1$  and  $\omega_2$ .

Determining  $\omega_o$ :  $\omega_o$  uses the value of 1/10 to 1/30 of the  $\omega_m$  or the angular frequency of FG,  $\omega_{FG}$ , whichever is lower. In the HA13426, the angular frequency of the Hall-effect signal is used for  $\omega_{FG}$ , and the  $\omega_o$  has the value of 1/30 to 1/100 of  $\omega_{FG}$ . Calculating  $A_o$  from equation(3):

$$A_o = \frac{K_j}{J \cdot \omega_o} \frac{100}{N_o} \dots\dots\dots (13)$$

Designing  $R_1$  and  $R_2$

From Figure 3 and equation (12):

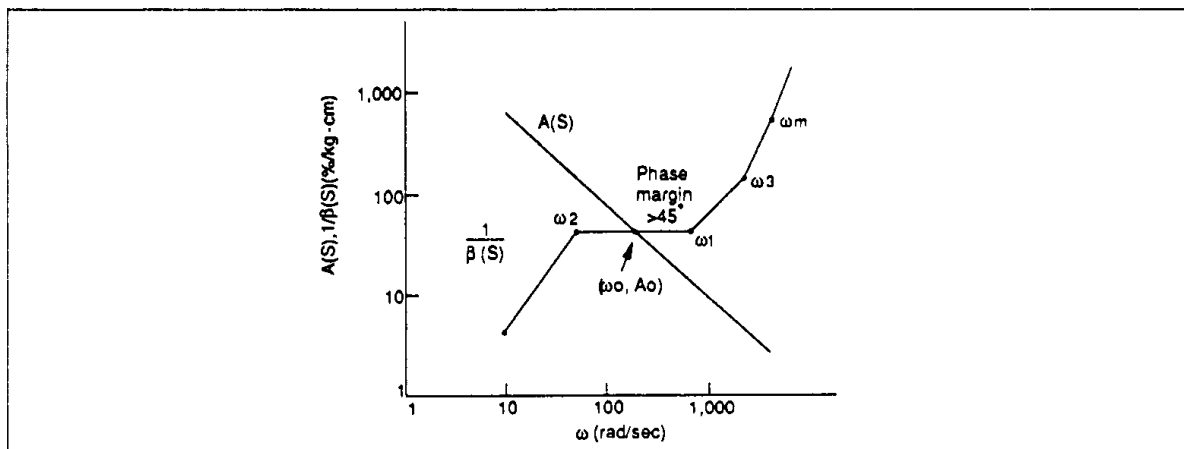
$$\frac{R_2}{R_1} = \frac{R_m}{K_T \cdot K_v \cdot G_{CTL} \cdot A_o} \dots\dots\dots (14)$$

Each IC is designed with  $K_v$  and  $G_{CTL}$  as shown in Table 5.

**Table 5  $K_v$  and  $G_{CTL}$**

Type	$K_v(V/\%)$	$G_{CTL}(V/V)$
HA13426	0.03	16 typ
HA13431	0.023	16 typ
HA13432/MP	0.023	8 typ

Small  $R_1$  increases  $C_1$  and  $C_2$  and large  $R_1$  will cause speed error by the cutoff current of the speed discriminator and the input bias current of the integrator. Values of 10-56k $\Omega$  are recommended.



**Figure 3 Stable Relationship of  $A(S)$  and  $\beta(S)$**



Determining  $\omega_1, \omega_2$  and  $\omega_3$ :

$$\omega_1 \geq 3\omega_0$$

$$\omega_2 \leq \omega_0/3$$

$$\omega_3 \geq 3\omega_0$$

Designing  $C_1, C_2, C_3$ : from equations (9), (10), (11),

$$C_1 = 1/\omega_1 R_2$$

$$C_2 = 1/\omega_2 R_2$$

$$C_3 = 1/\omega_3 R_3$$

where the  $R_3$  is  $22k\Omega$ .

**Using an External Clock**

As shown in Figure 4 an external clock can be provided at the OSC input pin. But applying too large an input causes mis-operation of the IC. Resistor  $R_s$  must be connected in series to control the current.

HA13426:

$$R_s \geq 2.5(V_{IH} - 1.4) - 1.5 \text{ (k}\Omega\text{)}$$

$$R_s \leq 7.5(1.4 - V_{IL}) - 1.5 \text{ (k}\Omega\text{)}$$

A speed-up capacitor parallel to  $R_s$  should be considered.

HA13431/432/432MP:

$$R_s \geq 3.7(V_{IH} - 1.7) - 2 \text{ (k}\Omega\text{)}$$

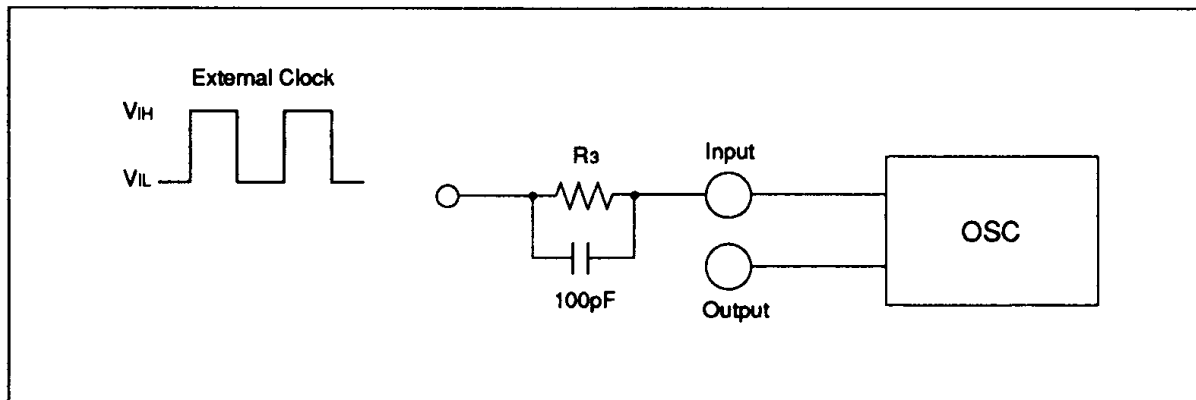
$$R_s \leq 1.0(1.7 - V_{IL}) - 2 \text{ (k}\Omega\text{)}$$

The input currents,  $I_{IH}$  and  $I_{IL}$ , are restricted as follows and the external clock must have a larger driving capacity:

$$I_{IH} = \frac{V_{IH} - 1.4}{R_s + R_i} \text{ (mA)}$$

$$I_{IL} = \frac{1.4 - V_{IL}}{R_s + R_i} \text{ (mA)}$$

where  $R_i$ , the input resistance of OSC, is  $1.5 k\Omega$  in HA13426 or  $2 k\Omega$  in the others.



**Figure 4 External Clock**

**Producing the Ready Signal**

As shown in Figure 5, an external comparator can produce the ready signal. Since the DC gain is extremely high (70dB or more), the rotation error,  $\Delta N$ , when the ready signal  $V_R$  becomes high is

determined by the accuracy of the speed discriminator without the influence of the comparator window.

Open collector output type comparators are recommended.

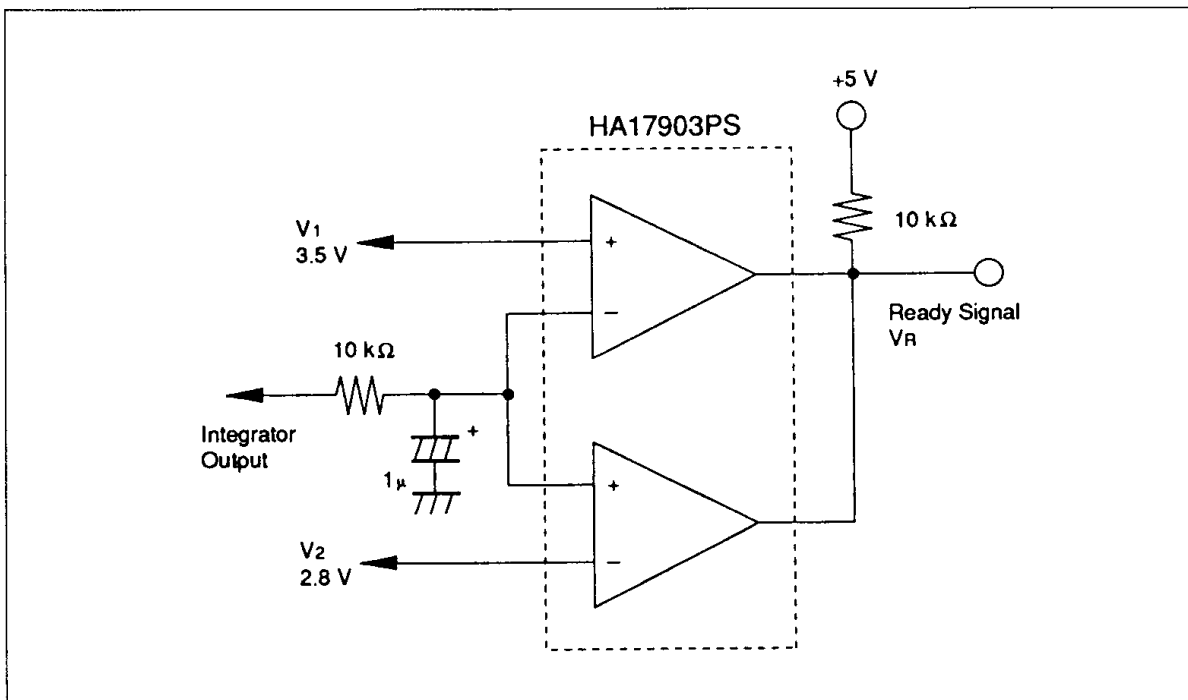


Figure 5 Ready Signal

Table 5 Absolute Maximum Ratings (Ta = 25° C)

Item	Symbol	Ratings	Unit	Note
Supply voltage	V <sub>CC</sub>	15	V	1
Input voltage	V <sub>IN</sub>	0 to V <sub>CC</sub>	V	2
Output current	I <sub>O</sub>	3	A	
Power dissipation	P <sub>T</sub>	25	W	3
Junction temperature	T <sub>j</sub>	150	°C	
Operating junction temperature range	T <sub>JP</sub>	-20 to +125	°C	
Storage temperature range	T <sub>STG</sub>	-55 to +125	°C	

The absolute maximum ratings are limiting values, to be applied individually, beyond which the device may be permanently damaged. Functional operation under any of these conditions is not guaranteed. Exposing a circuit to its absolute maximum rating for extended periods of time may affect the device's reliability.

- Notes:
- Recommended operating voltage:  
V<sub>CC</sub> = 12 V ± 15 % (10.2 to 13.8V)
  - Applied to Hall-effect element amp, mode select input.  
Maximum input voltage at start/stop is 6 V.
  - Thermal resistance:  
θ<sub>j-r</sub> ≤ 3°C/W  
θ<sub>j-a</sub> ≤ 40°C/W

**Table 6 Electrical Characteristics (Ta=25°C, Vcc=12 V)**

Item		Symbol	Min	Typ	Max	Unit	Test Condition
Total	Supply current	I <sub>so</sub>	—	50	70	mA	S/S = 2.0 V
		I <sub>s</sub>	—	55	75	mA	S/S = 0.8 V, R <sub>L</sub> = Open
	Over-temperature protection	T <sub>sd</sub>	—	150	—	°C	Shutdown
		T <sub>hys</sub>	—	20	—	°C	Hysteresis
Hall-effect element amp	Input bias current	I <sub>HB</sub>	—	2	10	μA	V <sub>H</sub> = 6.0 V
	Input common mode voltage range	V <sub>H</sub>	2.0	—	10	V	
	Voltage gain	G <sub>VH</sub>	—	10	—	dB	
Output stage	Quiescent output voltage	V <sub>Q</sub>	5.3	5.9	6.5	V	
	Phase difference	ΔV <sub>Q</sub>	—	—	±0.3	V	
	Saturation voltage (Note)	V <sub>CE(sat)1</sub>	—	2.4	3.2	V	I <sub>o</sub> = 2 A
	Output impedance	R <sub>o</sub>	—	0.2	—	Ω	I <sub>o</sub> = 0.4 A
Control amp	Internal ref. voltage	V <sub>ref1</sub>	3.0	3.2	3.4	V	
	Voltage gain (CTL amp to output)	G <sub>CTL</sub>	21	24	27	dB	
	Difference of gain	ΔG <sub>CTL</sub>	—	—	±2	dB	
Integrator	Input bias current	I <sub>B</sub>	—	—	±0.1	μA	
	Output voltage swing	A	—	0.7	—	V	I <sub>o</sub> = 0.3 mA
		A	—	0.7	—	V	I <sub>o</sub> = -0.3 mA
Speed discriminator	Output voltage swing	V <sub>OH</sub>	5.8	6.1	—	V	I <sub>o</sub> = 0.3 mA
		V <sub>OL</sub>	—	—	0.2	V	I <sub>o</sub> = -0.3 mA
	Cutoff current	I <sub>off</sub>	—	—	±0.1	μA	Charge pump off
	Operating frequency	f <sub>CLK</sub>	60	—	250	kHz	
	Count number	N	—	1024	—		
Start/stop	Input high voltage	V <sub>IH</sub>	2.0	—	—	V	Stop
	Input low voltage	V <sub>IL</sub>	—	—	0.8	V	Start
	Input high current	I <sub>IH</sub>	—	-0.15	-0.5	mA	V <sub>H</sub> = 2.0 V
	Input low current	I <sub>IL</sub>	—	-0.2	-0.5	mA	V <sub>L</sub> = 0.8V



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## Electrical Characteristics (Ta=25°C, Vcc=12 V) (cont)

Item	Symbol	Min	Typ	Max	Unit	Test Condition	
Current limiter	Reference voltage	0.52	0.56	0.60	V		
Mode select	1/16 division input voltage	$V_{1/16}$	—	—	0.8	V	
	1/32 division input voltage	$V_{1/32}$	—	6.3	—	V	Open
	1/64 division input voltage	$V_{1/64}$	11.2	—	—	V	
	1/16 division input current	$I_{1/16}$	—	-0.63	-1.3	mA	$V_{IN} = 0 V$
	1/64 division input current	$I_{1/64}$	—	1.0	1.5	mA	$V_{IN} = 12 V$
Oscillator	Operating frequency	$f_{osc}$	—	—	8.0	MHz	

Note: Sum of upper and lower transistor saturation voltages

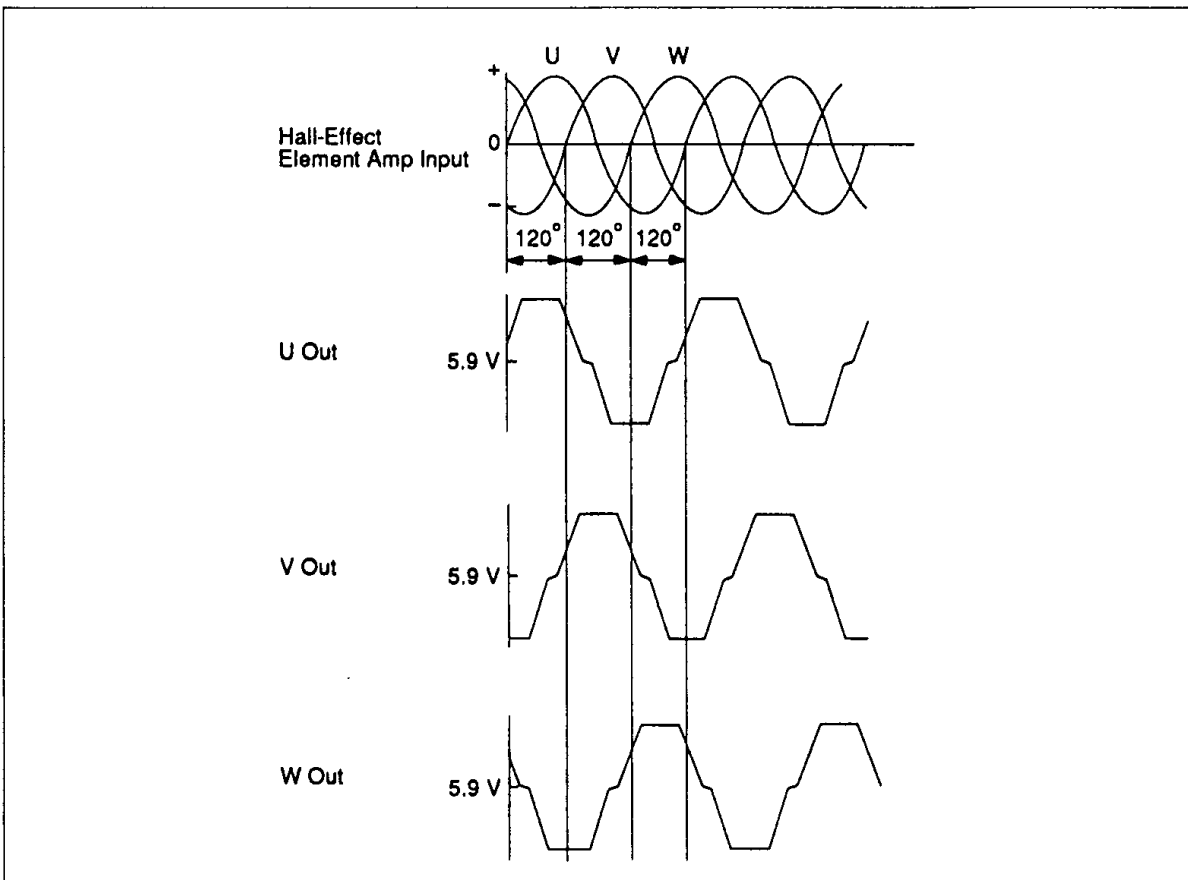


Figure 6 Timing Waveform

