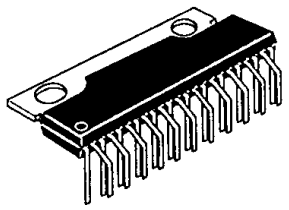
HA13426

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.

HA13426

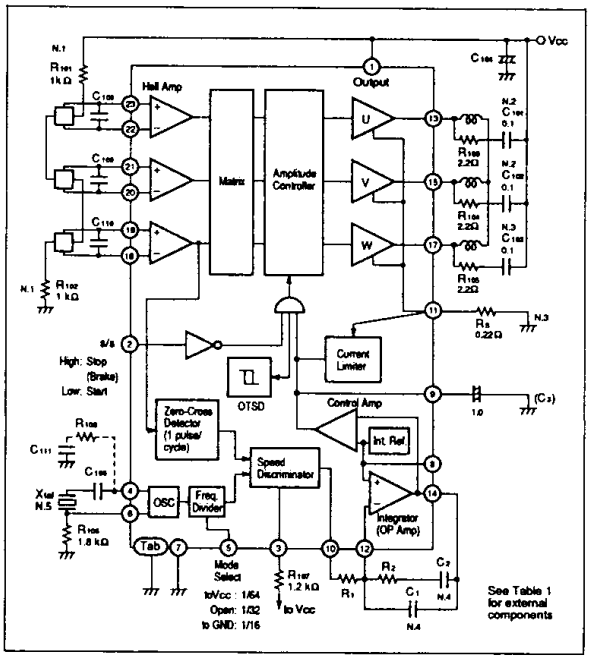


(SP-23TA)

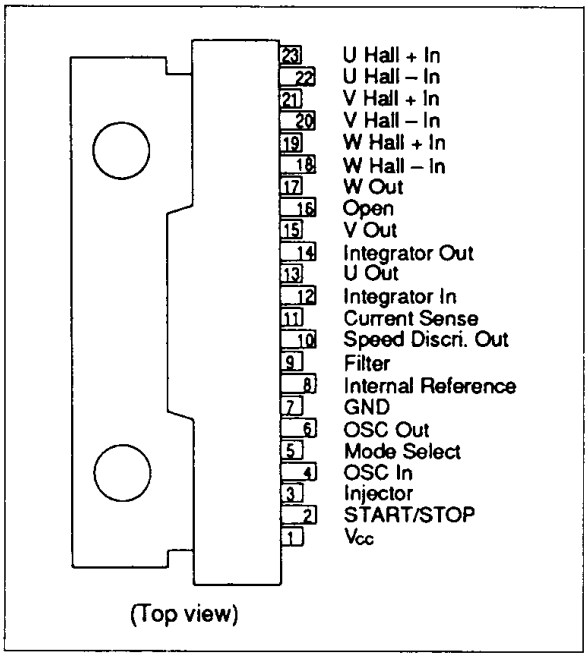
Features

- 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



Pin Arrangement



(Top view)

Ordering Information

Type No.	Package
HA13426	SP-23TA

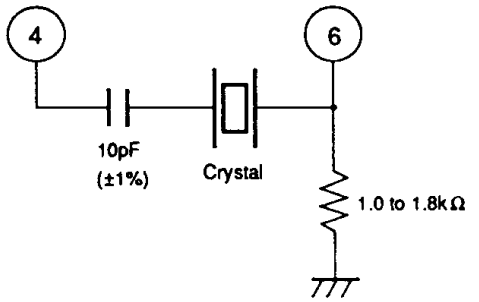
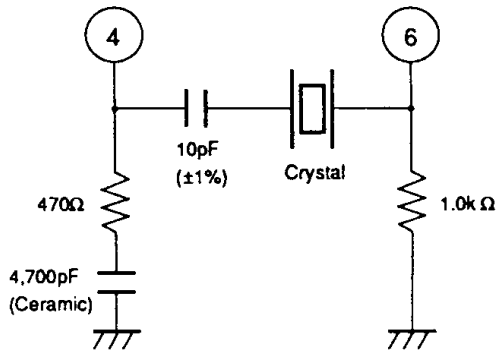
Table 1 External Components

Part No.	Recommended Value	Function	Note
R_{101}, R_{102}	1 kΩ	Hall effect element bias	1
R_{103}, R_{104}, R_{105}	2.2 Ω (0.5 W)	Stability	
R_{106}	1.8 kΩ	OSC bias	6
R_{107}	1.2 kΩ	Speed descrim. bias	
R_{108}	470 Ω	Stability	6
R_1,R_2	See functional description	Integration constant	
Rs	—	Current sense	3
C_{101}, C_{102}, C_{103}	0.1 μF	Stability	2
C_{104}	≥0.1 μF	Vcc bypassing	
C_{106}	10 pF	AC coupling OSC	
C_{108}, C_{109}, C_{110}	≥0.01 μF	Stability	
C_{111}	4700 pF	Stability	5
C_1,C_2	See functional description	Integration constant	4
C_3	See functional description	Filter constant	
Xtal	See functional description	Resonator	

Notes:
1. Set R101 and R102 so that output voltage of more than 50 mVpp is applied to hall-effect elements.
2. 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).
3. Output current is limited as shown below by Rs value.

$$Ilimit = \frac{0.56\ V \pm 10\ \%}{Rs(\Omega)}$$

   For example, output current is limited to 2.55 A±10 % at Rs=0.22 Ω
4. C1 and C2 must be nonpolar.
5. Determine external components of Oscillator as shown below in accordance with the frequency range.

1.0 MHz ≤ fosc ≤ 4.0 MHz	4.0 MHz ≤ fosc ≤ 8.0 MHz
	

Functional Description

Resonator Selection

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

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

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;

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

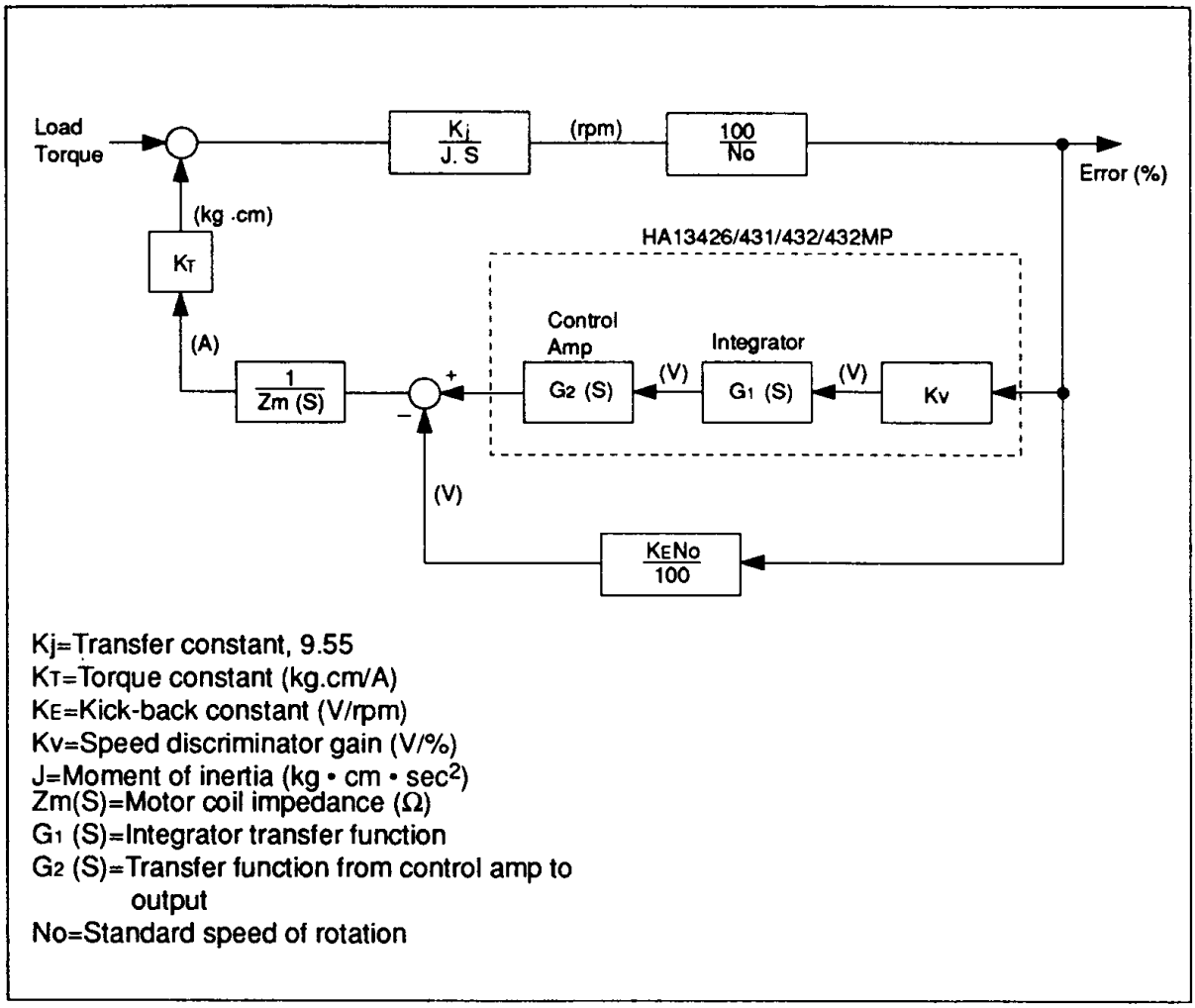
where m is the dividing ratio of the divider, and determined by one of the mode select pin (Table 4).

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.



Kj=Transfer constant, 9.55
K_T=Torque constant (kg.cm/A)
K_E=Kick-back constant (V/rpm)
Kv=Speed discriminator gain (V/%)
J=Moment of inertia (kg • cm • sec^2)
Zm(S)=Motor coil impedance (Ω)
G_1 (S)=Integrator transfer function
G_2 (S)=Transfer function from control amp to output
No=Standard speed of rotation

Figure 1 Block Diagram

In Figure 1, when

$$A(S) = \frac{Kj}{J \cdot S} \cdot \frac{100}{No} \quad \text{.....(3)}$$

$$\beta(S) = \frac{K_T}{Zm(S)} (Kv \cdot G_1(S) \cdot G_2(S) - \frac{K_E \cdot No}{100} \quad \text{.. (4)}$$

Then Figure 1 can be shown in Figure 2.

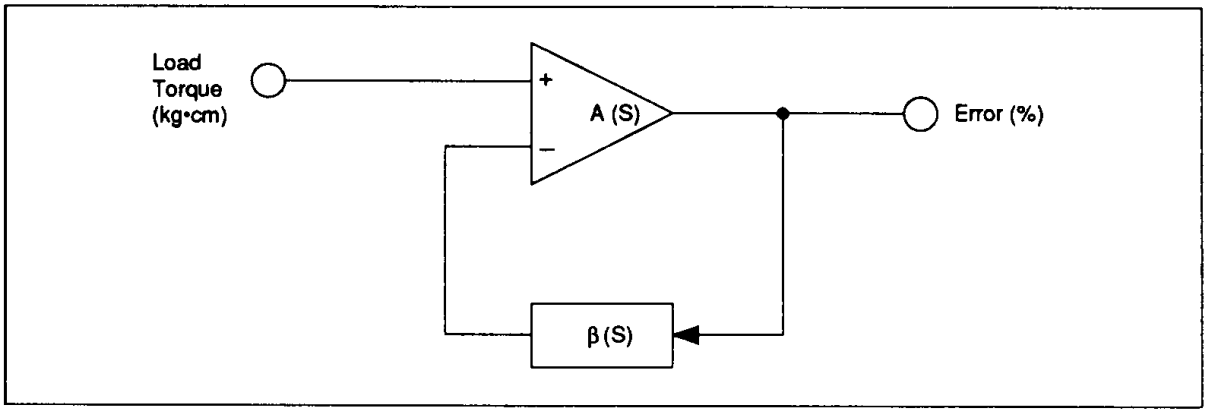


Figure 2 Simplified Block Diagram

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

$$Zm(S)=Rm(1+S/\omega m) \quad \ldots\ldots (5)$$

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

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

Then,

$$\omega_m = \frac{Rm}{Lm} \quad \ldots\ldots (8)$$

$$\omega_1 = \frac{1}{C_1R_2} \quad \ldots\ldots (9)$$

$$\omega_2 = \frac{1}{C_2R_2} \quad \ldots\ldots (10)$$

$$\omega_3 = \frac{1}{C_3R_3} \quad \ldots\ldots (11)$$

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

$$\beta(S)=\frac{K_T}{Rm(1+S/\omega m)}\left(\frac{R_2K_VG_{CTL}(1+\omega_2/S)}{R_1(1+S/\omega_1)(1+S/\omega_3)} \cdot \frac{K_EN_O}{100}\right)$$

$$=\frac{R_2K_TK_VG_{CTL}}{R_1Rm} \cdot \frac{1+\omega_2+/S}{(1+S/\omega m)\,(1+S/\omega_1)\,(1+S/\omega_3)} \quad \ldots\ldots (12)$$

$$\text{assuming}\left(\frac{R_2K_VG_{CTL}}{R_1} \gg \frac{K_EN_O}{100}\right)$$

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 $\beta(S)$, ω_o, should be between the angular frequency of the integrator, ω_1 and ω_2.

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

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

Designing R_1 and R_2
From Figure 3 and equation (12):

$$\frac{R_2}{R_1} = \frac{Rm}{K_T \cdot K_V \cdot G_{CTL} \cdot A_o} \quad \ldots\ldots (14)$$

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

Table 5 Kv and G_{CTL}

Type	Kv(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 10-56kΩ are recommended.

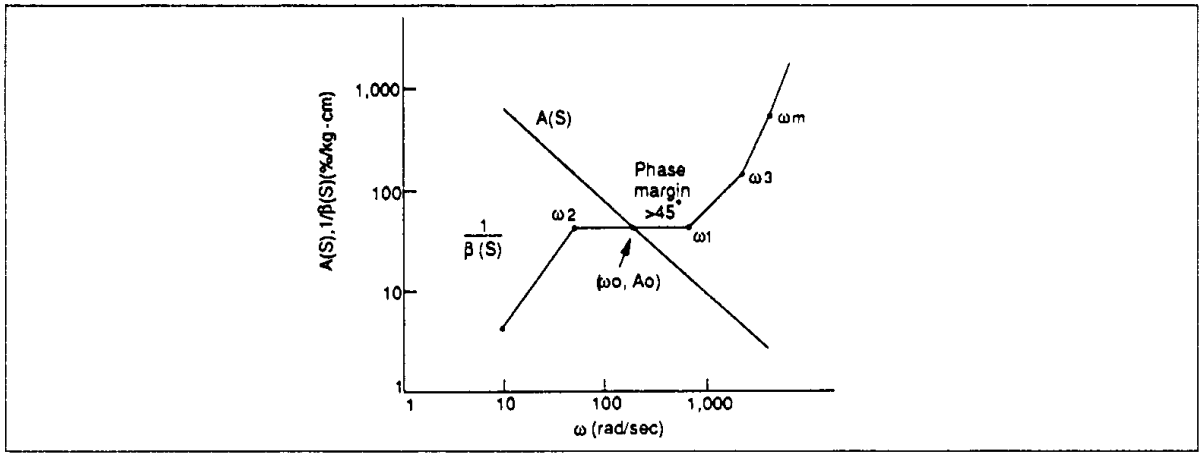


Figure 3 Stable Relationship of A(S) and β(S)

Determining ω_1,ω_2 and ω_3:

$\omega_1 \geq 3\omega_o$

$\omega_2 \leq \omega_o/3$

$\omega_3 \geq 3\omega_o$

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 22kΩ.

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 Rs must be connected in series to control the current.

HA13426:

$Rs \geq 2.5(V_{IH}-1.4)-1.5$ (kΩ)

$Rs \leq 7.5(1.4-V_{IL})-1.5$ (kΩ)

A speed-up capacitor parallel to Rs should be considered.

HA13431/432/432MP:

$Rs \geq 3.7(V_{IH}-1.7)-2$ (kΩ)

$Rs \leq 1.0(1.7-V_{IL})-2$ (kΩ)

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

$$I_{IH} = \frac{V_{IH}-1.4}{Rs+Ri} \quad \text{(mA)}$$

$$I_{IL} = \frac{1.4-V_{IL}}{Rs+Ri} \quad \text{(mA)}$$

where Ri, the input resistance of OSC, is 1.5 kΩ in HA13426 or 2 kΩ in the others.

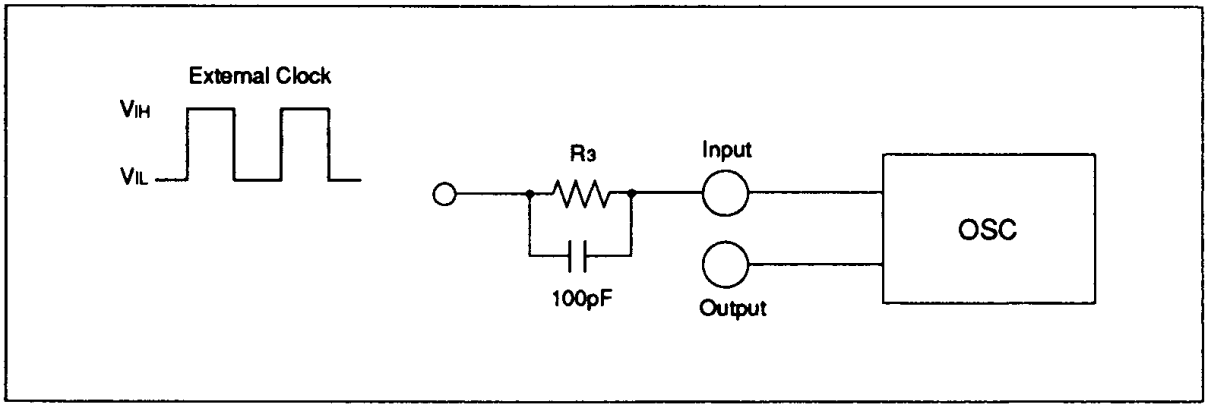


Figure 4 External Clock

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, ΔN, 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.

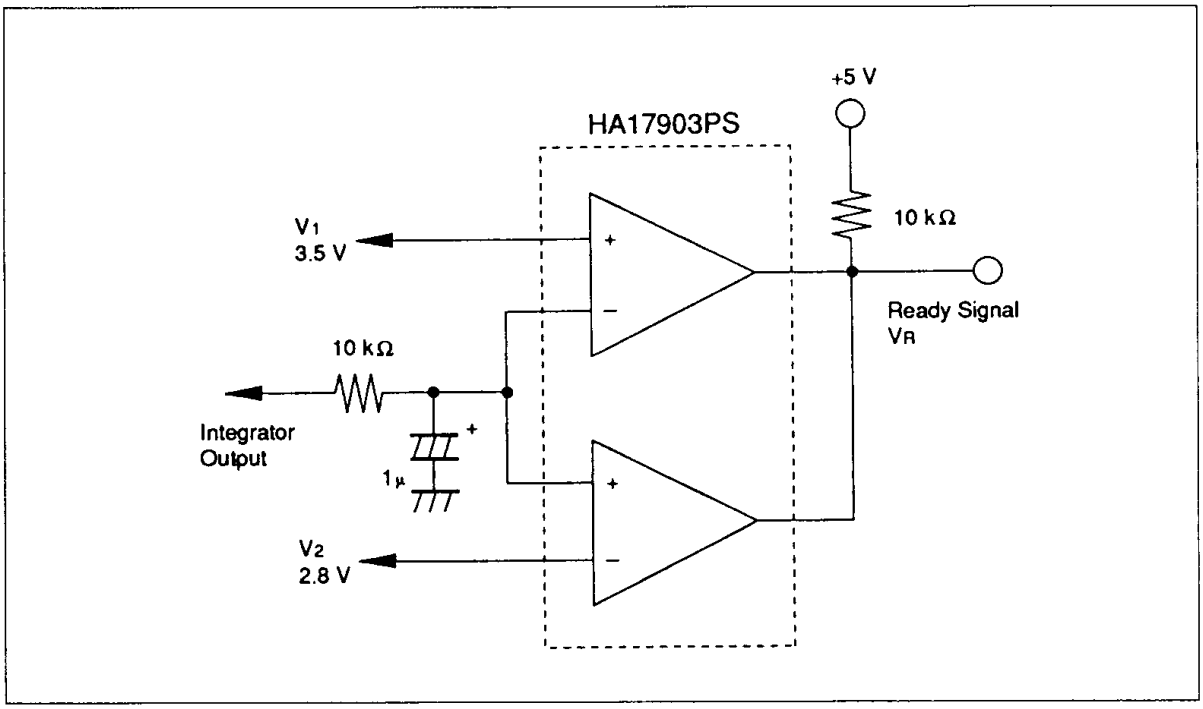


Figure 5 Ready Signal

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

Item	Symbol	Ratings	Unit	Note
Supply voltage	Vcc	15	V	1
Input voltage	VIN	0 to Vcc	V	2
Output current	Io	3	A	
Power dissipation	PT	25	W	3
Junction temperature	Tj	150	°C	
Operating junction temperature range	Tjop	–20 to +125	°C	
Storage temperature range	Tstg	–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: 1. Recommended operating voltage:
Vcc = 12 V±15 % (10.2 to 13.8V)
2. Applied to Hall-effect element amp, mode select input.
Maximum input voltage at start/stop is 6 V.
3. Thermal resistance:
θj-r ≤ 3°C/W
θj-a ≤ 40°C/W

Table 6 Electrical Characteristics (Ta = 25°C, V_{CC} = 12 V)

Item		Symbol	Min	Typ	Max	Unit	Test Condition
Total	Supply vurrent	I_{SO}	—	50	70	mA	S/S = 2.0 V
		I_S	—	55	75	mA	S/S = 0.8 V, R_L = Open
	Over-temperature protection	Tsd	—	150	—	°C	Shutdown
		Thys	—	20	—	°C	Hysteresis
Hall-effect element amp	Input bias current	I_{HB}	—	2	10	μA	V_H = 6.0 V
	Input common mode voltage range	V_H	2.0	—	10	V	
	Voltage gain	G_{VH}	—	10	—	dB	
Output stage	Quiescent output voltage	V_Q	5.3	5.9	6.5	V	
	Phase difference	$\triangle V_Q$	—	—	±0.3	V	
	Saturation voltage (Note)	$V_{CE(sat)1}$	—	2.4	3.2	V	I_O = 2 A
	Output impedance	R_O	—	0.2	—	Ω	I_O = 0.4 A
Control amp	Internal ref. voltage	V_{ref1}	3.0	3.2	3.4	V	
	Voltage gain (CTL amp to output)	G_{CTL}	21	24	27	dB	
	Difference of gain	$\triangle G_{CTL}$	—	—	±2	dB	
Integrator	Input bias current	I_B	—	—	±0.1	μA	
	Output voltage swing	A	—	0.7	—	V	I_O = 0.3 mA
		A	—	0.7	—	V	I_O = -0.3 mA
Speed discrimi-nator	Output voltage swing	V_{OH}	5.8	6.1	—	V	I_O = 0.3 mA
		V_{OL}	—	—	0.2	V	I_O = -0.3 mA
	Cutoff current	I_{off}	—	—	±0.1	μA	Charge pump off
	Operating frequency	f_{CLK}	60	—	250	kHz	
	Count number	N	—	1024	—		
Start/stop	Input high voltage	V_{IH}	2.0	—	—	V	Stop
	Input low voltage	V_{IL}	—	—	0.8	V	Start
	Input high current	I_{IH}	—	-0.15	-0.5	mA	V_H = 2.0 V
	Input low current	I_{IL}	—	-0.2	-0.5	mA	V_L = 0.8V

Electrical Characteristics (Ta = 25°C, V_{CC} = 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

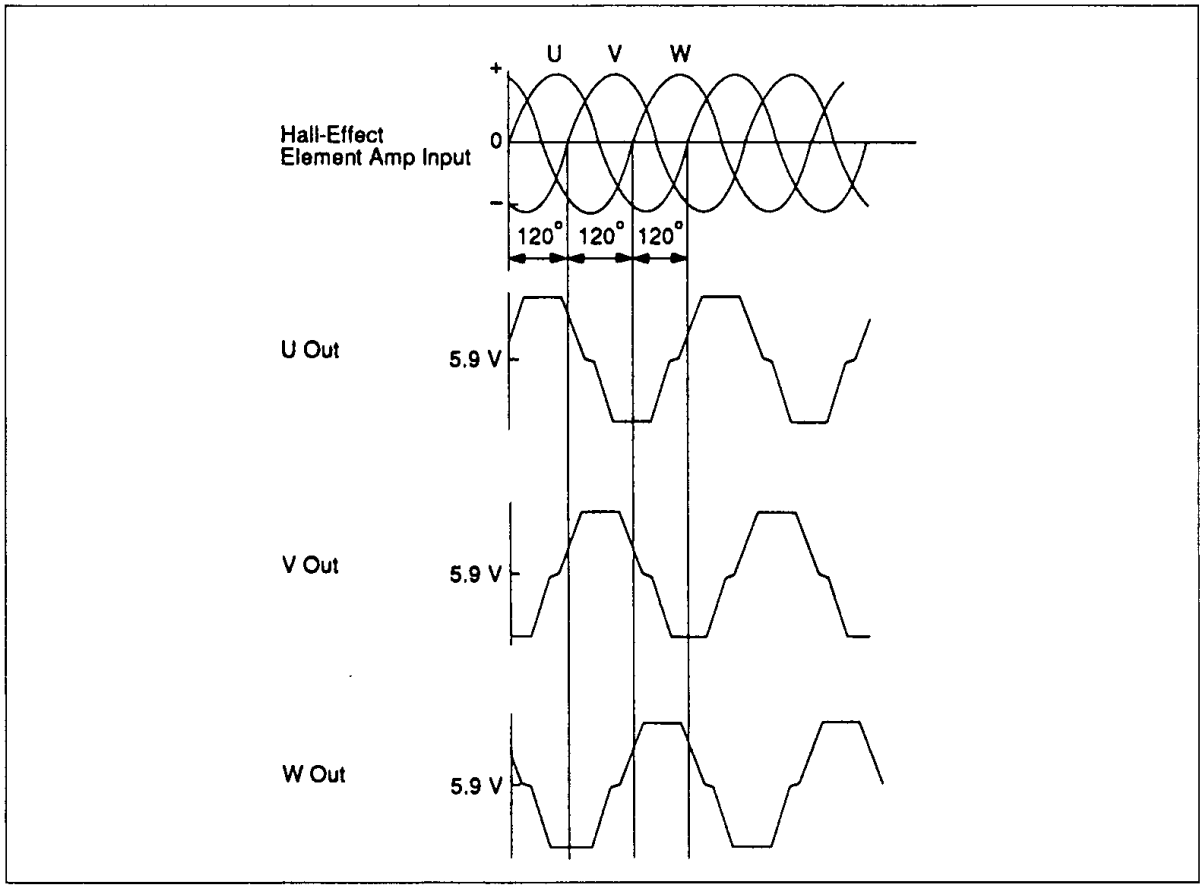


Figure 6 Timing Waveform