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Application Note

Inverter Control by V850 Series

Vector Control by Encoder

V850E/IA1

V850E/IA2

V850E/IA3

V850E/IA4

[MEMO]

NOTES FOR CMOS DEVICES

① VOLTAGE APPLICATION WAVEFORM AT INPUT PIN

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (MAX) and V_{IH} (MIN) due to noise, etc., the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (MAX) and V_{IH} (MIN).

② HANDLING OF UNUSED INPUT PINS

Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to V_{DD} or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.

③ PRECAUTION AGAINST ESD

A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.

④ STATUS BEFORE INITIALIZATION

Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.

⑤ POWER ON/OFF SEQUENCE

In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current.

The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.

⑥ INPUT OF SIGNAL DURING POWER OFF STATE

Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.

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- Product release schedule
- Availability of related technical literature
- Development environment specifications (for example, specifications for third-party tools and components, host computers, power plugs, AC supply voltages, and so forth)
- Network requirements

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INTRODUCTION

Target Readers

This application note is intended for users who understand the functions of the V850E/IA1, V850E/IA2, V850E/IA3, and V850E/IA4, and who design application systems that use these microcontrollers. The applicable products are shown below.

- V850E/IA1
Standard products: μ PD703116, 70F3116
Special products: μ PD703116(A), 703116(A1), 70F3116(A), 70F3116(A1)
- V850E/IA2:
Standard products: μ PD703114, 70F3114
Special products: μ PD703114(A), 70F3114(A)
- V850E/IA3
Standard products: μ PD703183, 70F3184
- V850E/IA4
Standard products: μ PD703185, 703186, 70F3186

Purpose

The purpose of this application note is to help the user understand how a vector is controlled by the encoder using a brushless DC motor that uses PWM output and A/D converter input as a system example of the timer/counter function of the V850E/IA1, V850E/IA2, V850E/IA3, and V850E/IA4.

Organization

This application note is divided into the following sections.

- Control method
- Hardware configuration
- Software configuration
- Program list

How to Use This Manual

It is assumed that the reader of this application note has general knowledge in the fields of electrical engineering, logic circuits, and microcontrollers.

- Cautions 1. Application examples in this manual are intended for the “standard” quality models for general-purpose electronic systems. When using an example in this manual for an application that requires the “special” quality grade, evaluate each component and circuit to be actually used to see if they satisfy the required quality standard.**
- 2. To use this manual for special-grade products, read the part numbers as follows:**

μ PD703114 → μ PD703114(A)
 μ PD70F3114 → μ PD70F3114(A)
 μ PD703116 → μ PD703116(A), 703116(A1)
 μ PD70F3116 → μ PD70F3116(A), 70F3116(A1)

For details of hardware functions (especially register functions, setting methods, etc.) and electrical specifications

→ See the **V850E/IA1 Hardware User's Manual**, **V850E/IA2 Hardware User's Manual**, and **V850E/IA3, V850E/IA4 Hardware User's Manual**.

For details of instruction functions

→ See the **V850E1 Architecture User's Manual**.

Conventions

Data significance:	Higher digits on the left and lower digits on the right
Active low representation:	$\overline{\text{xxx}}$ (overscore over pin or signal name)
Memory map address:	Higher addresses on the top and lower addresses on the bottom
Note:	Footnote for item marked with Note in the text
Caution:	Information requiring particular attention
Remark:	Supplementary information
Numeric representation:	Binary ... xxxx or xxxxB Decimal ... xxxx Hexadecimal ... xxxxH
Prefix indicating the power of 2 (address space, memory capacity):	K (kilo): $2^{10} = 1,024$ M (mega): $2^{20} = 1,024^2$ G (giga): $2^{30} = 1,024^3$
Data type:	Word: 32 bits Halfword: 16 bits Byte: 8 bits

Related Documents

The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such.

Documents related to V850E/IA1, V850E/IA2, V850E/IA3, V850E/IA4

Document Name	Document No.
V850E1 Architecture User's Manual	U14559E
V850E/IA1 Hardware User's Manual	U14492E
V850E/IA2 Hardware User's Manual	U15195E
V850E/IA3, V850E/IA4 Hardware User's Manual	U16543E
V850E/IA1, V850E/IA2 AC Motor Inverter Control Using Vector Operation Application Note	U14868E
Inverter Control by V850 Series 120° Excitation Method Control by Zero-Cross Detection Application Note	U17209E
Inverter Control by V850 Series Vector Control by Encoder Application Note	This manual

Documents related to development tools (user's manuals)

Document Name		Document No.
IE-V850E-MC (In-Circuit Emulator for V850E/IA1, V850E/IA2)		U14487E
IE-V850E1-CD-NW (PCMCIA Card Type On-Chip Debug Emulator for V850E/IA3, V850E/IA4)		U16647E
IE-703116-MC-EM1 (In-Circuit Emulator Option Board for V850E/IA1)		U14700E
IE-703114-MC-EM1 (In-Circuit Emulator Option Board for V850E/IA2)		U16533E
CA850 Ver. 3.00 C Compiler Package	Operation	U17293E
	C Language	U17291E
	Assembly Language	U17292E
	Link Directives	U17294E
PM+ Ver. 6.00		U17178E
ID850 Ver. 2.50 Integrated Debugger	Operation	U16217E
ID850NWC Ver. 2.51 Integrated Debugger (for V850E/IA3, V850E/IA4)	Operation	U16525E
ID850QB Ver. 2.80 Integrated Debugger (for V850E/IA3, V850E/IA4)	Operation	U16973E
SM850 Ver. 2.50 System Simulator (for V850E/IA1, V850E/IA2)	Operation	U16218E
SM850 Ver. 2.00 or Later System Simulator (for V850E/IA1, V850E/IA2)	External Part User Open Interface Specifications	U14873E
SM+ System Simulator (for V850E/IA1, V850E/IA2)	Operation	U17246E
	User Open Interface	U17247E
RX850 Ver. 3.13 or Later Real-Time OS	Basics	U13430E
	Installation	U13410E
	Technical	U13431E
RX850 Pro Ver. 3.15 Real-Time OS	Basics	U13773E
	Installation	U13774E
	Technical	U13772E
RD850 Ver. 3.01 Task Debugger		U13737E
RD850 Pro Ver. 3.01 Task Debugger		U13916E
AZ850 Ver. 3.10 System Performance Analyzer		U14410E
PG-FP4 Flash Memory Programmer		U15260E

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CHAPTER 1 CONTROL METHOD

1.1 Principle of Vector Control

Typically, when controlling a 3-phase motor, voltage and current are indicated as 3-phase AC. However, 2-phase AC is easier to represent than 3-phase AC. Also, control is even simpler when representing biaxial DC rather than 2-phase AC.

When converting biaxial DC (d-q axes), numerous armature coils are connected to the commutator and wound in the radial direction, similar to a DC motor such as is shown in part (c) of Figure 1-1 below. Two voltage values, v_d (d-axis voltage) and v_q (q-axis voltage), are applied and two currents, i_d (d-axis current) and i_q (q-axis current), flow across the brush that is situated along the d-q axis which rotates at the same speed as the electromagnetic field.

In the reference system, the current and voltage are controlled along the d-q axis in the same way as in DC motors.

Figure 1-1. Equivalent Circuits (1/3)

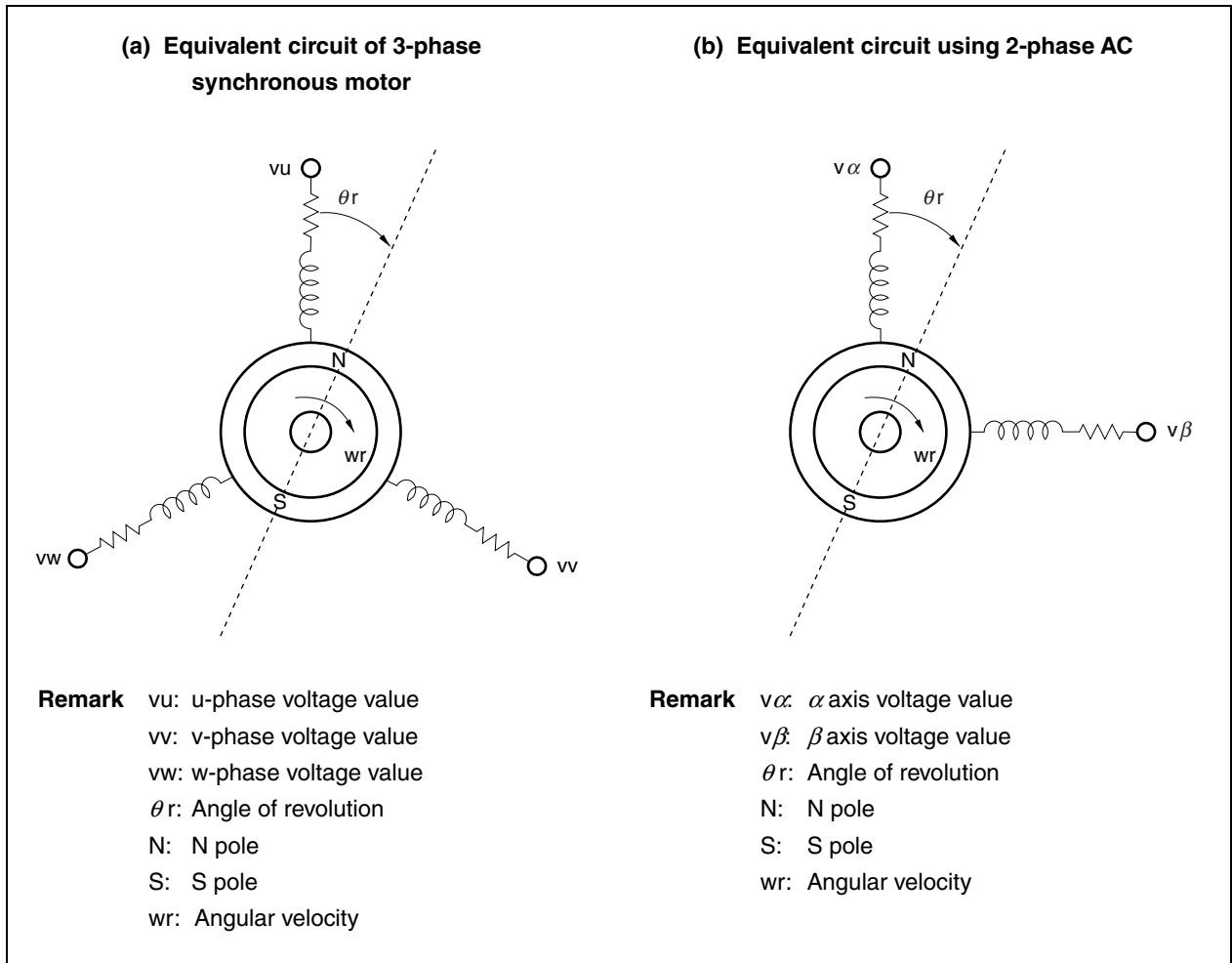
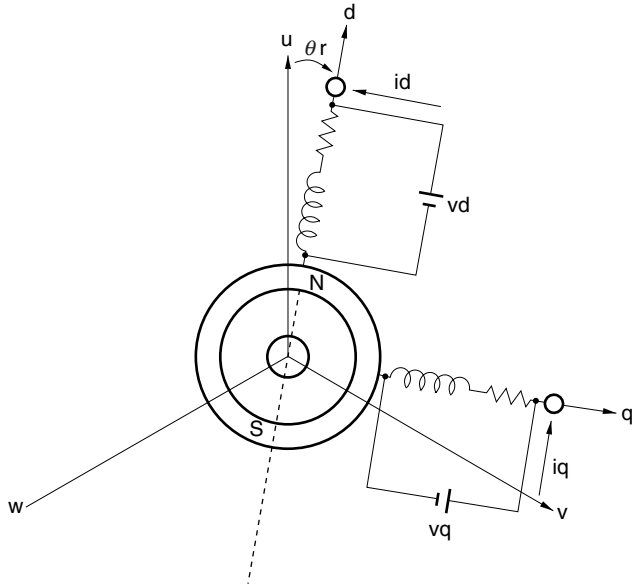


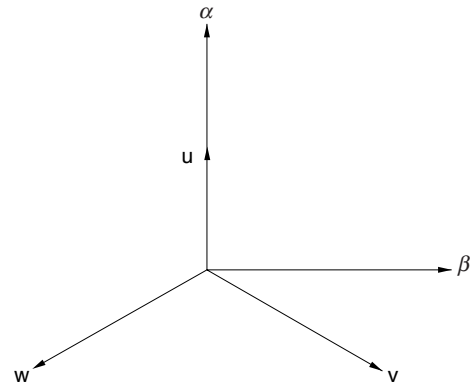
Figure 1-1. Equivalent Circuits (2/3)

(c) Equivalent circuit of biaxial DC type, (d-q) axes



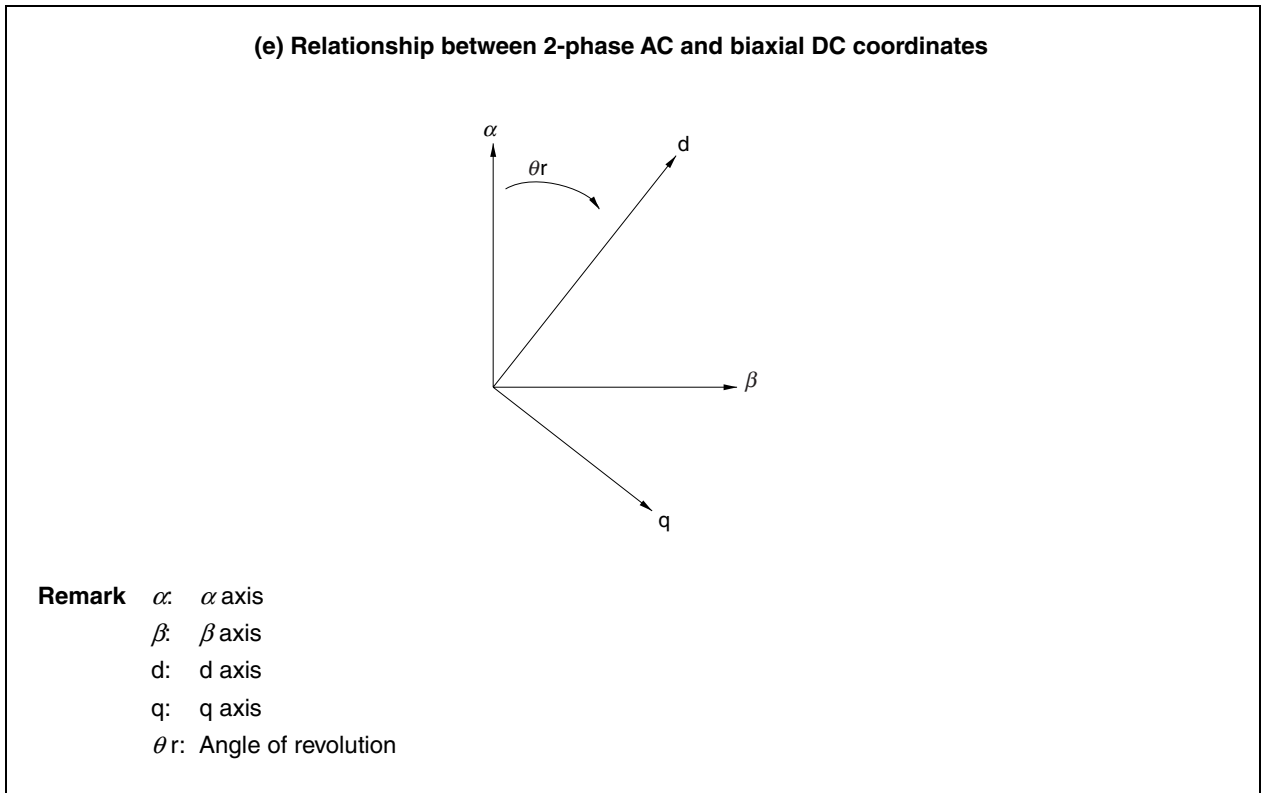
Remark u: u phase
 v: v phase
 w: w phase
 θ_r : Angle of revolution
 N: N pole
 S: S pole
 d: d axis
 id: d-axis current value
 vd: d-axis voltage value
 q: q axis
 iq: q-axis current value
 vq: q-axis voltage value

(d) Relationship between 3-phase and 2-phase AC coordinates



Remark u: u phase
 v: v phase
 w: w phase
 α : α axis
 β : β axis

Figure 1-1. Equivalent Circuits (3/3)



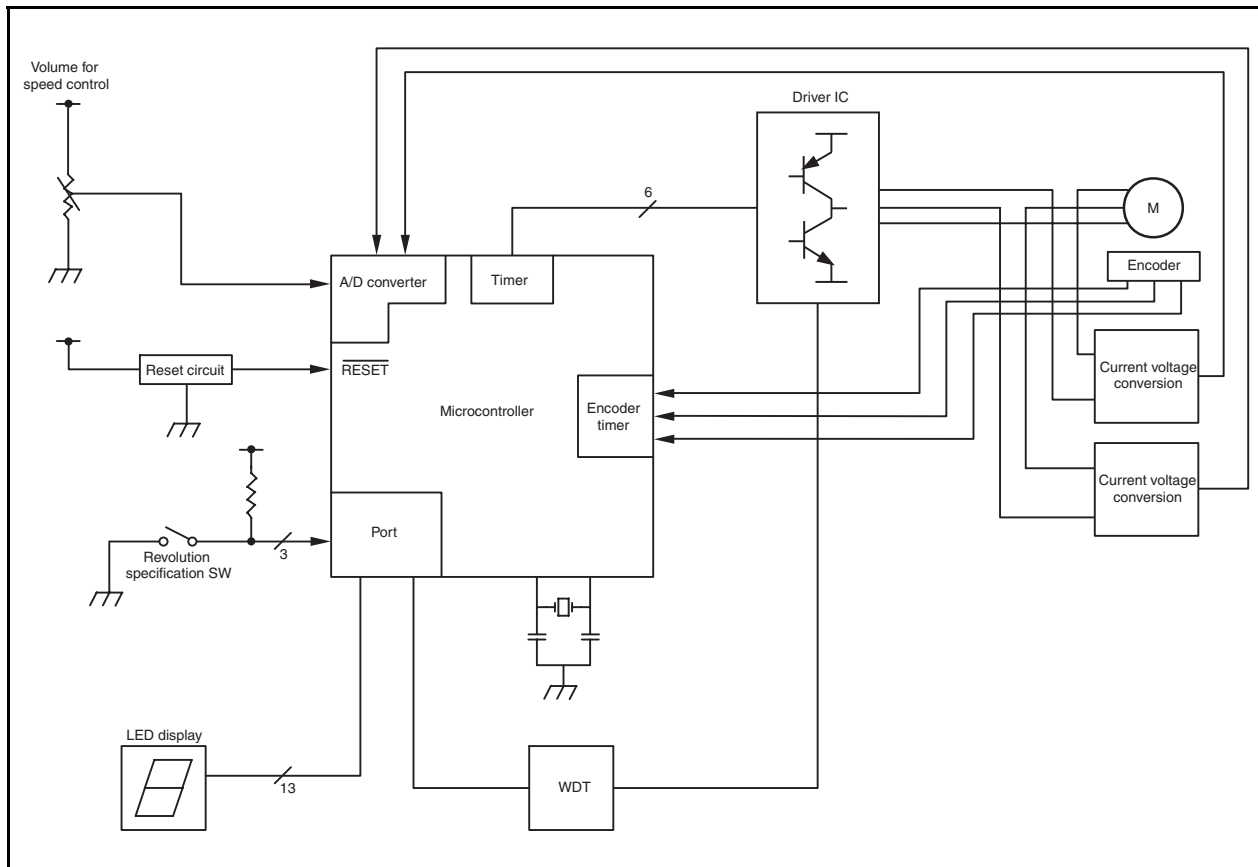
CHAPTER 2 HARDWARE CONFIGURATION

This chapter describes the hardware configuration.

2.1 Configuration

The reference system's main functions are described below. In this reference system, when the revolution specification switch is pressed after power application, the motor starts revolving in the direction specified.

Figure 2-1. Overall System Configuration



(1) Volume for speed control

Volume for increasing and decreasing the number of revolutions of the motor

(2) Revolution specification SW

CW, CCW, and STOP switches

(3) LED display

LED displaying the number of revolutions, operation time, etc.

(4) WDT

Watchdog timer

(5) Driver IC

Driver for driving motor

(6) Current voltage converter

Converting the motor driving current to voltage, used for detecting overcurrent

(7) Encoder timer

Information of revolution and position from the motor

2.2 Circuit Diagram

Figures 2-2 to 2-5 show diagrams of the sample reference system circuit.

This sample reference system circuit diagram includes the V850E/IA1, V850E/IA2, V850E/IA3, or V850E/IA4, a reset circuit, oscillator, a pin handling microcontroller peripheral block, operation mode switch block, LED output block, watchdog timer circuit block, drive circuit block, motor controller, and motor revolution indicator.

(1) Microcontroller and microcontroller peripheral block

The V850E/IA1, V850E/IA2, V850E/IA3, or V850E/IA4 includes a reset circuit, an oscillator that uses a resonator, and a block for handling the MODE pin and unused pins.

(2) Operation mode switch block

This block includes switches that set the operation mode as CW or CCW operation.

(3) LED output block

This block includes 16 LEDs, which are used to indicate the revolution speed (rpm), errors, etc.

(4) Watchdog timer circuit block

This block is specified to output stop signals when pulse output from the V850E/IA1, V850E/IA2, V850E/IA3, or V850E/IA4 stops for one ms or longer.

(5) Drive circuit block

The 6-phase outputs from the inverter timer are converted to U-, V-, and W-phase output for the motor driver. This drive circuit is not shown in detail in this example, since it varies depending on the motor's specifications.

(6) Motor controller

This block includes the HPS-3-AS, LM324, and other devices that are used to measure the motor's U and V drive currents via A/D conversion.

(7) Motor revolution indicator

This block includes a volume adjuster and the LM324 for setting the motor's revolution speed (rpm).

Figure 2-2. Circuit Diagram of V850E/IA1

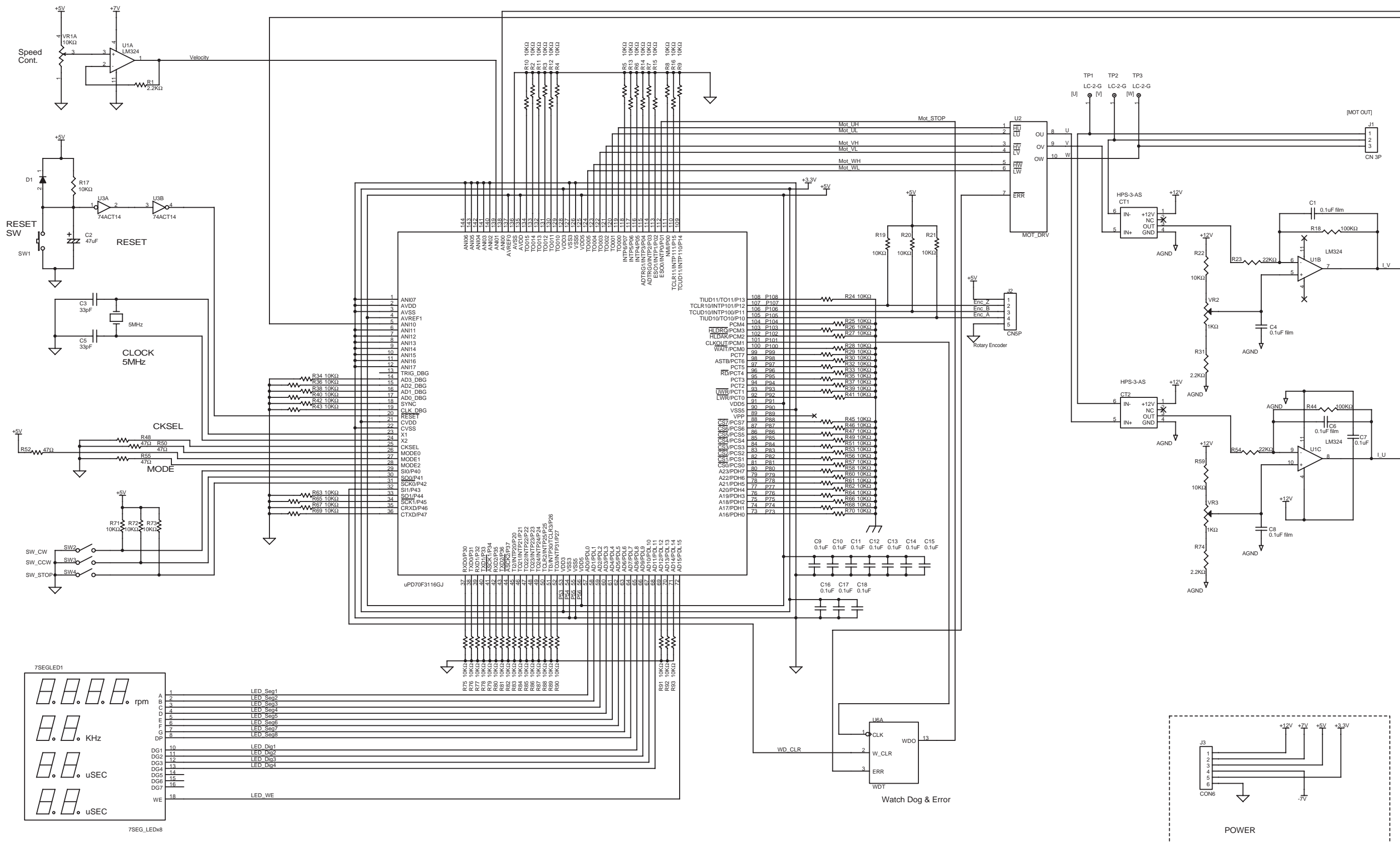


Figure 2-3. Circuit Diagram of V850E/IA2

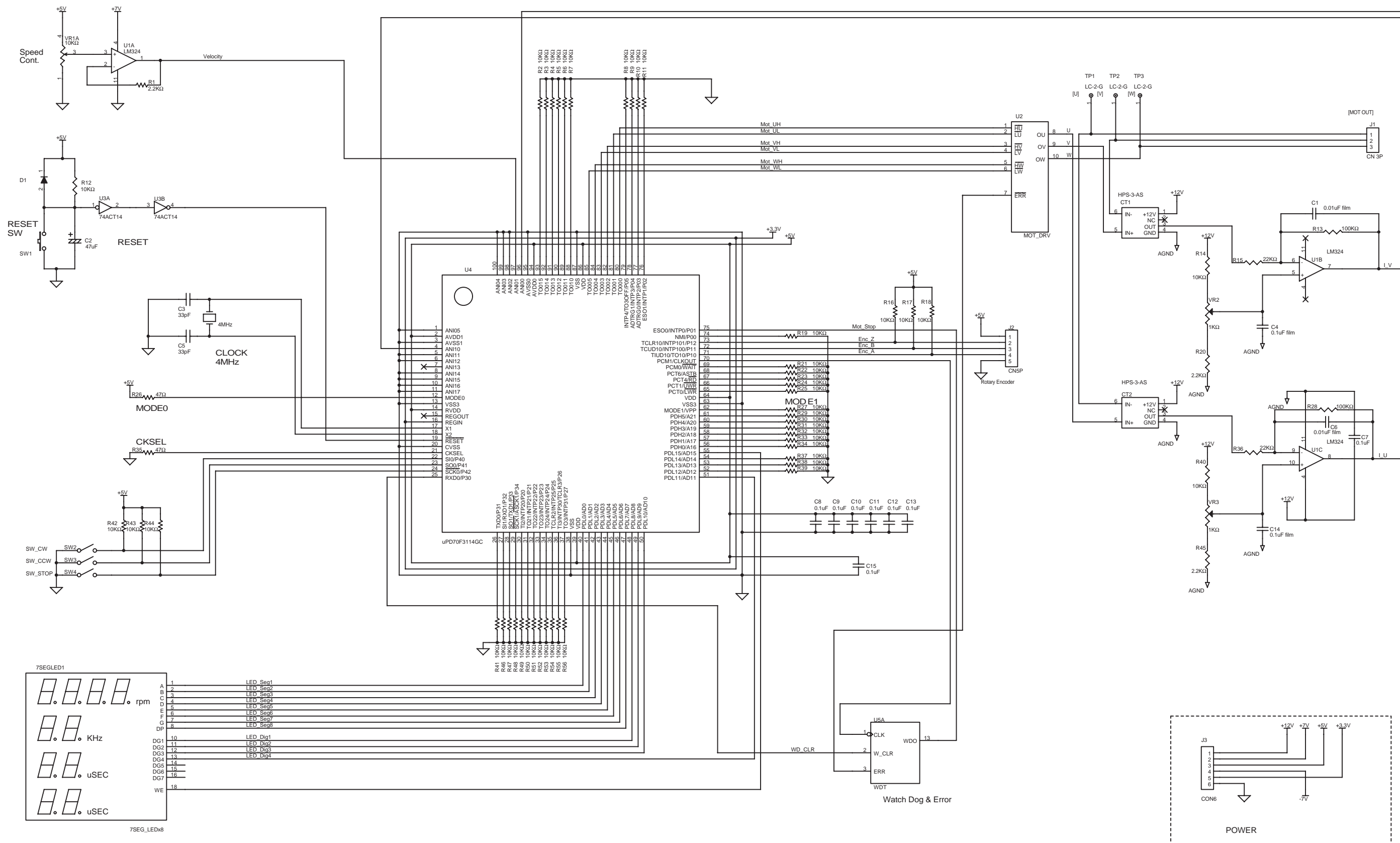


Figure 2-4. Circuit Diagram of V850E/IA3

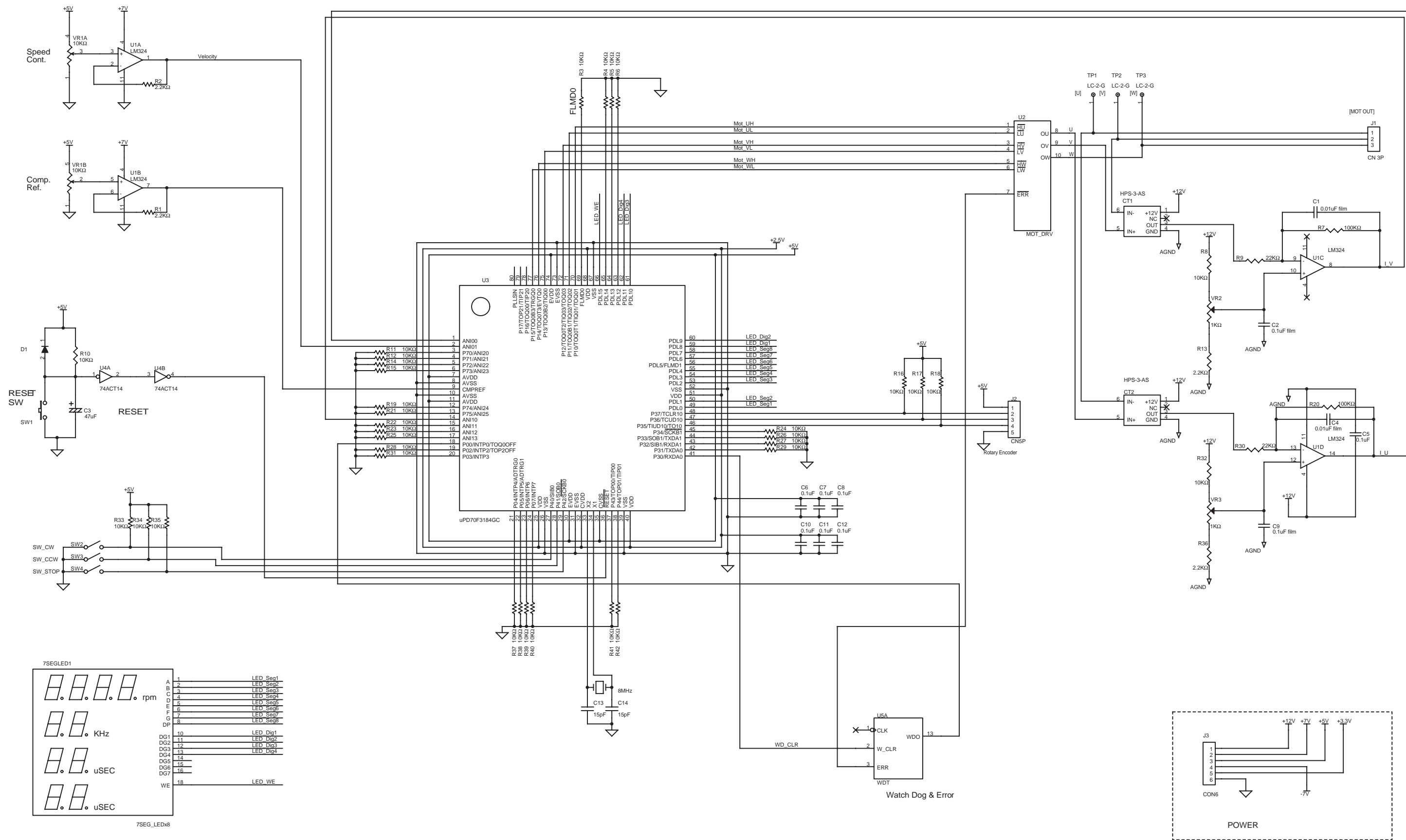
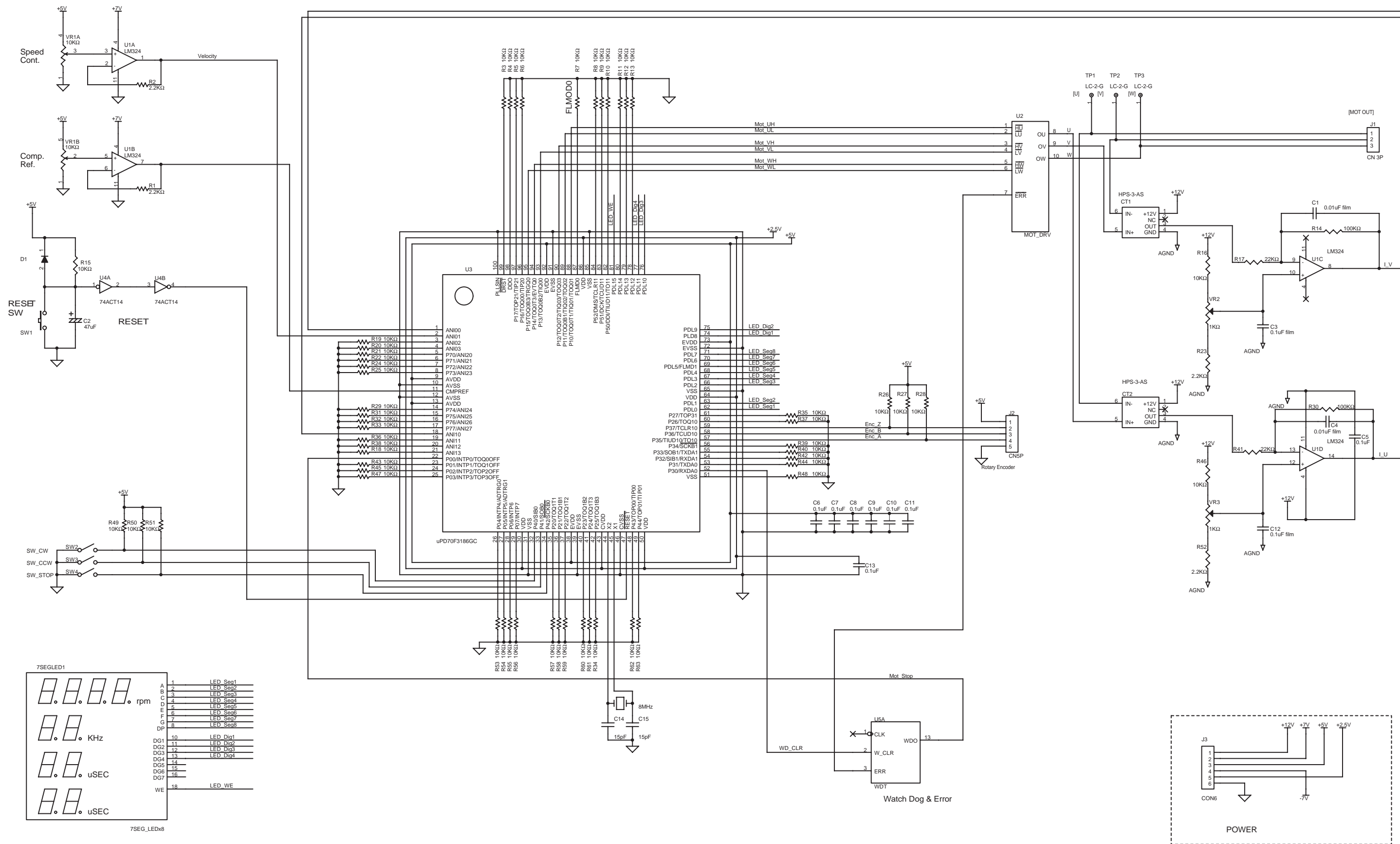


Figure 2-5. Circuit Diagram of V850E/IA4

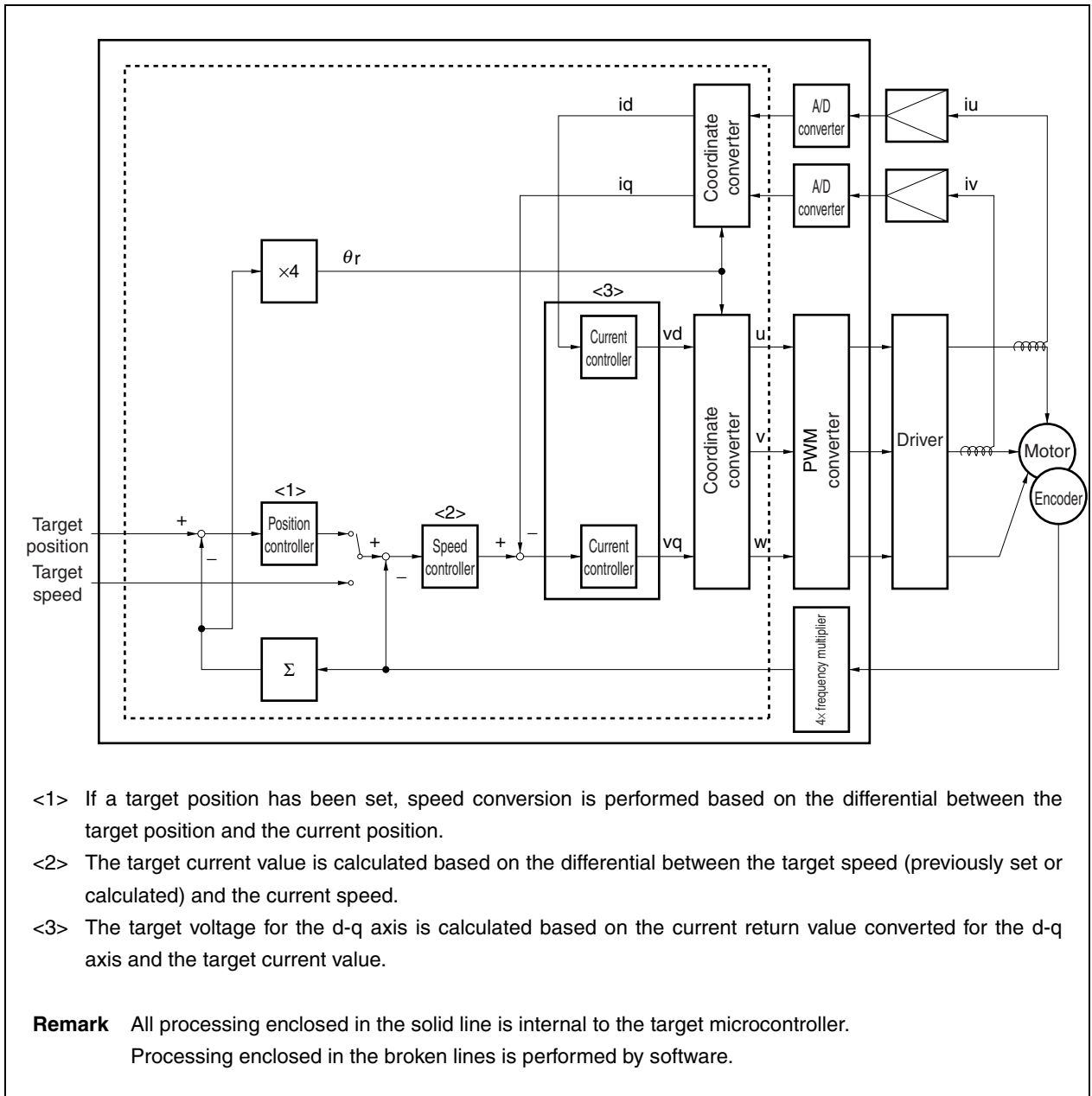


CHAPTER 3 SOFTWARE CONFIGURATION

3.1 Control Block

In the reference system, processing of timer interrupts is used to calculate control along the d-q axis (as is shown in Figure 3-1) and final output of the U, V, and W phase voltage values is performed by the inverter timer function of the target microcontroller.

Figure 3-1. Software Control Block Diagram of Reference System



3.2 Speed Control

In the reference system, PI (Proportion, Integral) control is used in the speed control block. The equations used for speed control are shown below.

```
d_speed = o_speed - now_speed
o_iqp   = ksp × d_speed
o_iqi   = o_iqi (n - 1) + (ksi × d_speed (n - 1))
o_iq    = o_iqp + o_iqi (n)
```

Remark

d_speed:	Difference between target speed and current speed
o_speed:	Target speed
now_speed:	Current speed
o_iqp:	Speed proportion component current value
ksp:	Speed proportion constant
o_iqi:	Speed integral component current value
ksi:	Speed integral constant
o_iq:	Target current value
n:	Current component
n-1:	Previous component

3.3 Position Speed Detection by Encoder

For ×4 frequency multiplication, the encoder uses a timer for 2-phase encoder input. Absolute positions along the motor axes must be detected, so encoder values are cleared in the Z phase and absolute positions are detected.

3.4 Current Control

For current control, the d-axis current (i_d) and q-axis current (i_q) are converted via the following equations to obtain a target voltage for each axis.

$$o_vd = k_i \times (-i_d)$$

$$o_vq = k_i \times (o_iq - i_q)$$

Remark o_vd : Target d-axis voltage
 k_i : Current proportion gain
 i_d : d-axis current value
 o_vq : Target q-axis voltage
 o_iq : Target current value
 i_q : q-axis current value

i_d and i_q are obtained by converting current values for the u and v phases to d-q axis coordinates. The equations are shown below.

$$i_d = i_v \times \sin \theta_r - i_u \times \sin (\theta_r - 2\pi/3)$$

$$i_q = i_v \times \cos \theta_r - i_u \times \cos (\theta_r - 2\pi/3)$$

Remark i_d : d-axis current value
 i_q : q-axis current value
 i_u : u-phase current value
 i_v : v-phase current value
 θ_r : Angle of revolution

3.5 Three-Phase Voltage Conversion

The equations used to convert voltage values (v_d and v_q) calculated for the d-q axis to 3-phase coordinates are shown below.

$$o_vu = o_vd \times \cos \theta_r - o_vq \times \sin \theta_r$$

$$o_vv = o_vd \times \cos (\theta_r - 2\pi/3) - o_vq \times \sin (\theta_r - 2\pi/3)$$

$$o_vw = -o_vu - o_vv$$

Remark o_vu : Target u-phase voltage
 o_vv : Target v-phase voltage
 o_vw : Target w-phase voltage
 o_vd : Target d-axis voltage
 o_vq : Target q-axis voltage
 θ_r : Angle of revolution

3.6 PWM Conversion

The calculated target voltage is output by an inverter timer.

3.7 Peripheral I/O

The following types of peripheral I/O functions are used in this reference system.

Table 3-1. List of Peripheral I/O Functions

Function	Peripheral I/O Function Name (V850E/IA1)	Peripheral I/O Function Name (V850E/IA2)	Peripheral I/O Function Name (V850E/IA3)	Peripheral I/O Function Name (V850E/IA4)
Inverter timer	Timer 00 (TM00)	Timer 00 (TM00)	Timer Q0 (TMQ0)	Timer Q0 (TMQ0)
10 ms timer	Timer 21 (TM21)	Timer 21 (TM21)	Timer P0 (TMP0)	Timer P0 (TMP0)
Motor control timer	Timer 3 (TM3)	Timer 3 (TM3)	Timer P1 (TMP1)	Timer P1 (TMP1)
Time measuring timer	Timer 3 (TM3)	Timer 3 (TM3)	Timer P1 (TMP1)	Timer P1 (TMP1)
U-phase current	ANI00	ANI00	ANI00	ANI00
V-phase current	ANI10	ANI10	ANI10	ANI10
Setting speed (volume)	ANI01	ANI01	ANI01	ANI01
A-phase encoder	TIUD10	TIUD10	TIUD10	TIUD10
B-phase encoder	TCUD10	TCUD10	TCUD10	TCUD10
Z-phase encoder	TCLR10	TCLR10	TCLR10	TCLR10
CW key input	P40	P40	P40	P40
CCW key input	P41	P41	P41	P41
STOP key input	P42	P42	P42	P42
WDT reset output	P43	P30	P30	P30
LED output	PDL0 to PDL11, PDL15	PDL0 to PDL11, PDL15	PDL0 to PDL11, PDL15	PDL0 to PDL11, PDL15

(1) Description of peripheral I/O functions**(a) Inverter timer**

Inverter timers are used to output PWM waveforms.
In this reference system, the settings are as shown below.

- 20 kHz symmetrical triangular waveform mode
- Dead time: 6 μ s
- Inverter timer output: Low active
- When ESO0 or TOQ0OFF pin input is at high level, PWM output is stopped.

(b) Motor control timer

Motor control timers are used to issue interrupts at a 50 μ s interval.

(c) 10 ms timer

10 ms timers are used to issue interrupts at a 10 ms interval.

(d) Speed measuring timer

Used for measuring the revolution speed of the motor.

(e) Current value input

ANI00: U-phase current value (-5 to +5 A)

ANI10: V-phase current value (-5 to +5 A)

(f) Speed specification volume value input

ANI01 is used to input a value from 0 to 1,023.

3.8 Software Processing Structure

The software processing structure is shown below.

Figure 3-2. Main Processing Structure

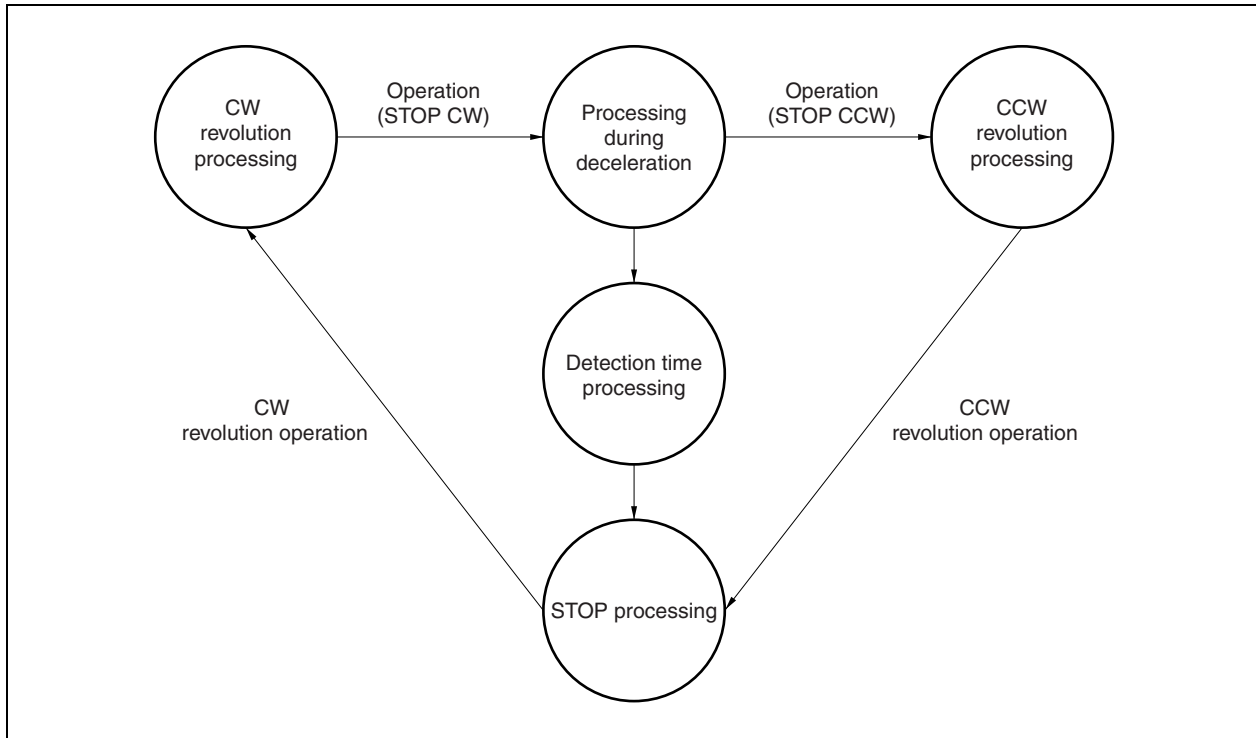
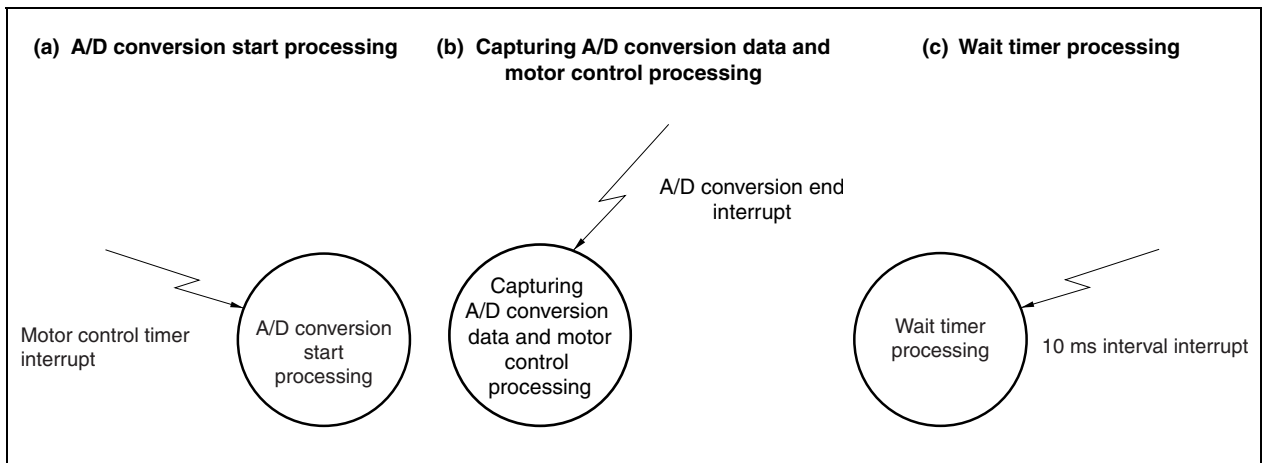


Figure 3-3. Interrupt Processing Structure



The status of the operation mode switch is monitored by the main processing, and processing is transferred to CW, CCW, and stop status. The motor is controlled in the specified status by using a motor control timer interrupt.

There are the following three motor control statuses.

- Stop status
The motor is not controlled.
- Initial operation status
Revolution control is performed until the position information from the encoder is input.
- Speed control status
Feedback revolution control is performed so that the indication speed is attained.

3.9 Flowchart

3.9.1 Main processing

Figure 3-4 shows the flowchart of the main processing.

Figure 3-4. Main Processing

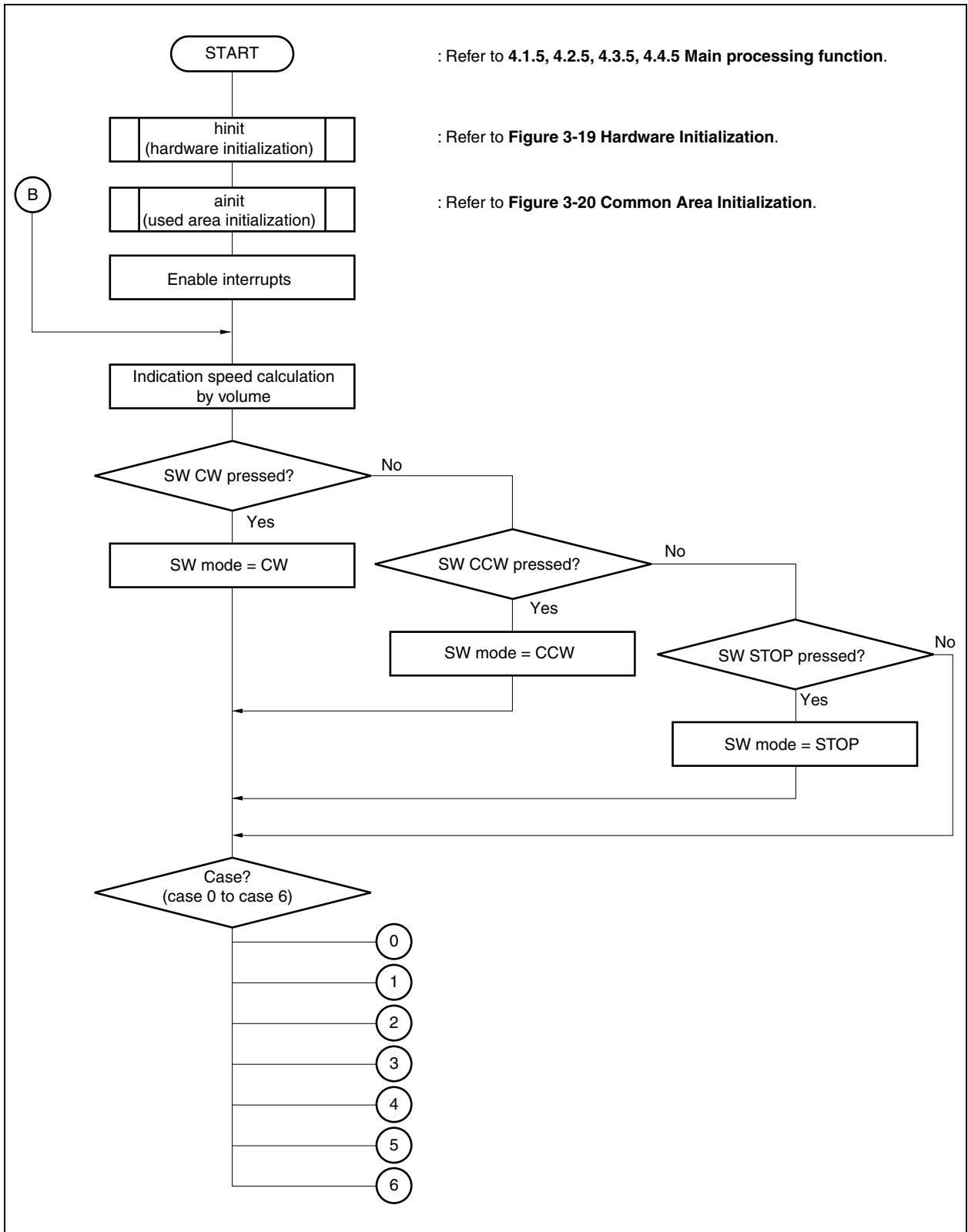


Figure 3-5. Case 0 (Processing During Stoppage)

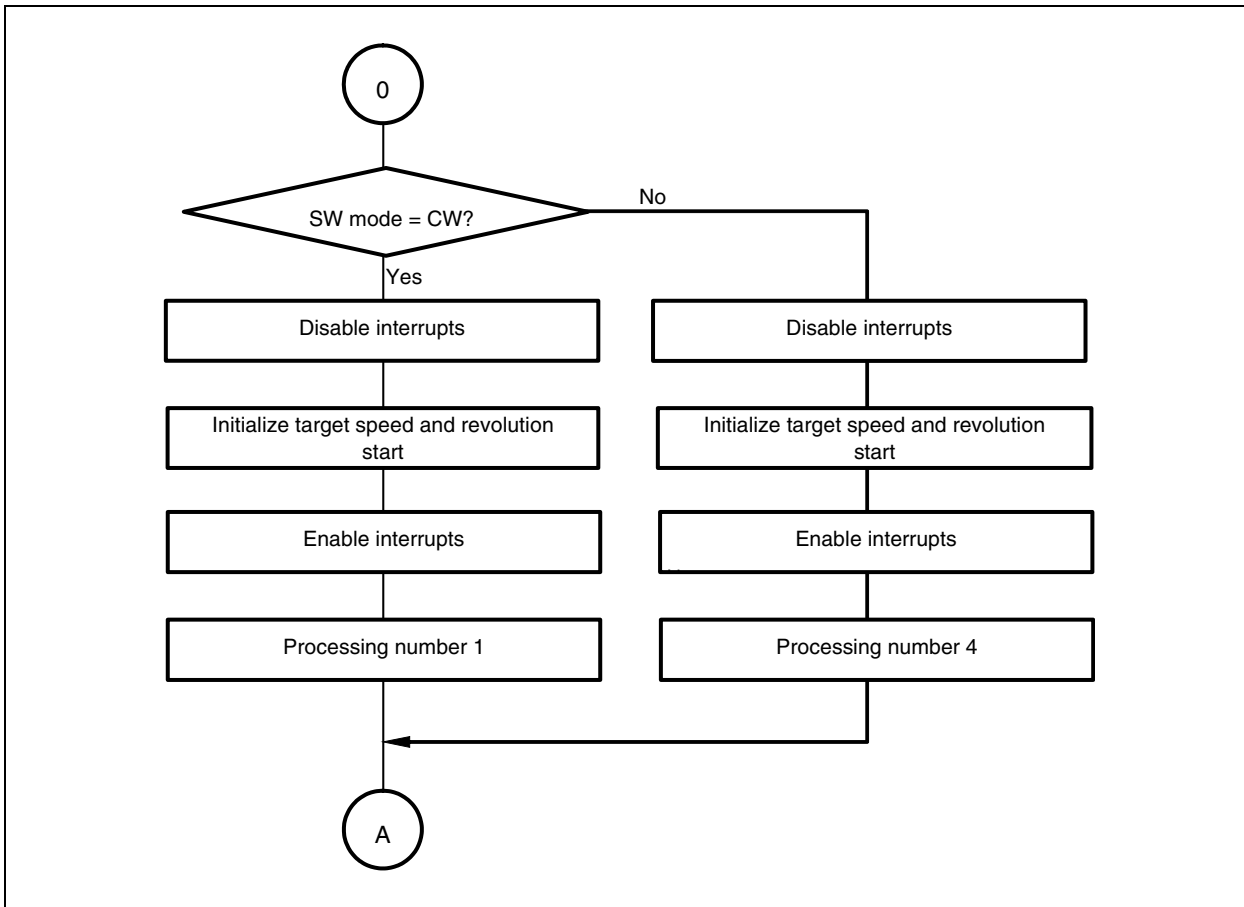


Figure 3-6. Case 1 (CW Acceleration Processing)

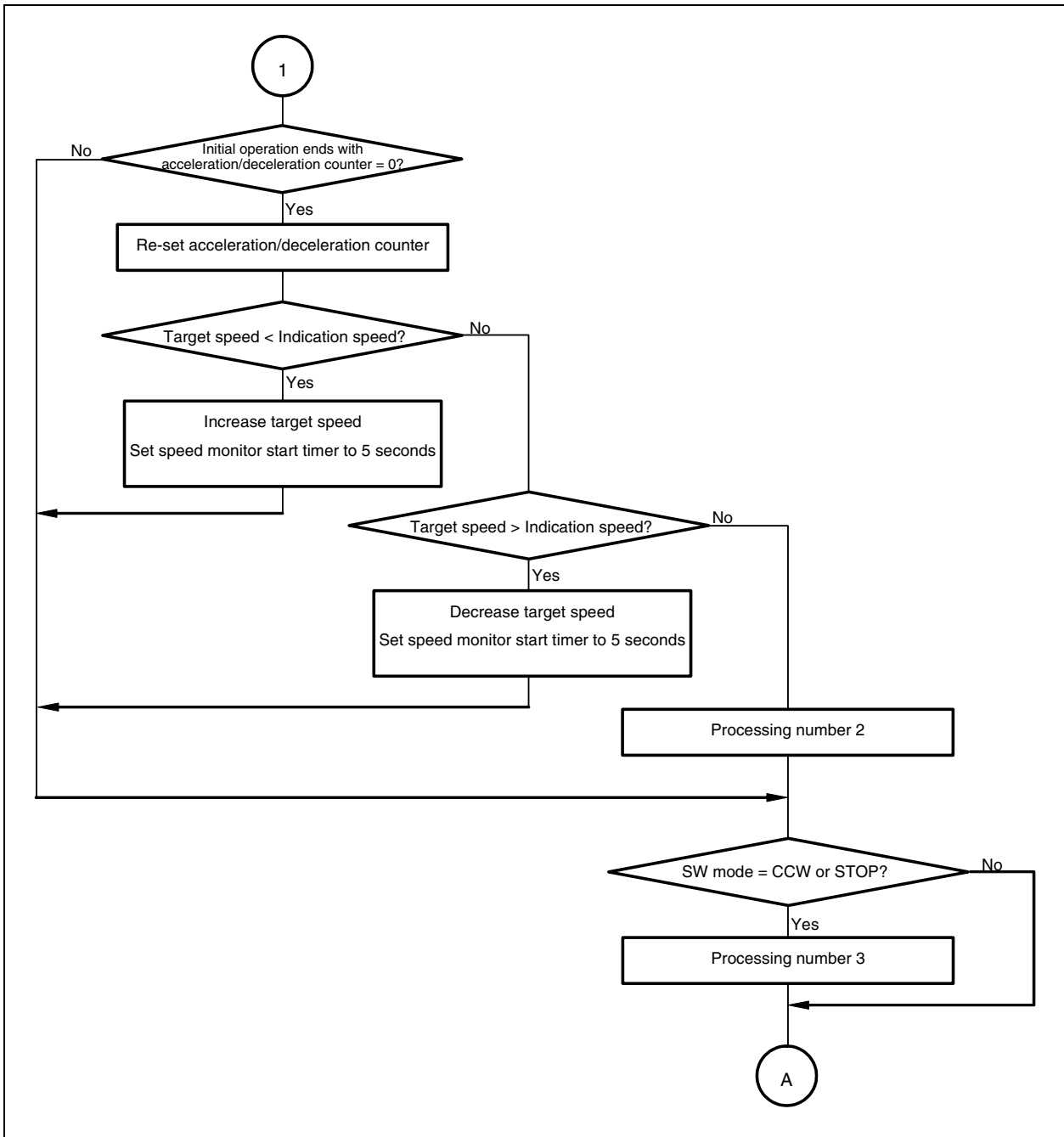


Figure 3-7. Case 2 (CW Constant-Speed Processing)

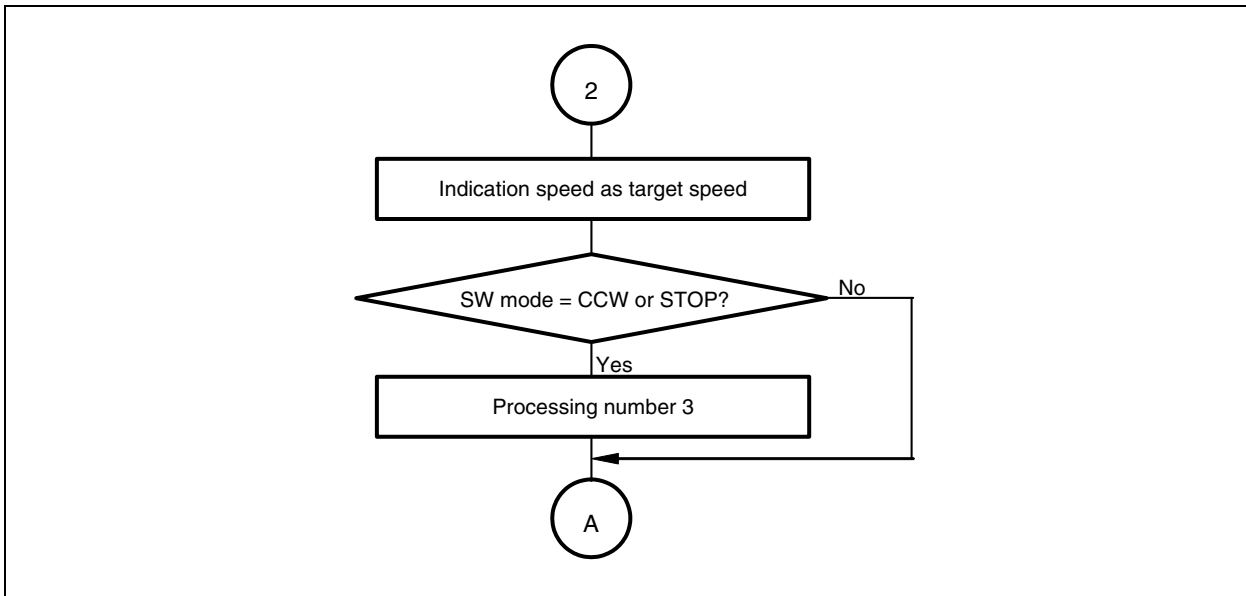


Figure 3-8. Case 3 (CW Stop Processing)

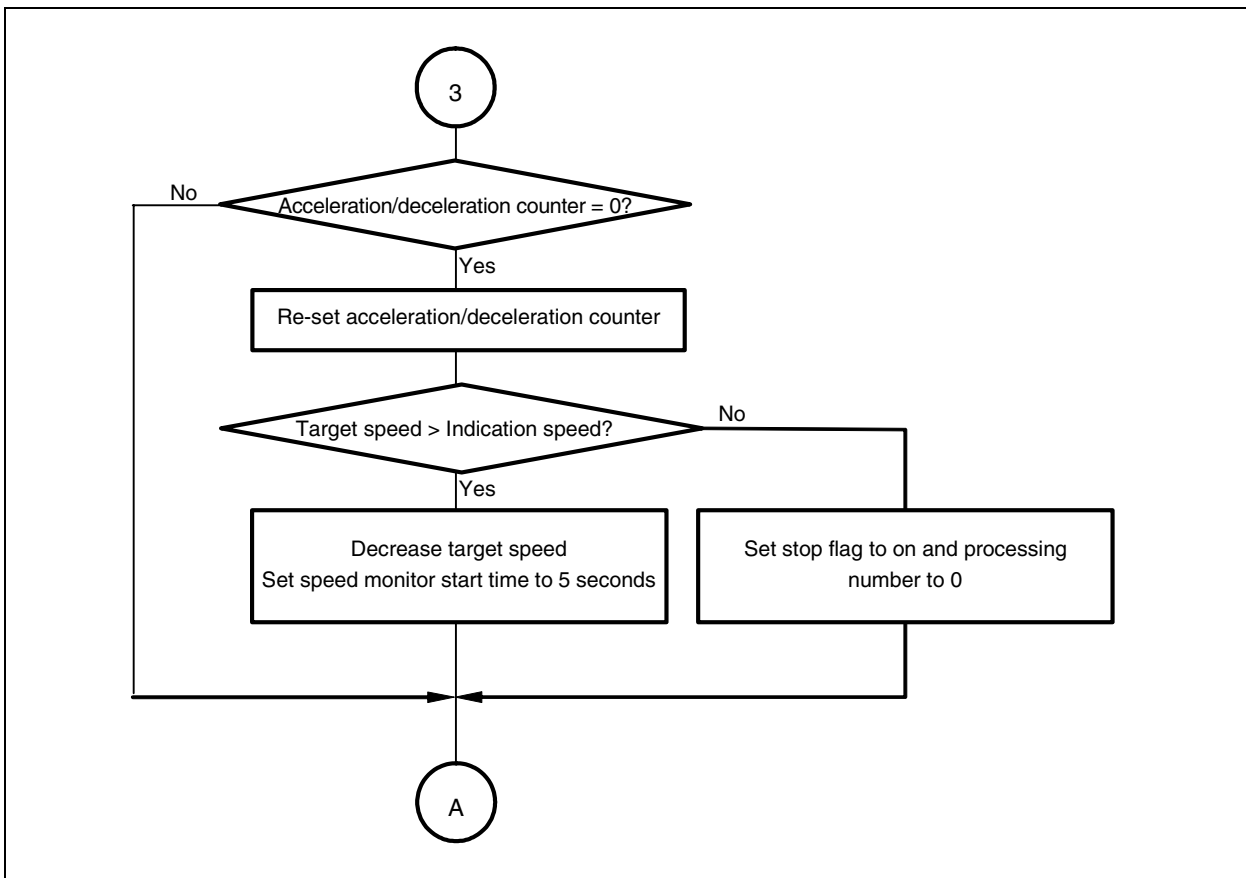


Figure 3-9. Case 4 (CCW Acceleration Processing)

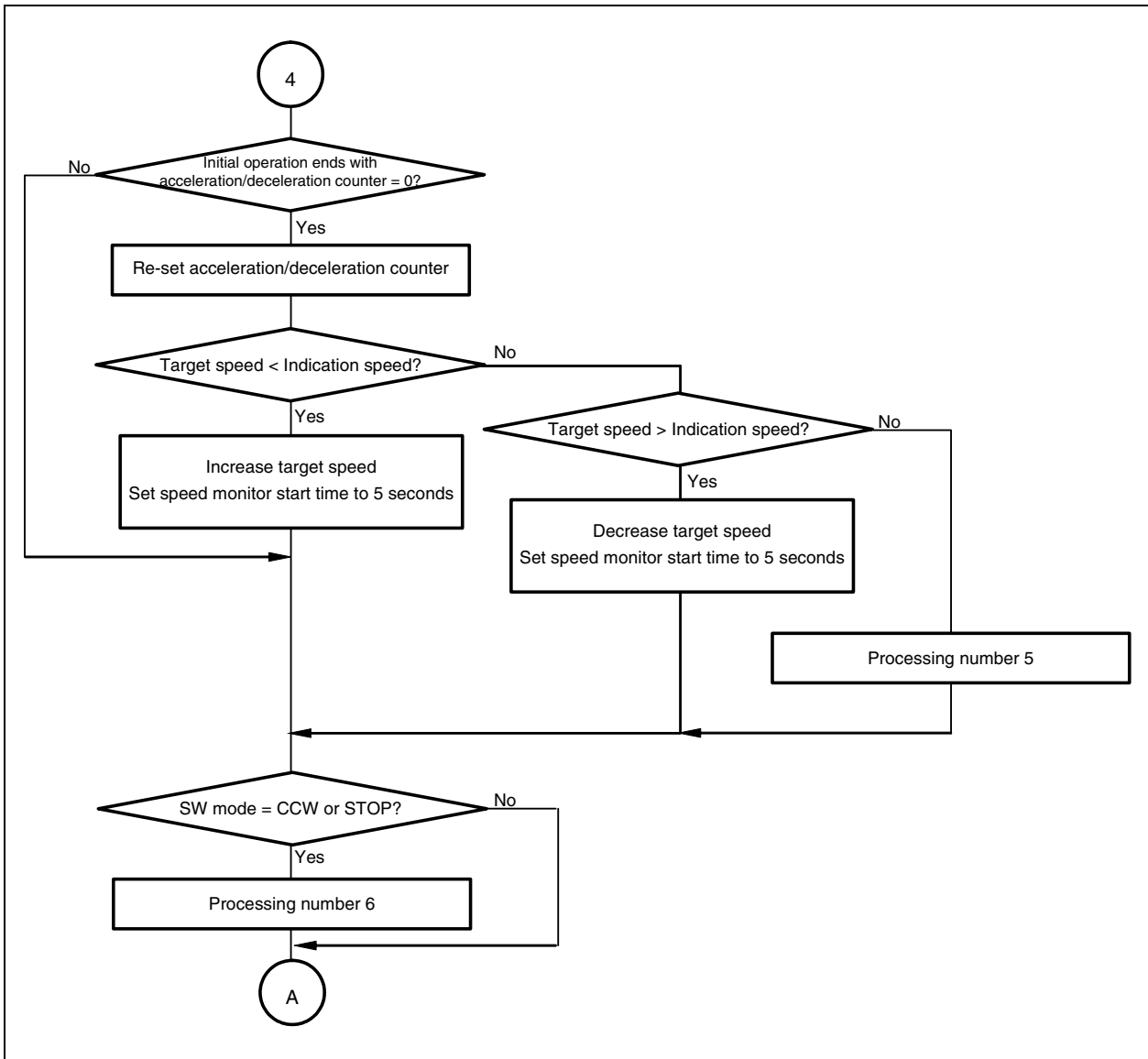


Figure 3-10. Case 5 (CCW Constant-Speed Processing)

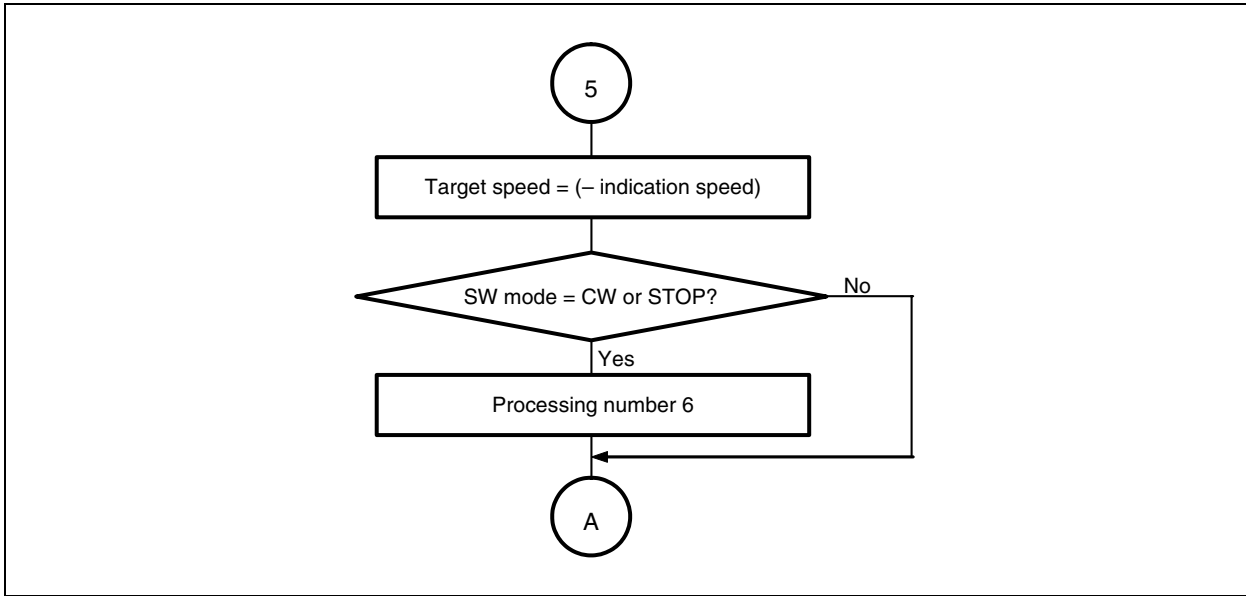


Figure 3-11. Case 6 (CCW Stop Processing)

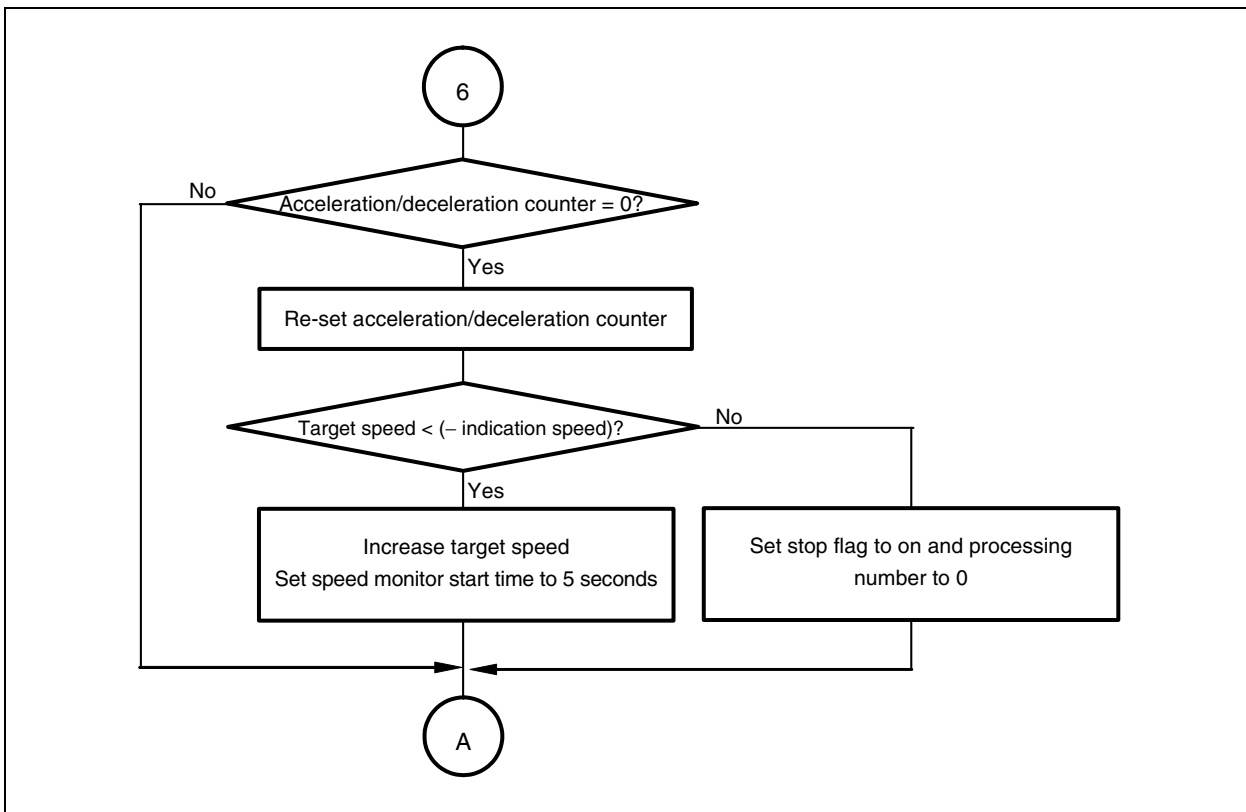
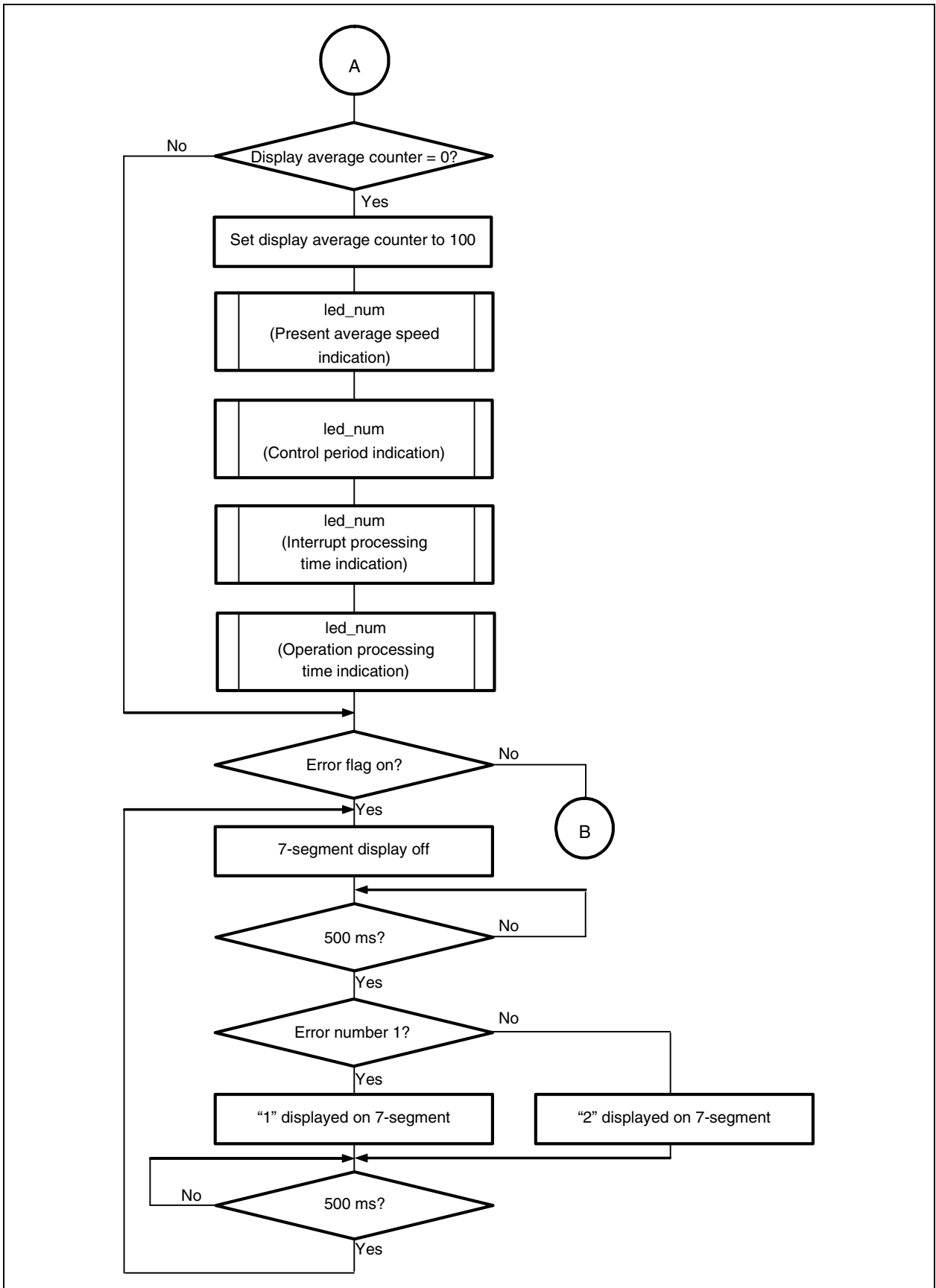
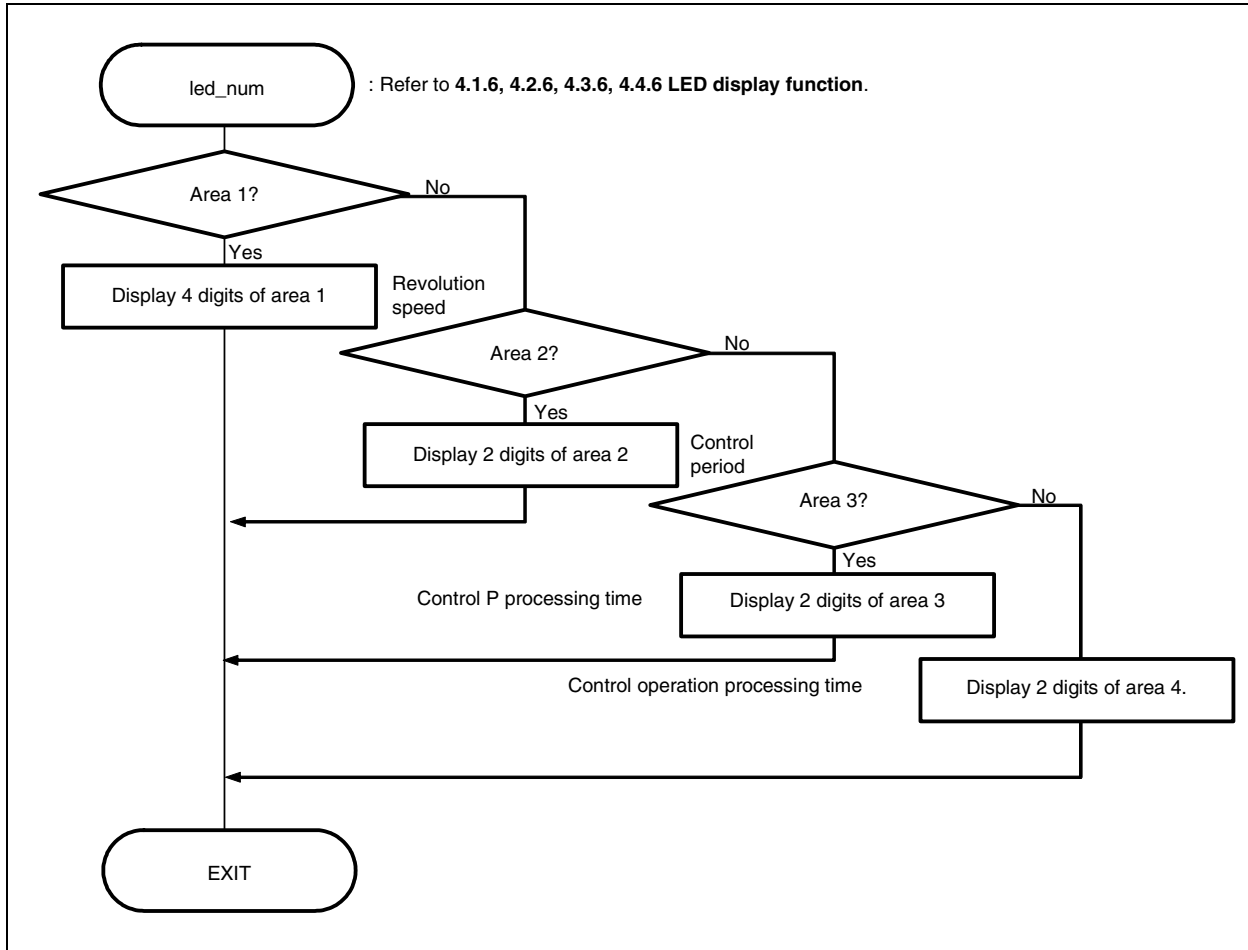


Figure 3-12. LED Display Processing



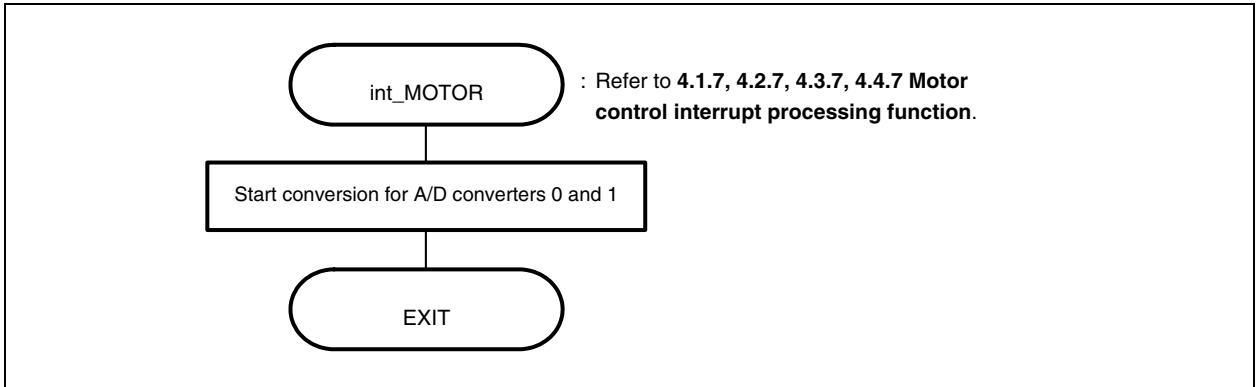
3.9.2 LED display

Figure 3-13. LED Display



3.9.3 Motor control timer interrupt processing

Figure 3-14. Motor Control Timer Interrupt Processing



3.9.4 Motor control processing

Figure 3-15. Control Interrupt Processing (1/5)

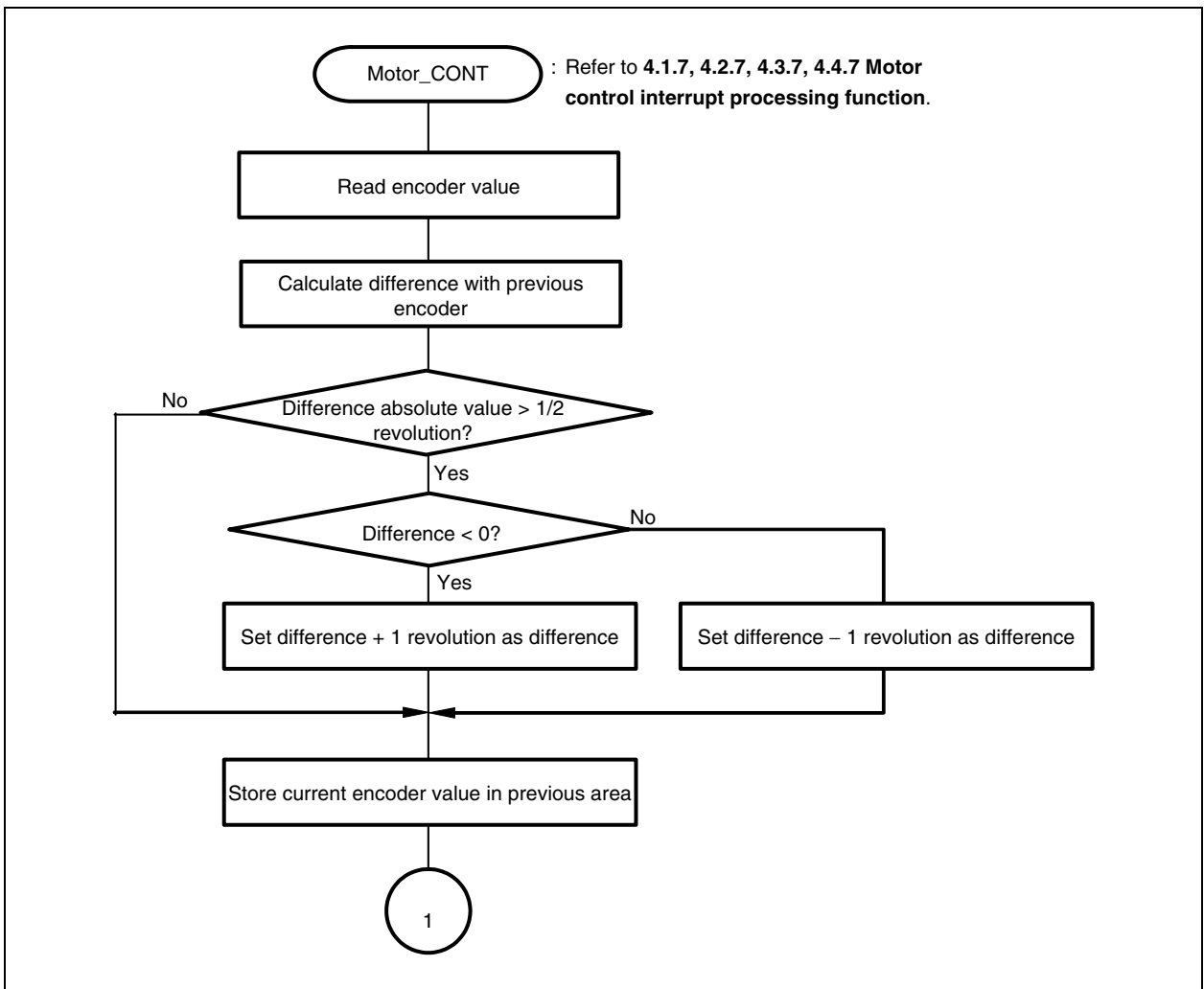
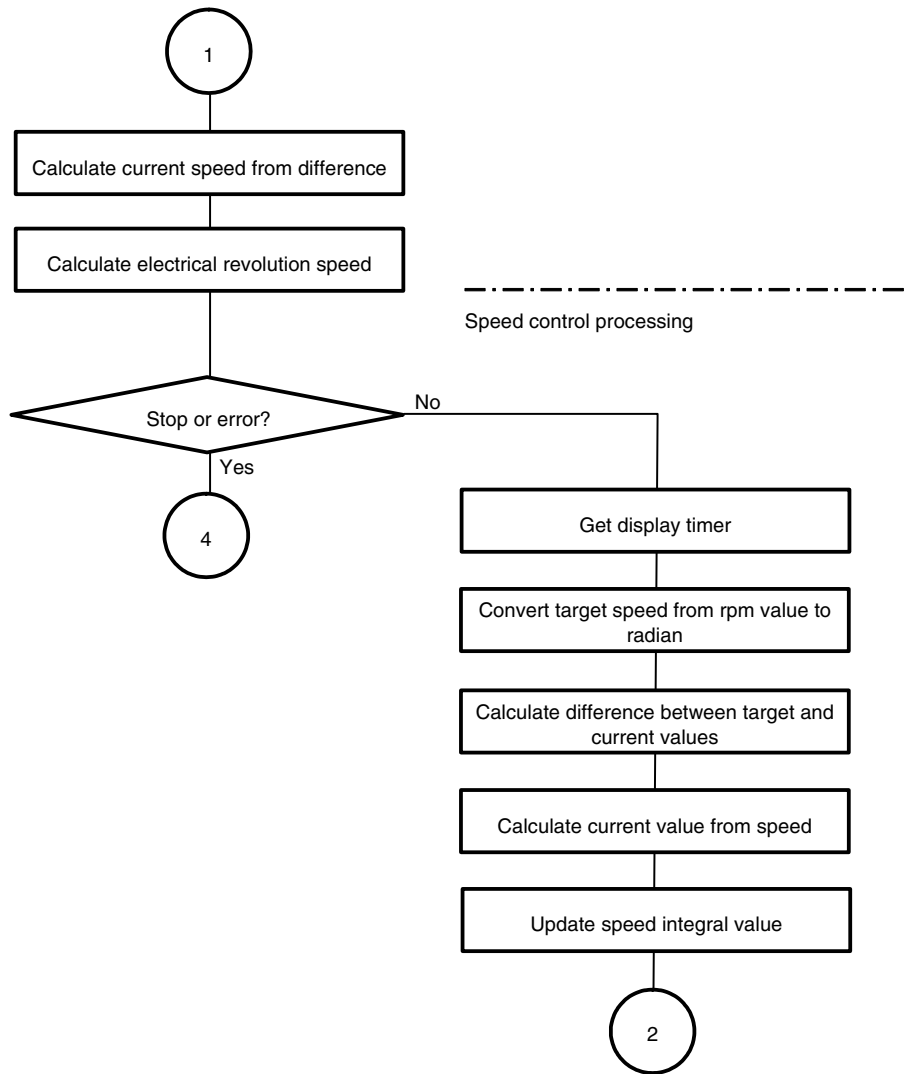


Figure 3-15. Control Interrupt Processing (2/5)



- Remarks**
1. Electrical revolution speed = Speed × Number of poles
 2. Current value = (KSP × Speed difference + Speed integral value)/KSIGETA
 3. Speed integral value = Previous speed integral value + KSI × Speed difference
 4. KSI: Speed integral constant
KSIGETA: Speed integral constant jack-up constant
KSP: Speed proportion constant

Figure 3-15. Control Interrupt Processing (3/5)

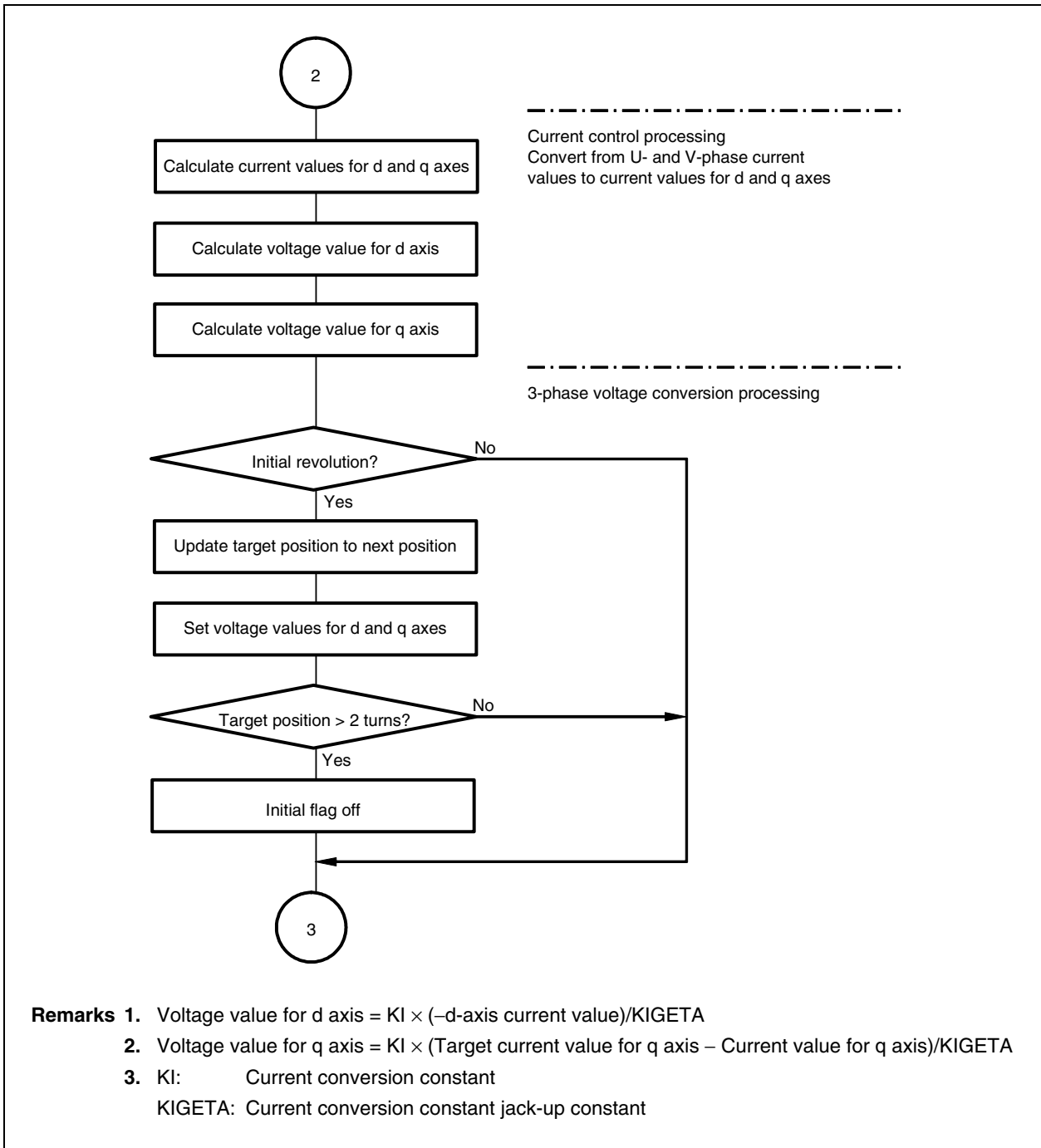


Figure 3-15. Control Interrupt Processing (4/5)

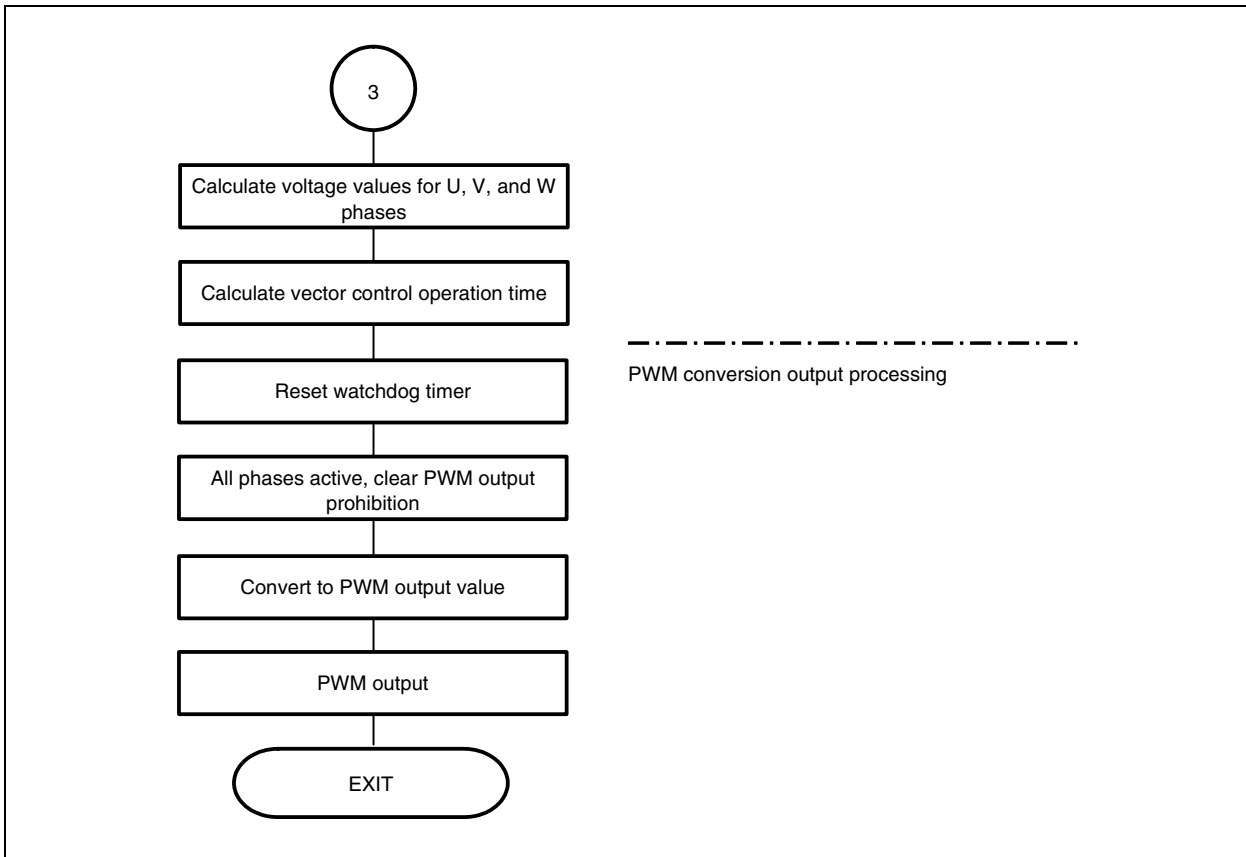
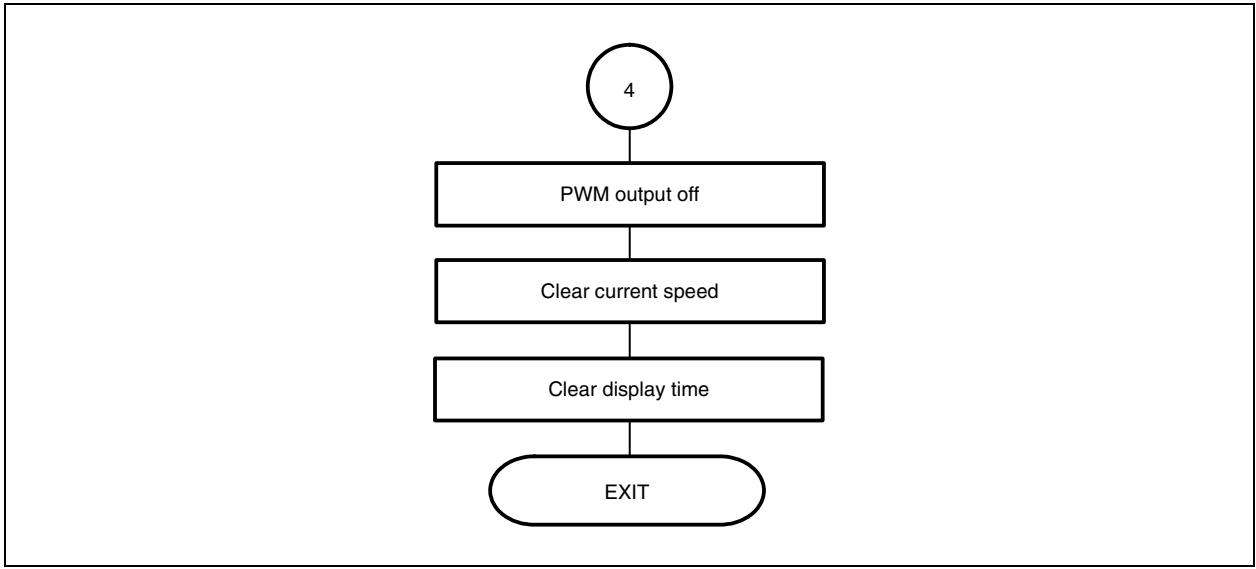
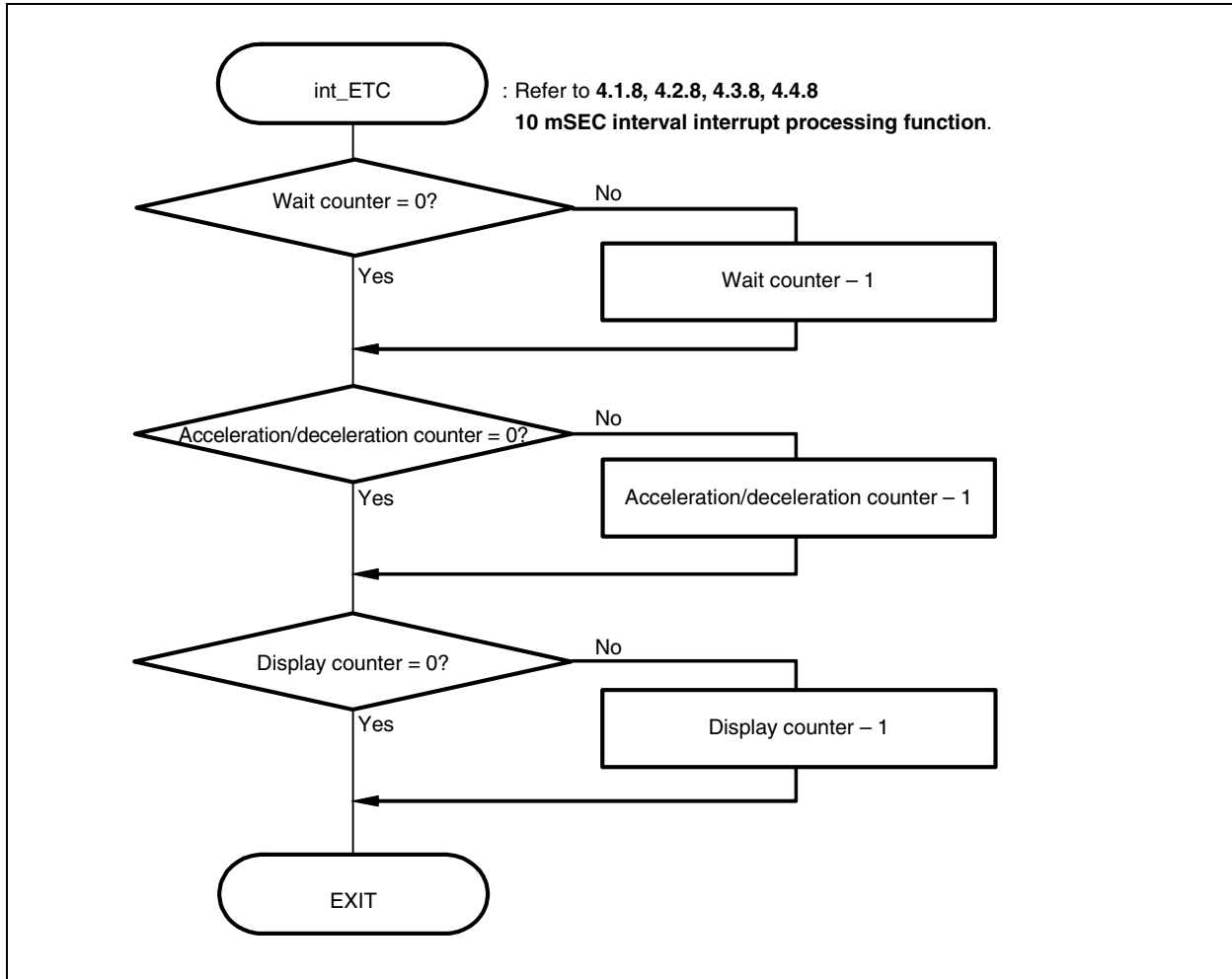


Figure 3-15. Control Interrupt Processing (5/5)



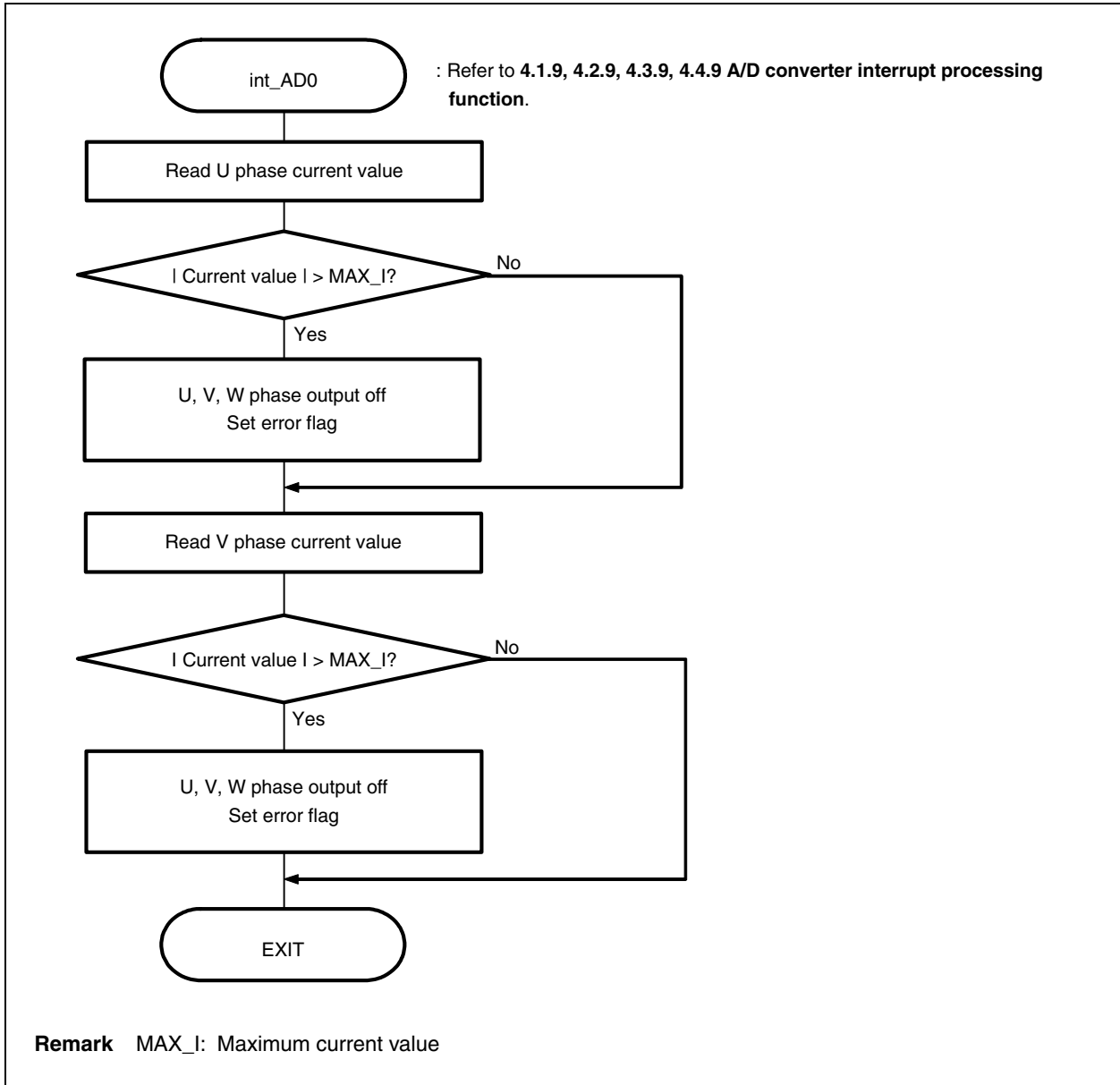
3.9.5 10 mSEC interval interrupt processing

Figure 3-16. 10 mSEC Interval Interrupt Processing



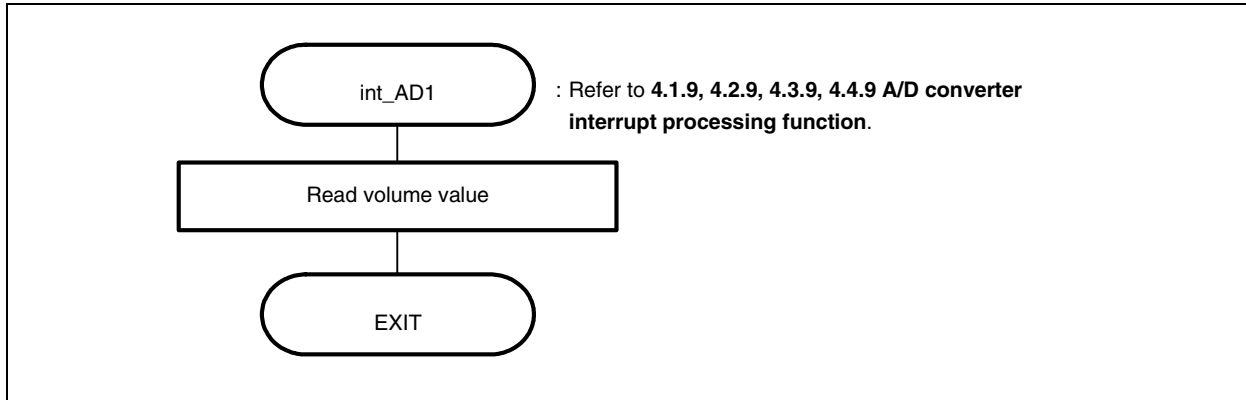
3.9.6 A/D converter channel 0 interrupt processing

Figure 3-17. A/D Converter Channel 0 Interrupt Processing



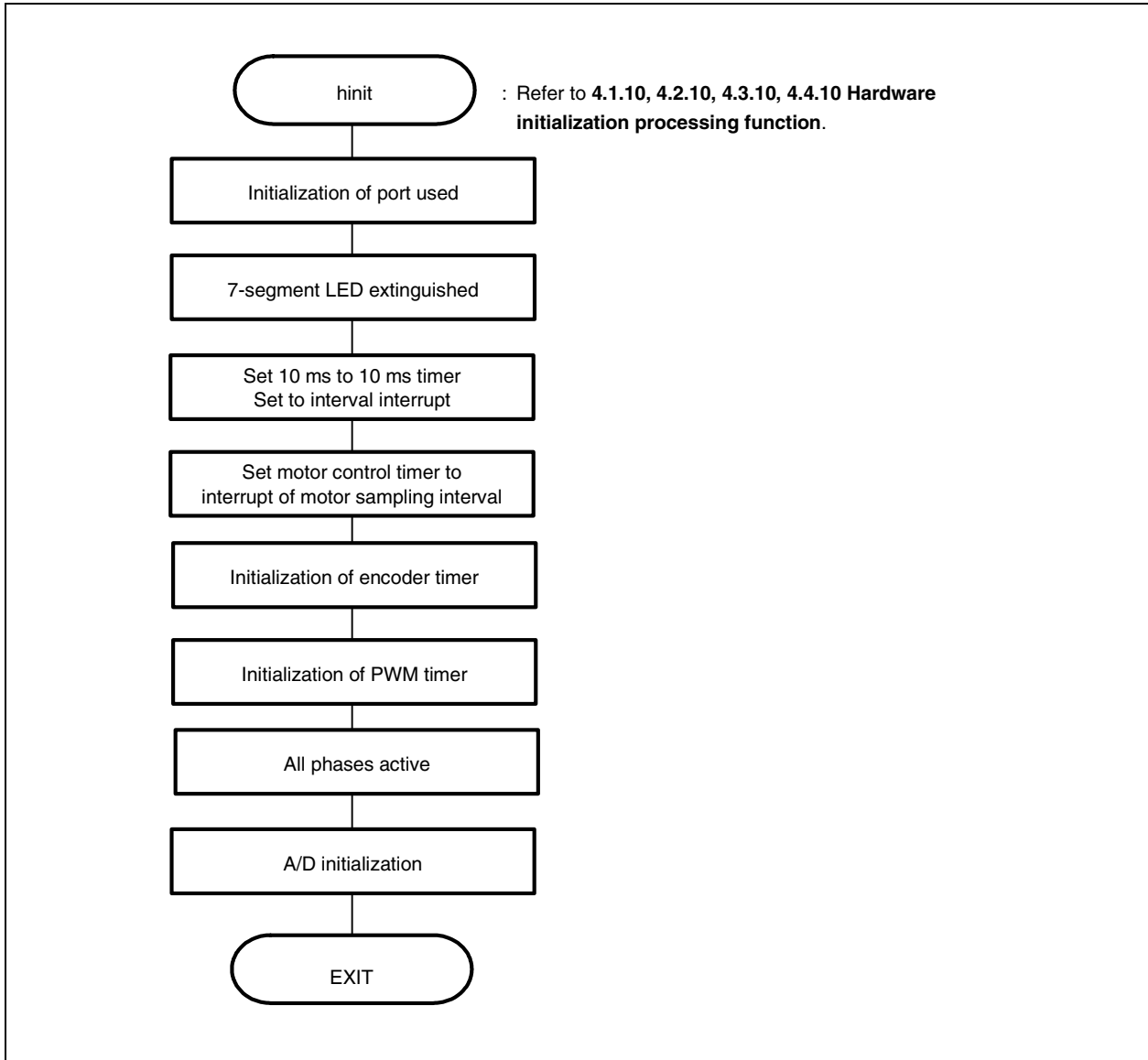
3.9.7 A/D converter channel 1 interrupt processing

Figure 3-18. A/D Converter Channel 1 Interrupt Processing



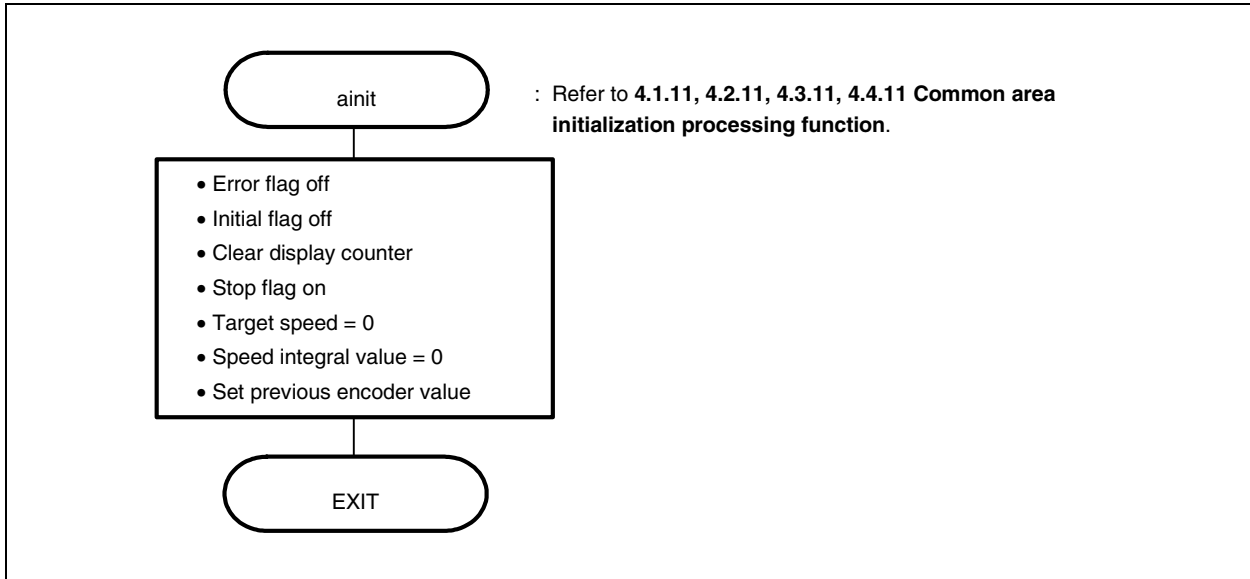
3.9.8 Hardware initialization

Figure 3-19. Hardware Initialization



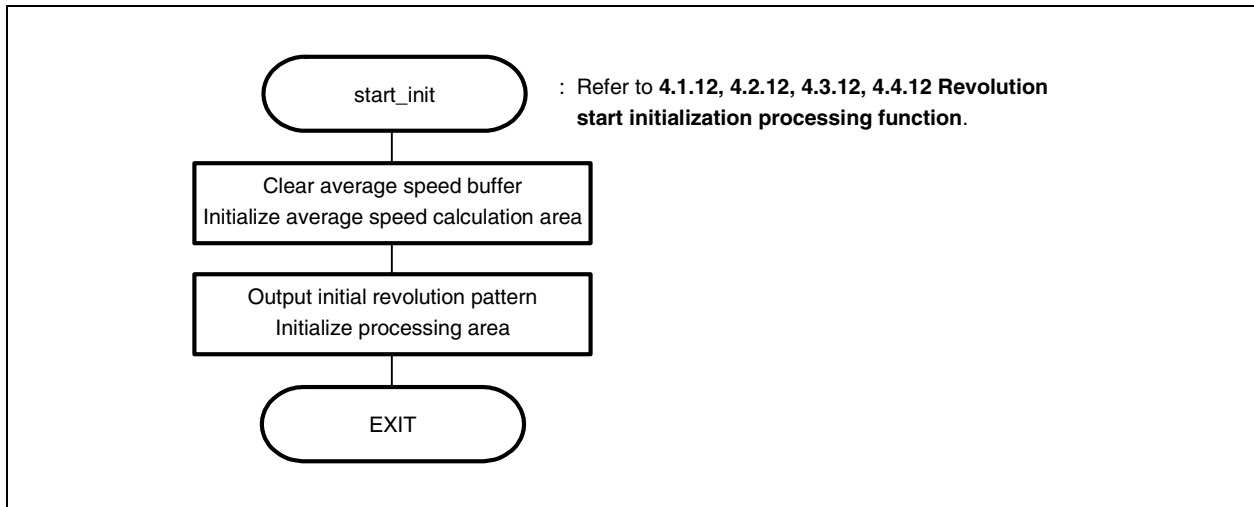
3.9.9 Common area initialization

Figure 3-20. Common Area Initialization



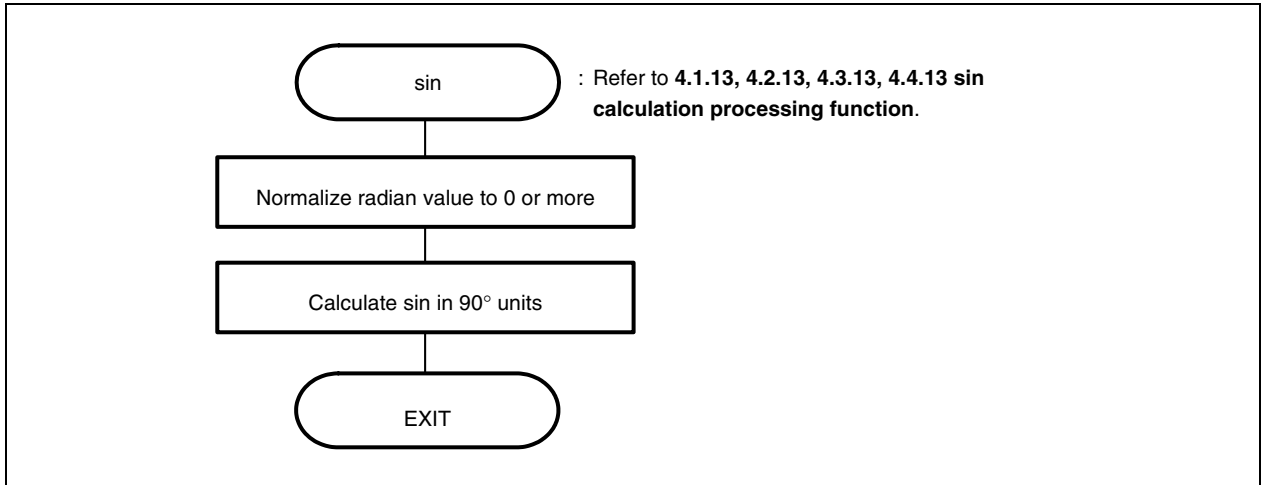
3.9.10 Revolution start initialization

Figure 3-21. Revolution Start Initialization



3.9.11 sin calculation

Figure 3-22. sin Calculation



3.10 Common Areas

The following table shows the major common areas used by the reference system.

Table 3-2. Common Area List

Symbol	Type	Usage	Set Value
error_flag	unsigned char	Error flag	0: No error ERR_NO1: Overcurrent ERR_NO2: Speed difference error
init_flag	unsigned char	Indicates initial revolution	ON: Initial revolution in progress OFF: Stop or normal revolution in progress
cont_time	unsigned short	Interrupt processing time	1 μ s units
cont_time1	unsigned short	Vector operation time	1 μ s units
disp_co	unsigned short	Average speed counter for display	
volume	unsigned short	Speed volume value	
timer_count	unsigned short	Time wait counter	10 ms units
accel_count	unsigned short	Acceleration/deceleration operation time counter	10 ms units
stop_flag	unsigned char	Stop flag	ON: Stopped OFF: Revolving
before_posi[21][2]	signed short	Position buffer	
total_sa	signed short	Position total difference	
sum_speed	signed int	Total value area for average speed calculation	0, 1, ...
speed_co	signed int	Counter for average speed calculation	0, 1, ...
now_speed	signed int	Present speed	rpm
object_speed	signed int	Target speed	rpm
d_speed	unsigned int	Display speed	rpm
iua	signed short	U-phase current	
iva	signed short	V-phase current	
o_iqai	signed int	Speed integral value	
base_position	signed int	Speed estimation value reference point	
sa_time	unsigned int	Speed measurement value	
timer_count	unsigned short	Time wait counter	
accel_count	unsigned short	Acceleration/deceleration operation time counter	
o_trm	signed int	Target position for initialization	
before_enc	signed short	Previous encoder value	

3.11 Tables

(1) LED output pattern

Contains display pattern data 0 to 9.

```
unsigned short led_pat[10] = { 0xfc, 0x60, ~ };
```

3.12 Constant Definitions

The following table shows the major constants used by the reference system.

Symbol	Usage	Value ^{Note}
PAI	π	3.141592
TH_U	Radian value, jack-up constant	1000
RAD	Radian value of one revolution	$2 \times \text{PAI} \times \text{TH_U}$
OFFSET	Original point OFFSET	1733
RPM_RADS	rpm \rightarrow radian conversion constant	$2 \times \text{PAI} \times \text{TH_U}/60$
KSP	Speed proportion constant	500
KSI	Speed integral constant	50
KI	Current conversion constant	1
P	Number of motor poles	2
KSPGETA	Speed proportion constant jack-up constant	0
KSIGETA	Speed integral constant jack-up constant	9
KIGETA	Current conversion constant jack-up constant	9
SGETA	sin jack-up constant	14
PWM_TS	PWM cycle	80 μs
PWM_DATA	PWM set value	$\text{PWM_TS}/0.03125$
SPEED_MAX	Maximum speed	500 (3000 rpm)
SPEED_MINI	Minimum speed	100 (600 rpm)
SA_SPEED_MAX	Maximum speed difference	800
IQAMAX	Maximum speed integral value	40000000
MAX_I	Maximum current value	800
TS	Motor control period	80 μs
WATCH_START	Speed monitor start time, 10 ms	500
ACCEL_VAL_1ST	Initial acceleration/deceleration time constant	50
ACCEL_VAL	Acceleration/deceleration time constant	3
ACCEL_SPD	Acceleration/deceleration constant	50
MAXPULSE	Number of pulses of one revolution	10000

Note Value used in the V850E/IA3 and V850E/IA4.

For the value used in the V850E/IA1 and V850E/IA2, check it with the program list.

CHAPTER 4 PROGRAM LIST

4.1 Program List (V850E/IA1)

4.1.1 Symbol definition

```
/*
*****
*/
/*      Common area
*****
*/
unsigned char  ram_start ;
unsigned char  error_flag ;          /* Error flag */
unsigned char  init_flag ;          /* Initial flag */
unsigned short cont_time ;           /* Interrupt control time uSEC */
unsigned short cont_time1 ;         /* Vector operation time uSEC */
unsigned short disp_co ;            /* Interrupt control time display timer */
unsigned short volume ;             /* Volume value */
unsigned short timer_count ;        /* Time wait counter */
unsigned short accel_count ;        /* Acceleration/deceleration operation time */
/* counter */
unsigned char  stop_flag ;          /* Stop flag */
signed short   before_posi[21][2] ; /* Position buffer */
signed short   total_sa ;          /* Position total difference */
signed int     sum_speed ;
signed int     speed_co ;
signed int     now_speed ;         /* Present speed rms */
signed int     object_speed ;     /* Target speed rms */
unsigned int   d_speed ;          /* Display speed rms */
unsigned char  ram_end ;

#pragma section const begin
const unsigned short led_pat[10] = { 0xfc, 0x60, 0xda, 0xf2, 0x66, 0xb6, 0xbe, 0xe0,
                                     0xfe, 0xe6 } ;

#pragma section const end
/*
*****
*/
/*      Common flags
*****
*/
extern unsigned char  ram_start ;
extern unsigned char  error_flag ;          /* Error flag */
extern unsigned char  init_flag ;          /* Initial flag */
extern unsigned short cont_time ;           /* Interrupt control time uSEC */
extern unsigned short cont_time1 ;         /* Vector operation time uSEC */
extern unsigned short disp_co ;            /* Interrupt control time display timer */
extern unsigned short volume ;             /* Volume value */
extern unsigned short timer_count ;        /* Time wait counter */
extern unsigned short accel_count ;        /* Acceleration/deceleration operation */
/* time counter */
extern unsigned char  stop_flag ;          /* Stop flag */
```

```

extern signed short   before_posi[21][2] ; /* Position buffer */
extern signed short   total_sa ;          /* Position total difference */
extern signed int     sum_speed ;
extern signed int     speed_co ;
extern signed int     now_speed ;        /* Present speed rms */
extern signed int     object_speed ;     /* Target speed rms */
extern unsigned int   d_speed ;         /* Display speed rms */
extern unsigned char  ram_end ;

#pragma section const begin
extern const unsigned short led_pat[] ;;
#pragma section const end
/*****
/*      Motor common definition
*****/
extern signed short   iua ;             /* U-phase current */
extern signed short   iva ;             /* V-phase current */
extern signed int     o_iqai ;         /* Speed integral value area */
extern signed int     o_trm ;          /* Target position for initialization */
extern signed int     base_position ;  /* Speed estimation value reference point */
extern unsigned int   sa_time ;        /* Speed measurement value */
extern unsigned short timer_count ;    /* Time wait counter */
extern unsigned short accel_count ;    /* Acceleration/deceleration operation */
/* time counter */
extern signed short   before_enc ;     /* Previous encoder value */

```

4.1.2 Constant definition

```

/*****
/*      I/O
*****/
#define BASE_IO      0xc200000
#define LED11        3
#define LED12        2
#define LED13        1
#define LED14        0
#define LED21        5
#define LED22        4
#define LED31        7
#define LED32        6
#define LED41        9
#define LED42        8

#define DIPSW        0x10
#define SW           0x20
#define DA1          0x30
#define DA2          0x40
#define DA3          0x50

```

```

#define WRESET      0x60
#define MODE        0x70
/*****
/*      Constant
*****/
#define ON          1
#define OFF         0
#define CW          1          /* CW operation mode */
#define CCW         2          /* CCW operation mode */
#define STOP        0          /* Operation stop mode */
#define ERR_NO1     1          /* Overcurrent error */
#define ERR_NO2     2          /* Speed difference error */
/*****
/*      Motor constant
*****/
#define PAI          3.14159265      /* π */
#define TH_U         1000           /* Radian value jack-up constant */
#define RAD          (int)(2*PAI*TH_U) /* Radian value of one revolution */
#define OFFSET       1945          /* Original point OFFSET */
#define RPM_RADS     (int)((2*PAI*TH_U)/60) /* rpm -> radian conversion constant */
/* Motor constant */
#define KSP          500           /* Speed proportion constant */
#define KSI          50            /* Speed integral constant */
#define KI           1             /* Current conversion constant */
#define P            2             /* Number of poles */

#define KSPGETA      0             /* KSP jack-up constant */
#define KSIGETA      9             /* KSI jack-up constant */
#define KIGETA       9             /* KI jack-up constant */
#define SGETA        14           /* sin jack-up constant */

#define PWM_TS       50            /* PWM cycle */
#define PWM_DATA     (PWM_TS/0.05) /* PWM set value */
#define SPEED_MAX    3000         /* Maximum speed rpm */
#define SPEED_MINI   600          /* Minimum speed rpm */
#define SA_SPEED_MAX 800          /* Maximum speed difference rpm */
#define IQAMAX       40000000     /* Maximum speed integral value */
#define MAX_I        800          /* Maximum current value */
#define TS           200          /* Motor control time interval uSEC */
#define WATCH_START  500         /* Speed monitor start time 10 mSEC */
#define ACCEL_VAL_1ST 50          /* Initial acceleration/deceleration */
/* time constant */
#define ACCEL_VAL    3            /* Acceleration/deceleration time */
/* constant */
#define ACCEL_SPD    50           /* Acceleration/deceleration constant */
#define MAXPULSE     10000       /* Number of pulses of one revolution */

*****/

```

```

/*      Function constant                                                    */
/***** /
void      fcalcu( signed int *wrm, signed int *trm );
void      OUT_data( unsigned short reg, unsigned short data );
unsigned short IN_data( int reg );
void      led_num( int no, long data ) ;
/***** /
/*      Motor-related common area                                          */
/***** /
signed short  iua ;          /* U-phase current */
signed short  iva ;          /* V-phase current */
signed int    o_iqai ;      /* Speed integral value area */
signed int    o_trm ;      /* Target position for initialization */
signed int    base_position ; /* Speed estimation value reference point */
unsigned int  sa_time ;     /* Speed measurement value */
unsigned short timer_count ; /* Time wait counter */
unsigned short accel_count ; /* Acceleration/deceleration operation time counter */
signed short  before_enc ;  /* Previous encoder value */

```

4.1.3 Interrupt handler setting

```

/***** /
/*      Interrupt symbol table                                            */
/***** /
    .extern _ _start
    .extern _int_MOTOR
    .extern _int_AD0
    .extern _int_AD1
    .extern _int_ETC

    .globl V_RESET
    .globl V_ETC
    .globl V_MOTOR
    .globl V_AD0
    .globl V_AD1
#*****
    .section ".handler",text
V_RESET:
    jr      _start
V_ETC:
    ld.w    [sp],r1
    add     4,sp
    jr      _int_ETC          -- Other timers
V_MOTOR:
    ld.w    [sp],r1
    add     4,sp
    jr      _int_MOTOR       -- Speed control timer
V_AD0:

```

```

        ld.w    [sp],r1
        add    4,sp
        jr     _int_AD0          -- A/D converter CH0
V_AD1:
        ld.w    [sp],r1
        add    4,sp
        jr     _int_AD1          -- A/D converter CH1

        .extern V_RESET
        .extern V_ETC
        .extern V_MOTOR
        .extern V_AD0
        .extern V_AD1
/*****
/*      Interrupt jump table                                     */
*****/

        .section ".vect_RESET",text
        mov    #V_RESET,r1
        jmp    [r1]

        .section ".id_NO",text
        .byte  0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff

        .section ".vect_ETC",text
        add    -4,sp
        st.w   r1,[r3]
        mov    #V_ETC,r1
        jmp    [r1]

        .section ".vect_MOTOR",text
        add    -4,sp
        st.w   r1,[r3]
        mov    #V_MOTOR,r1
        jmp    [r1]

        .section ".vect_AD0",text
        add    -4,sp
        st.w   r1,[r3]
        mov    #V_AD0,r1
        jmp    [r1]

        .section ".vect_AD1",text
        add    -4,sp
        st.w   r1,[r3]
        mov    #V_AD1,r1
        jmp    [r1]

```


4.1.4 Startup routine setting

```

=====
# DESCRIPTIONS:
#   This assembly program is a sample of start-up module for ca850.
#   If you modified this program, you must assemble this file, and
#   locate a given directory.
#
#   Unless -G is specified, sections are located as the following.
#
#           |           :           |
#           |           :           |
#   tp -> -+-----+ + __start  __tp_TEXT
#           | start up |
#           |-----|
# text section |         |
#           | user program |
#           |         |
#           |-----|
#           | library |
#           -+-----+
#
# sdata section |         |
#
#   gp -> -+-----+ +           __ssbss
#
# sbss section |         |
#
#           +-----+ + __stack  __esbss  __sbss
#           | stack area |
# bss section |         |
#           | 0x400 bytes |
#   sp -> -+-----+ + __stack + STACKSIZE  __ebss
#           |           :           |
#           |           :           |
#           |           :           |
#   ep -> -+-----+ + __ep_DATA
# tidata section |         |
#
#           -+-----+ +
# sidata section |         |
#
#           -+-----+ +
#           |           :           |
#           |           :           |
#
#=====
#-----
#   special symbols
#-----

```

```

.extern _ _tp_TEXT, 4
.extern _ _gp_DATA, 4
.extern _ _ep_DATA, 4
.extern _ _ssbss, 4
.extern _ _esbss, 4
.extern _ _sbss, 4
.extern _ _ebss, 4

#-----
#      C program main function
#-----
      .extern _main

#-----
#      dummy data declaration for creating sbss section
#-----
      .sbss
      .lcomm _ _sbss_dummy, 0, 0

#-----
#      system stack
#-----
      .set  STACKSIZE, 0x400
      .bss
      .lcomm _ _stack, STACKSIZE, 4

#-----
#      start up
#      pointers: tp - text pointer
#                gp - global pointer
#                sp - stack pointer
#                ep - element pointer
#      exit status is set to r10
#-----
      .text
      .align 4
      .globl _ _start
      .globl _exit
      .globl _ _exit
__ _start:
      mov     0x12,r10
      st.b    r10,VSWC[r0]          -- Set peripheral I/O wait

      mov     0x07,r10             -- x10
      st.b    r0,PHCMD[r0]

```

```

    st.b    r10,CKC[r0]           -- PLL xx multiplication
    nop
    nop
    nop
    nop
    nop

    mov     #_ _tp_TEXT, tp       -- set tp register
    mov     #_ _gp_DATA, gp       -- set gp register offset
    add     tp, gp                -- set gp register
    mov     #_ _stack+STACKSIZE, sp -- set sp register
    mov     #_ _ep_DATA, ep       -- set ep register
#
    mov     #_ _sbss, r13         -- clear sbss section
    mov     #_ _ebss, r12
    cmp     r12, r13
    jnl    .L11
.L12:
    st.w    r0, [r13]
    add     4, r13
    cmp     r12, r13
    jl     .L12
.L11:
#
    mov     #_ _sbss, r13         -- clear bss section
    mov     #_ _ebss, r12
    cmp     r12, r13
    jnl    .L14
.L15:
    st.w    r0, [r13]
    add     4, r13
    cmp     r12, r13
    jl     .L15
.L14:
#
    jarl    _main, lp            -- call main function
_ _exit:
    halt                -- end of program
_ _startend:
    nop
#
#----- end of start up module -----#
#
#

```

4.1.5 Main processing function

```

#include    "Common.h"
#include    "Motor.h"

```

```

#pragma      ioreg                /* Peripheral I/O register definition */

static int save_psw;
/*****
/*      3-phase motor control program      */
*****/

void main()
{
unsigned char  proc_no ;          /* Present processing number */
signed int    speed ;           /* Indication speed rms */
signed int    accel_spd ;
int           sw, sw_mode ;
/* */

    hinit() ;                   /* Hardware initialization */
    ainit() ;                   /* Initialization of area used */
    proc_no = 0 ;
    _ _EI();
    while( 1 ) {
        accel_spd = ( SPEED_MAX - SPEED_MINI ) / 100;
        speed = ( ( SPEED_MAX - SPEED_MINI ) * volume / 1024 )
                + SPEED_MINI ;   /* Indication speed calculation by volume */
        sw = ~IN_data( SW ) & 0x07 ; /* Read operation button */
        if ( sw == 1 ) {
            sw_mode = CW ;
        } else if ( sw == 2 ) {
            sw_mode = CCW ;
        } else if ( sw == 4 ) {
            sw_mode = STOP ;
        }
        switch( proc_no ) {
/* STOP processing */
        case 0 :
            if ( sw_mode == CW ) {
                _ _DI() ;
                object_speed = SPEED_MINI ; /* Set target speed to minimum value */
                stop_flag = OFF ;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
                accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
                init_flag = 2 ; /* CCW initial request */
                start_init() ; /* Initialize revolution start */
                _ _EI() ;
                proc_no = 1 ; /* Set next processing number */
            } else if ( sw_mode == CCW ) {
                _ _DI() ;
                stop_flag = OFF ; /* Stop flag off */
                object_speed = -SPEED_MINI ; /* Set target speed to minimum value */
                timer_count = WATCH_START ; /* Set speed monitor start time to */
                /* 5 SEC */
            }
        }
    }
}

```

```

        accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
        init_flag = 3 ;                /* CCW initial request */
        start_init() ;                /* Initialize revolution start */
        _EI() ;
        proc_no = 4 ;                  /* Set CCW processing number */
    }
    break ;
/* CW processing, acceleration */
    case 1 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ; /* Set acceleration/deceleration counter */
            if ( object_speed < speed ) {
                object_speed += accel_spd ;
                if ( object_speed > speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else if ( object_speed > speed ) {
                object_speed -= accel_spd ;
                if ( object_speed < speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                proc_no = 2 ;          /* Constant-speed processing */
            }
        }
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;              /* Deceleration, set processing number */
        }
        break ;
/* CW processing, constant-speed */
    case 2 :
        object_speed = speed ;
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;              /* Deceleration, set processing number */
        }
        break ;
/* CW stop processing */
    case 3 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ; /* Set acceleration/deceleration counter */
            if ( object_speed > SPEED_MINI ) {
                object_speed -= accel_spd ;
                if ( object_speed < SPEED_MINI ) object_speed = SPEED_MINI;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                stop_flag = ON ;      /* Stop flag on */
                proc_no = 0 ;         /* Set stop processing number */
            }
        }
        break ;

```

```

/* CCW processing, acceleration */
    case 4 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;          /* Set acceleration/deceleration counter */
            if ( object_speed < -speed ) {
                object_speed += accel_spd ;
                if ( object_speed > -speed ) object_speed = -speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else if ( object_speed > -speed ) {
                object_speed -= accel_spd ;
                if ( object_speed < -speed ) object_speed = -speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                proc_no = 5 ;                  /* Constant-speed processing */
            }
        }
        if ( (sw_mode == CW) || (sw_mode == STOP) ) {
            proc_no = 6 ;                      /* Deceleration, set processing number */
        }
        break ;
/* CCW processing, constant-speed */
    case 5 :
        object_speed = -speed ;
        if ( (sw_mode == CW) || (sw_mode == STOP) ) {
            proc_no = 6 ;                      /* Deceleration, set processing number */
        }
        break ;
/* CCW stop processing */
    case 6 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;          /* Set acceleration/deceleration counter */
            if ( object_speed < -SPEED_MINI ) {
                object_speed += accel_spd ;
                if ( object_speed > -SPEED_MINI ) object_speed = -SPEED_MINI;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                stop_flag = ON ;               /* Stop flag on */
                proc_no = 0 ;                 /* Set stop processing number */
            }
        }
        break ;
}

if ( ( proc_no == 2 ) || ( proc_no == 5 ) ) {
    if ( timer_count == 0 ) {
        if ( abs( object_speed - now_speed ) > SA_SPEED_MAX ) {
            error_flag = ERR_NO2 ;          /* Set error No. */
        }
    }
}

```

```

    }
}

if ( disp_co == 0 ) {
    led_num(1, d_speed / 100 );          /* Number of revolutions */
    d_speed = 0 ;
    disp_co = 100 ;
    if ( abs(now_speed) == 0 ) {
        disp_co = 0;
    }
    led_num(2, 1000/PWM_TS );           /* Carrier frequency */
    led_num(3, cont_time );            /* Overall processing time */
    led_num(4, cont_time1 );          /* Vector operation processing time */
}

if ( error_flag ) {
    while( 1 ) {
        OUT_data( LED41, ~0x00 ) ;     /* LED display off */
        OUT_data( LED42, ~0x00 ) ;
        timer_count = 50 ;
        while( timer_count ) ;
        if ( error_flag == ERR_NO1 ) {
            OUT_data( LED41, ~0x9e ) ; /* E1 display */
            OUT_data( LED42, ~0x60 ) ;
        } else if ( error_flag == ERR_NO2 ) {
            OUT_data( LED41, ~0x9e ) ; /* E2 display */
            OUT_data( LED42, ~0xda ) ;
        } else {
            OUT_data( LED41, ~0x9e ) ; /* E3 display */
            OUT_data( LED42, ~0xf2 ) ;
        }
        timer_count = 50 ;
        while( timer_count ) ;
    }
}
}
}
}

```

4.1.6 LED display function

```

/*****
/*      LED value display subroutine                               */
/*          no : Display area number (1 to 4)                     */
/*          data: Display data (0 to 99)                          */
*****/
void led_num( int no, long data )
{
    if ( no == 1 ) {
        data = data % 10000;
    }
}

```

```

    OUT_data( LED11, ~led_pat[data/1000]&0xff ) ;
    OUT_data( LED12, ~led_pat[(data%1000)/100]&0xff ) ;
    OUT_data( LED13, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED14, ~led_pat[data%10]&0xff ) ;
} else if ( no == 2 ) {
    OUT_data( LED21, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED22, ~led_pat[data%10]&0xff ) ;
} else if ( no == 3 ) {
    OUT_data( LED31, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED32, ~led_pat[data%10]&0xff ) ;
} else {
    OUT_data( LED41, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED42, ~led_pat[data%10]&0xff ) ;
}
}
}
/*****
/*      External I/O output subroutine                               */
/*          reg : Output register number                           */
/*          data: Output data                                       */
/*****
void  OUT_data( unsigned short reg, unsigned short data )
{
    if ( reg == WRESET ) {
        P4.3 = 0;
        data = 1;                /* Dummy step */
        P4.3 = 1;
    } else {
        PDL = data | ( reg << 8 );
        PDL = reg | ( reg << 8 ) | 0x8000;
    }
}
}
/*****
/*      External I/O input subroutine                               */
/*          reg: Input register number                             */
/*****
unsigned short  IN_data( int reg )
{
    unsigned char *po;
    /* */
    if ( reg == SW ) {
        return P4;
    } else {
        return 0;
    }
}
}

```


4.1.7 Motor control interrupt processing function

```

#include    "Common.h"
#include    "Motor.h"
#pragma    ioreg          /* Peripheral I/O register definition */
/*****
/*      Motor control timer interrupt processing
*****/
__interrupt
void    int_MOTOR(void)
{
    ADSCM00 = 0x8001 ;      /* Start AD0 */
    ADSCM10 = 0x8000 ;      /* Start AD1 */
}
/*****
/*      Motor control processing
*****/
void    Motor_CONT(void)
{
    signed int    wrm, wre, trm, tre ;
    signed int    o_wre, we, o_iqap, o_iqa ;
    signed int    ida, iqa, o_vdal, o_vqa1 ;
    signed int    o_vd0, o_vq0, o_vda, o_vqa ;
    signed int    o_vua, o_vva, o_vwa, wiua, wiva ;
    signed int    s_time, wk ;
    signed short  now_enc, sa_enc ;
    /* */
    /*****
    /*      Calculation processing of speed and rotor position
    *****/
    now_enc = -TM10 ;
    sa_enc = now_enc - before_enc ;
    if ( abs( sa_enc ) > ( MAXPULSE / 2 ) ) {
        if ( sa_enc < 0 ) {
            sa_enc += MAXPULSE ;
        } else {
            sa_enc -= MAXPULSE ;
        }
    }
    before_enc = now_enc ;
    wrm = now_speed = (signed long)sa_enc * RAD / MAXPULSE; /* Set current speed */

    wre = wrm * P ;
    tre = ( trm * P + OFFSET ) % RAD ;
    /*****
    /*      Speed control processing
    *****/
    if ( ( stop_flag == OFF ) && ( error_flag == 0 ) ) {

```

```

s_time = TM3 ;
o_wre = object_speed * RPM_RADS * P / TH_U ;      /* rpm -> radian conversion */
we = o_wre - wre ;
o_iqap = ( ( wre * KSP ) + ( we * KSP ) ) >> KSPGETA ;
o_iqa = o_iqap + ( o_iqai >> KSIGETA ) ;

if ( o_iqai > IQAMAX ) {
    o_iqai = IQAMAX ;
} else if ( o_iqai < -IQAMAX ) {
    o_iqai = -IQAMAX ;
} else {
    o_iqai += ( KSI * we ) ;
}

/*****
/*      Current control processing                               */
*****/

ida = ( ( ( iva * sin( tre ) ) - ( iua * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
iqa = ( ( ( iva * sin( tre + RAD/4 ) ) - ( iua * sin( tre + 11*RAD/12 ) ) ) ) >> SGETA ;

o_vda = ( KI * -ida ) >> KIGETA ;
o_vqa = ( KI * ( o_iqa - iqa ) ) >> KIGETA ;

/*****
/*      3-phase voltage conversion processing                       */
*****/

if ( init_flag == 2 ) {                                     /* CW initial processing */
    o_trm += ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm > ( 2 * RAD ) ) {
        init_flag = 0;
    }
} else if ( init_flag == 3 ) {                               /* CCW initial processing */
    o_trm -= ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm < -( 2 * RAD ) ) {
        init_flag = 0;
    }
} else {
    o_trm = 0 ;
}

o_vua = ( ( ( o_vda * sin( tre + RAD/4 ) ) - ( o_vqa * sin( tre ) ) ) ) >> SGETA ;
o_vva = ( ( ( o_vda * sin( tre + 11*RAD/12 ) ) - ( o_vqa * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
o_vwa = -o_vua - o_vva ;

cont_time1 = ( TM3 - s_time ) * 10 / 16;                /* Convert to uSEC */

```

```

/***** /
/*      PWM conversion output processing      */
/***** /

    OUT_data( WRESET, 0 ) ;                /* Reset watchdog timer */
    POER0 = 0x3f ;                        /* All phases active */
    TUC00 = 0x02 ;                        /* Clear PWM output prohibition */

/* PWM counter value calculation output */
    o_vua += ( PWM_DATA / 2 ) ;
    o_vva += ( PWM_DATA / 2 ) ;
    o_vwa += ( PWM_DATA / 2 ) ;

    if ( o_vua <= 0 ) {
        o_vua = 1 ;
    } else if ( o_vua >= PWM_DATA ) {
        o_vua = PWM_DATA - 1 ;
    }
    if ( o_vva <= 0 ) {
        o_vva = 1 ;
    } else if ( o_vva >= PWM_DATA ) {
        o_vva = PWM_DATA - 1 ;
    }
    if ( o_vwa <= 0 ) {
        o_vwa = 1 ;
    } else if ( o_vwa >= PWM_DATA ) {
        o_vwa = PWM_DATA - 1 ;
    }

    BFCM00 = o_vua ;
    BFCM01 = o_vva ;
    BFCM02 = o_vwa ;
} else {
    POER0 = 0 ;                            /* PWM output off */
    now_speed = 0;
    cont_time1 = 0;
}
}

```

4.1.8 10 mSEC interval interrupt processing function

```

/***** /
/*      Other timer interrupt processing (10 mSEC interval)      */
/***** /

__multi_interrupt
void int_ETC(void)
{
    unsigned short dummy ;
    /* Wait timer processing */
    if ( timer_count != 0 ) {

```

```

    timer_count -= 1 ;
}
/* Acceleration/deceleration timer processing */
if ( accel_count != 0 ) {
    accel_count -= 1 ;
}
/* */
if ( disp_co != 0 ) {
    d_speed += abs( now_speed ) ;
    disp_co -= 1 ;
}
}

```

4.1.9 A/D converter interrupt processing function

```

/***** /
/*      A/D converter interrupt processing for U-phase current and speed volume */
/***** /
_ _multi_interrupt
void int_AD0(void)
{
    iua = (( ADCR00 & 0x3ff ) - 0x200) ;
    if ( abs(iua) > MAX_I ) {
        POER0 = 0 ;                /* PWM output off */
        error_flag = ERR_NO1 ;    /* Set error No. */
    }
    volume = 1023 - ( ADCR01 & 0x3ff ) ; /* Set volume value */
    Motor_CONT() ;
    cont_time = TM3 * 10 / 16;      /* Convert to uSEC */
}
/***** /
/*      A/D converter interrupt processing for V-phase current          */
/***** /
_ _interrupt
void int_AD1(void)
{
    iva = (( ADCR10 & 0x3ff ) - 0x200) ;
    if ( abs(iva) > MAX_I ) {
        POER0 = 0 ;                /* PWM output off */
        error_flag = ERR_NO1 ;    /* Set error No. */
    }
}
}

```

4.1.10 Hardware initialization processing function

```

/***** /
/*      Hardware (peripheral I/O) initialization          */
/***** /

```

```

void hinit( void )
{
short dummy ;
/* Port mode register initialization */
  PMC1 = 0x3f ;          /* ENC select */
  PMC2 = 0x07 ;
  PM2  = 0x07 ;

  PM4 = 0xf7 ;
  PMDL = 0x0000 ;

  OUT_data( LED11, 0xff ) ;          /* LED OFF */
  OUT_data( LED12, 0xff ) ;
  OUT_data( LED13, 0xff ) ;
  OUT_data( LED14, 0xff ) ;
  OUT_data( LED21, 0xff ) ;
  OUT_data( LED22, 0xff ) ;
  OUT_data( LED31, 0xff ) ;
  OUT_data( LED32, 0xff ) ;
  OUT_data( LED41, 0xff ) ;
  OUT_data( LED42, 0xff ) ;
/* Set 10 mSEC timer TM2 */
  STOPTE0 = 0x0000;
  PRM02 = 0x01;          /* Select fXX/2 */
  CSE0 = 0x0028;        /* Select fCLK/64 (3.2 uSEC) */
  TCRE0 = 0x2000;       /* Start timer */
  CVSE50 = 1562*2 ;     /* 10 mSEC */
  CMSE050 = 0x2400;
  CC2IC5 = 0x06;

/* Set motor control interrupt timer TM3 */
  PRM03 = 1 ;          /* fCLK = fXX */
  TMC30 = 0x51;        /* fXX = 4 MHz*10/64(1.6 uSEC) */
  TMC31 = 0x09 ;
  CC30 = TS * 10 / 16 ; /* TS uSEC interval */
  TMC30 = 0x53;        /* Start timer */
  CC3IC0 = 0x02;       /* Reset interrupt mask */
/* TM10 initialization */
  PRM02 = 1 ;          /* fCLK = fXX/2 */
  TUM0 = 0x80 ;        /* Select UDC mode */
  PRM10 = 0x07 ;       /* Select operation mode 4 */
  TMC10 = 0x40 ;       /* Start count */
/* TM00 initialization */
  PRM01 = 0 ;          /* fCLK = fXX/2 */
  SPEC0 = 0x0000 ;
  TOMR0 = 0x80 ;       /* Set output mode */
  PSTO0 = 0x00 ;       /* Disable real-time output */
  BFCM00 = PWM_DATA /2 ; /* Set duty to 50 */
  BFCM01 = PWM_DATA /2 ; /* Set duty to 50 */

```

```

BFCM02 = PWM_DATA /2 ;           /* Set duty to 50 */
BFCM03 = PWM_DATA ;             /* Set PWM cycle */
DTRR0 = 40*3 ;                  /* Dead time 6 uSEC */
POER0 = 0x3f ;                  /* All phases active */
TMC00 = 0x8018 ;                /* Start TMPWM timer */
/* Set A/D */
ADSCM00 = 0x0001 ;
ADSCM10 = 0x0000 ;
ADIC0 = 0x03 ;
ADIC1 = 0x03 ;
}

```

4.1.11 Common area initialization processing function

```

/*****
/*      Common area initialization      */
/***** /
void  ainit( void )
{
/* Initialization of flags */
  error_flag = 0 ;                /* Clear error flag */
  init_flag = OFF ;              /* Initial flag off */
  disp_co = 100 ;
  d_speed = 0 ;
/* Motor control area initialization */
  stop_flag = ON ;               /* Stop flag on */
  object_speed = 0 ;            /* Target speed 0 */
  o_iqai = 0 ;                  /* Speed integral value 0 */
  o_trm = 0 ;
  before_enc = -TM10 ;          /* Set previous encoder value */
}

```

4.1.12 Revolution start initialization processing function

```

/*****
/*      Revolution start initialization      */
/***** /
void  start_init( void )
{
  int  i;
/* */
  for ( i = 0 ; i < 21 ; i++ ) before_posi[i][1] = 0;
  total_sa = 0 ;
  sum_speed = 0 ;
  speed_co = 100000 / TS ;
}

```

4.1.13 sin calculation processing function

```

/***** /
/*      sin x                                     */
/*      Data                                     */
/*      Radian unit                             */
/*      Return value                             */
/*      Sign value*16384                         */
/***** /
int sin( int x )
{
    x = x % RAD ;
    if ( x < 0 ) x += RAD ;
    if ( x < (RAD/4) ){
        return sins( x ) ;
    } else if ( x < (RAD/2) ) {
        return sins( (RAD/2) - x ) ;
    } else if ( x < (RAD*3/4) ) {
        return -sins( x - (RAD/2) ) ;
    } else {
        return -sins( RAD - x ) ;
    }
}

/***** /
int sins( int x )
{
short z1, z2, z3, z4, z5 ;
/* */
    if ( x <= (RAD/8) ) {
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z3 = z1 * z2 >> SGETA ;
        z5 = z2 * z3 >> SGETA ;
        return ( (12868*z1) - (1322*z3) + (40*z5) ) >> SGETA ;
    } else {
        x = (RAD/4) - x ;
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z4 = z2 * z2 >> SGETA ;
        return ( (268432772) - (5050*z2) + (252*z4) ) >> SGETA ;
    }
}

```

4.1.14 Link directive file for V850E/IA1

```

/***** /
/*      Link directive file for V850E/IA1       */
/***** /

```

```

VECT_RESET: !LOAD ?RX V0x0000000 {
    .vect_RESET = $PROGBITS ?AX .vect_RESET;
};
ID_NO: !LOAD ?RX V0x0000070 {
    .id_NO = $PROGBITS ?AX .id_NO;
};
VECT_ETC: !LOAD ?RX V0x0000240 {
    .vect_ETC = $PROGBITS ?AX .vect_ETC;
};
VECT_MOTOR: !LOAD ?RX V0x0000260 {
    .vect_MOTOR = $PROGBITS ?AX .vect_MOTOR;
};
VECT_AD0: !LOAD ?RX V0x00003a0 {
    .vect_AD0 = $PROGBITS ?AX .vect_AD0;
};
VECT_AD1: !LOAD ?RX V0x00003b0 {
    .vect_AD1 = $PROGBITS ?AX .vect_AD1;
};

HANDLER: !LOAD ?RX V0x00001000 {
    .handler = $PROGBITS ?AX .handler;
};
TEXT: !LOAD ?RX {
    .text = $PROGBITS ?AX .text;
};

CONST : !LOAD ?R {
    .const = $PROGBITS ?A .const;
};

DATA : !LOAD ?RW V0x0fffc000 {
    .data = $PROGBITS ?AW ;
    .sdata = $PROGBITS ?AWG ;
    .sbss = $NOBITS ?AWG ;
    .bss = $NOBITS ?AW ;
};

__tp_TEXT @ %TP_SYMBOL;
__gp_DATA @ %GP_SYMBOL &__tp_TEXT{DATA};
__ep_DATA @ %EP_SYMBOL;

```


4.2 Program List (V850E/IA2)

4.2.1 Symbol definition

```

/*****
/*      Common area
*****/
unsigned char  ram_start ;
unsigned char  error_flag ;          /* Error flag */
unsigned char  init_flag ;          /* Initial flag */
unsigned short cont_time ;          /* Interrupt control time uSEC */
unsigned short cont_time1 ;        /* Vector operation time uSEC */
unsigned short disp_co ;          /* Interrupt control time display timer */
unsigned short volume ;          /* Volume value */
unsigned short timer_count ;      /* Time wait counter */
unsigned short accel_count ;      /* Acceleration/deceleration operation time */
                                   /* counter */

unsigned char  stop_flag ;          /* Stop flag */
signed short  before_posi[21][2] ; /* Position buffer */
signed short  total_sa ;          /* Position total difference */
signed int    sum_speed ;
signed int    speed_co ;
signed int    now_speed ;          /* Present speed rms */
signed int    object_speed ;      /* Target speed rms */
unsigned int  d_speed ;          /* Display speed rms */
unsigned char ram_end ;

#pragma section const begin
const unsigned short led_pat[10] = { 0xfc, 0x60, 0xda, 0xf2, 0x66, 0xb6, 0xbe, 0xe0,
                                     0xfe, 0xe6 } ;

#pragma section const end
/*****
/*      Common flags
*****/
extern unsigned char  ram_start ;
extern unsigned char  error_flag ;          /* Error flag */
extern unsigned char  init_flag ;          /* Initial flag */
extern unsigned short cont_time ;          /* Interrupt control time uSEC */
extern unsigned short cont_time1 ;        /* Vector operation time uSEC */
extern unsigned short disp_co ;          /* Interrupt control time display timer */
extern unsigned short volume ;          /* Volume value */
extern unsigned short timer_count ;      /* Time wait counter */
extern unsigned short accel_count ;      /* Acceleration/deceleration operation */
                                   /* time counter */

extern unsigned char  stop_flag ;          /* Stop flag */
extern signed short  before_posi[21][2] ; /* Position buffer */
extern signed short  total_sa ;          /* Position total difference */
extern signed int    sum_speed ;

```

```

extern signed int      speed_co ;
extern signed int      now_speed ;          /* Present speed rms */
extern signed int      object_speed ;      /* Target speed rms */
extern unsigned int    d_speed ;          /* Display speed rms */
extern unsigned char   ram_end ;

#pragma section const begin
extern const unsigned short led_pat[] ;;
#pragma section const end
/*****
/*      Motor common definition
*****/

extern signed short    iua ;              /* U-phase current */
extern signed short    iva ;              /* V-phase current */
extern signed int      o_iqai ;          /* Speed integral value area */
extern signed int      o_trm ;           /* Target position for initialization */
extern signed int      base_position ;   /* Speed estimation value reference point */
extern unsigned int    sa_time ;         /* Speed measurement value */
extern unsigned short  timer_count ;     /* Time wait counter */
extern unsigned short  accel_count ;     /* Acceleration/deceleration operation */
/* time counter */
extern signed short    before_enc ;      /* Previous encoder value */

```

4.2.2 Constant definition

```

/*****
/*      I/O
*****/

#define BASE_IO      0xc200000
#define LED11        3
#define LED12        2
#define LED13        1
#define LED14        0
#define LED21        5
#define LED22        4
#define LED31        7
#define LED32        6
#define LED41        9
#define LED42        8

#define DIPSW        0x10
#define SW           0x20
#define DA1          0x30
#define DA2          0x40
#define DA3          0x50
#define WRESET       0x60
#define MODE         0x70
/*****

```

```

/*      Constant                                                                 */
/***** /
#define ON          1
#define OFF        0
#define CW         1          /* CW operation mode */
#define CCW        2          /* CCW operation mode */
#define STOP       0          /* Operation stop mode */
#define ERR_NO1    1          /* Overcurrent error */
#define ERR_NO2    2          /* Speed difference error */
/***** /
/*      Motor constant                                                            */
/***** /
#define PAI         3.14159265          /*  $\pi$  */
#define TH_U        1000                /* Radian value jack-up constant */
#define RAD         (int)(2*PAI*TH_U)   /* Radian value of one revolution */
#define OFFSET      1945                /* Original point OFFSET */
#define RPM_RADS    (int)((2*PAI*TH_U)/60) /* rpm -> radian conversion constant */
/* Motor constant */
#define KSP         500                /* Speed proportion constant */
#define KSI         50                 /* Speed integral constant */
#define KI          1                  /* Current conversion constant */
#define P           2                  /* Number of poles */

#define KSPGETA     0                  /* KSP jack-up constant */
#define KSIGETA     9                  /* KSI jack-up constant */
#define KIGETA      9                  /* KI jack-up constant */
#define SGETA       14                 /* sin jack-up constant */

#define PWM_TS      50                 /* PWM cycle */
#define PWM_DATA    (PWM_TS/0.05)     /* PWM set value */
#define SPEED_MAX   3000               /* Maximum speed rpm */
#define SPEED_MINI  600                /* Minimum speed rpm */
#define SA_SPEED_MAX 800               /* Maximum speed difference rpm */
#define IQAMAX      40000000          /* Maximum speed integral value */
#define MAX_I       800                /* Maximum current value */
#define TS          200                /* Motor control time interval uSEC */
#define WATCH_START 500               /* Speed monitor start time 10 mSEC */
#define ACCEL_VAL_1ST 50               /* Initial acceleration/deceleration */
/* time constant */
#define ACCEL_VAL   3                  /* Acceleration/deceleration time */
/* constant */
#define ACCEL_SPD   50                 /* Acceleration/deceleration constant */
#define MAXPULSE    10000             /* Number of pulses of one revolution */
/***** /
/*      Function constant                                                            */
/***** /
void          fcalcu( signed int *worm, signed int *trm );
void          OUT_data( unsigned short reg, unsigned short data );

```

```

unsigned short  IN_data( int reg );
void            led_num( int no, long data ) ;
/***** /
/*      Motor-related common area                               */
/***** /
signed short    iua ;          /* U-phase current */
signed short    iva ;          /* V-phase current */
signed int      o_iqai ;       /* Speed integral value area */
signed int      o_trm ;        /* Target position for initialization */
signed int      base_position ; /* Speed estimation value reference point */
unsigned int    sa_time ;      /* Speed measurement value */
unsigned short  timer_count ;  /* Time wait counter */
unsigned short  accel_count ;  /* Acceleration/deceleration operation time counter */
signed short    before_enc ;   /* Previous encoder value */

```

4.2.3 Interrupt handler setting

```

/***** /
/*      Interrupt symbol table                               */
/***** /

    .extern __start
    .extern _int_MOTOR
    .extern _int_AD0
    .extern _int_AD1
    .extern _int_ETC

    .globl V_RESET
    .globl V_ETC
    .globl V_MOTOR
    .globl V_AD0
    .globl V_AD1
#*****

    .section ".handler",text
V_RESET:
    Jr      __start
V_ETC:
    ld.w   [sp],r1
    add    4,sp
    jr     _int_ETC          -- Other timers
V_MOTOR:
    ld.w   [sp],r1
    add    4,sp
    jr     _int_MOTOR       -- Speed control timer
V_AD0:
    ld.w   [sp],r1
    add    4,sp
    jr     _int_AD0        -- A/D converter CH0
V_AD1:

```

```

ld.w    [sp],r1
add     4,sp
jr      _int_AD1          -- A/D converter CH1

.extern V_RESET
.extern V_ETC
.extern V_MOTOR
.extern V_AD0
.extern V_AD1
/*****
/*   Interrupt jump table                                     */
/*****

.section ".vect_RESET",text
mov     #V_RESET,r1
jmp     [r1]

.section ".id_NO",text
.byte   0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff

.section ".vect_ETC",text
add     -4,sp
st.w    r1,[r3]
mov     #V_ETC,r1
jmp     [r1]

.section ".vect_MOTOR",text
add     -4,sp
st.w    r1,[r3]
mov     #V_MOTOR,r1
jmp     [r1]

.section ".vect_AD0",text
add     -4,sp
st.w    r1,[r3]
mov     #V_AD0,r1
jmp     [r1]

.section ".vect_AD1",text
add     -4,sp
st.w    r1,[r3]
mov     #V_AD1,r1
jmp     [r1]

```

4.2.4 Startup routine setting

```

#=====
# DESCRIPTIONS:
#   This assembly program is a sample of start-up module for ca850.

```



```

.extern __sbss, 4
.extern __ebss, 4

#-----
#   C program main function
#-----
    .extern _main

#-----
#   dummy data declaration for creating sbss section
#-----
    .sbss
    .lcomm __sbss_dummy, 0, 0

#-----
#   system stack
#-----
    .set    STACKSIZE, 0x400
    .bss
    .lcomm __stack, STACKSIZE, 4

#-----
#   start up
#       pointers: tp - text pointer
#                   gp - global pointer
#                   sp - stack pointer
#                   ep - element pointer
#   exit status is set to r10
#-----
    .text
    .align 4
    .globl __start
    .globl _exit
    .globl __exit
__start:
    mov     0x02,r10
    st.b   r10,VSWC[r0]           -- Set peripheral I/O wait

    mov     0x07,r10             -- x10
    st.b   r0,PHCMD[r0]
    st.b   r10,CKC[r0]          -- PLL xx multiplication
    nop
    nop
    nop
    nop

```

```

        nop

        mov     #_ _tp_TEXT, tp           -- set tp register
        mov     #_ _gp_DATA, gp         -- set gp register offset
        add     tp, gp                   -- set gp register
        mov     #_ _stack+STACKSIZE, sp -- set sp register
        mov     #_ _ep_DATA, ep         -- set ep register
#
        mov     #_ _sbss, r13           -- clear sbss section
        mov     #_ _esbss, r12
        cmp     r12, r13
        jnl     .L11
.L12:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl      .L12
.L11:
#
        mov     #_ _sbss, r13           -- clear bss section
        mov     #_ _ebss, r12
        cmp     r12, r13
        jnl     .L14
.L15:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl      .L15
.L14:
#
        jarl    _main, lp               -- call main function
_ _exit:
        halt                                -- end of program
_ _startend:
        nop
#
#----- end of start up module -----#
#

```

4.2.5 Main processing function

```

#include     "Common.h"
#include     "Motor.h"
#pragma     ioreg                /* Peripheral I/O register definition */

static int save_psw;
/*****
/*      3-phase motor control program      */

```



```

/***** /
void    main()
{
unsigned char    proc_no ;                /* Present processing number */
signed int      speed ;                  /* Indication speed rms */
signed int      accel_spd ;
int             sw, sw_mode ;
/* */
    hinit() ;                            /* Hardware initialization */
    ainit() ;                             /* Initialization of area used */
    proc_no = 0 ;
    __EI();
    while( 1 ) {
        accel_spd = ( SPEED_MAX - SPEED_MINI ) / 100;
        speed = ( ( SPEED_MAX - SPEED_MINI ) * volume / 1024 )
                + SPEED_MINI ;           /* Indication speed calculation by volume */
        sw = ~IN_data( SW ) & 0x07 ;     /* Read operation button */
        if ( sw == 1 ) {
            sw_mode = CW ;
        } else if ( sw == 2 ) {
            sw_mode = CCW ;
        } else if ( sw == 4 ) {
            sw_mode = STOP ;
        }
        switch( proc_no ) {
/* STOP processing */
            case 0 :
                if ( sw_mode == CW ) {
                    __DI() ;
                    object_speed = SPEED_MINI ; /* Set target speed to minimum value */
                    stop_flag = OFF ;
                    timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
                    accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
                    init_flag = 2 ; /* CCW initial request */
                    start_init() ; /* Initialize revolution start */
                    __EI() ;
                    proc_no = 1 ; /* Set next processing number */
                } else if ( sw_mode == CCW ) {
                    __DI() ;
                    stop_flag = OFF ; /* Stop flag off */
                    object_speed = -SPEED_MINI ; /* Set target speed to minimum value */
                    timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
                    accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
                    init_flag = 3 ; /* CCW initial request */
                    start_init() ; /* Initialize revolution start */
                    __EI() ;
                    proc_no = 4 ; /* Set CCW processing number */
                }
            }
        }
}

```

```
        break ;
/* CW processing, acceleration */
    case 1 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;          /* Set acceleration/deceleration counter */
            if ( object_speed < speed ) {
                object_speed += accel_spd ;
                if ( object_speed > speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else if ( object_speed > speed ) {
                object_speed -= accel_spd ;
                if ( object_speed < speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                proc_no = 2 ;                  /* Constant-speed processing */
            }
        }
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;                      /* Deceleration, set processing number */
        }
        break ;
/* CW processing, constant-speed */
    case 2 :
        object_speed = speed ;
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;                      /* Deceleration, set processing number */
        }
        break ;
/* CW stop processing */
    case 3 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;          /* Set acceleration/deceleration counter */
            if ( object_speed > SPEED_MINI ) {
                object_speed -= accel_spd ;
                if ( object_speed < SPEED_MINI ) object_speed = SPEED_MINI;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                stop_flag = ON ;               /* Stop flag on */
                proc_no = 0 ;                  /* Set stop processing number */
            }
        }
        break ;
/* CCW processing, acceleration */
    case 4 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;          /* Set acceleration/deceleration counter */
            if ( object_speed < -speed ) {
                object_speed += accel_spd ;
```

```

        if ( object_speed > -speed ) object_speed = -speed;
        timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
    } else if ( object_speed > -speed ) {
        object_speed -= accel_spd ;
        if ( object_speed < -speed ) object_speed = -speed;
        timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
    } else {
        proc_no = 5 ;                /* Constant-speed processing */
    }
}
if ( (sw_mode == CW) || (sw_mode == STOP) ) {
    proc_no = 6 ;                    /* Deceleration, set processing number */
}
break ;
/* CCW processing, constant-speed */
case 5 :
    object_speed = -speed ;
    if ( (sw_mode == CW) || (sw_mode == STOP) ) {
        proc_no = 6 ;                /* Deceleration, set processing number */
    }
    break ;
/* CCW stop processing */
case 6 :
    if ( accel_count == 0 ) {
        accel_count = ACCEL_VAL ;    /* Set acceleration/deceleration counter */
        if ( object_speed < -SPEED_MINI ) {
            object_speed += accel_spd ;
            if ( object_speed > -SPEED_MINI ) object_speed = -SPEED_MINI;
            timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
        } else {
            stop_flag = ON ;          /* Stop flag on */
            proc_no = 0 ;              /* Set stop processing number */
        }
    }
    break ;
}

if ( ( proc_no == 2 ) || ( proc_no == 5 ) ) {
    if ( timer_count == 0 ) {
        if ( abs( object_speed - now_speed ) > SA_SPEED_MAX ) {
            error_flag = ERR_NO2 ;    /* Set error No.*/
        }
    }
}

if ( disp_co == 0 ) {
    led_num(1, d_speed / 100 );      /* Number of revolutions */
    d_speed = 0 ;
}

```

```

disp_co = 100 ;
if ( abs(now_speed) == 0 ) {
    disp_co = 0;
}
led_num(2, 1000/PWM_TS );          /* Carrier frequency */
led_num(3, cont_time );           /* Overall processing time */
led_num(4, cont_time1 );         /* Vector operation processing time */
}
if ( error_flag ) {
    while( 1 ) {
        OUT_data( LED41, ~0x00 );    /* LED display off */
        OUT_data( LED42, ~0x00 );
        timer_count = 50 ;
        while( timer_count ) ;
        if ( error_flag == ERR_NO1 ) {
            OUT_data( LED41, ~0x9e ); /* E1 display */
            OUT_data( LED42, ~0x60 );
        } else if ( error_flag == ERR_NO2 ) {
            OUT_data( LED41, ~0x9e ); /* E2 display */
            OUT_data( LED42, ~0xda );
        } else {
            OUT_data( LED41, ~0x9e ); /* E3 display */
            OUT_data( LED42, ~0xf2 );
        }
        timer_count = 50 ;
        while( timer_count ) ;
    }
}
}
}

```

4.2.6 LED display function

```

/***** /
/*      LED value display subroutine                               */
/*      no   : Display area number (1 to 4)                       */
/*      data : Display data (0 to 99)                             */
/***** /
void led_num( int no, long data )
{
    if ( no == 1 ) {
        data = data % 10000;
        OUT_data( LED11, ~led_pat[data/1000]&0xff );
        OUT_data( LED12, ~led_pat[(data%1000)/100]&0xff );
        OUT_data( LED13, ~led_pat[(data%100)/10]&0xff );
        OUT_data( LED14, ~led_pat[data%10]&0xff );
    } else if ( no == 2 ) {
        OUT_data( LED21, ~led_pat[(data%100)/10]&0xff );
    }
}

```

```

        OUT_data( LED22, ~led_pat[data%10]&0xff ) ;
    } else if ( no == 3 ) {
        OUT_data( LED31, ~led_pat[(data%100)/10]&0xff ) ;
        OUT_data( LED32, ~led_pat[data%10]&0xff ) ;
    } else {
        OUT_data( LED41, ~led_pat[(data%100)/10]&0xff ) ;
        OUT_data( LED42, ~led_pat[data%10]&0xff ) ;
    }
}
}
/*****
/*   External I/O output subroutine                               */
/*       reg : Output register number                           */
/*       data : Output data                                     */
/*****
void OUT_data( unsigned short reg, unsigned short data )
{
    if ( reg == WRESET ) {
        P3.0 = 0;
        data = 1;          /* Dummy step */
        P3.0 = 1;
    } else {
        PDL = data | ( reg << 8 );
        PDL = reg | ( reg << 8 ) | 0x8000;
    }
}
}
/*****
/*   External I/O input subroutine                               */
/*       reg : Input register number                           */
/*****
unsigned short IN_data( int reg )
{
    unsigned char *po;
    /* */
    if ( reg == SW ) {
        return P4;
    } else {
        return 0;
    }
}
}

```

4.2.7 Motor control interrupt processing function

```

#include    "Common.h"
#include    "Motor.h"
#pragma    ioreg          /* Peripheral I/O register definition */
/*****
/*   Motor control timer interrupt processing                   */
/*****

```

```

__interrupt
void int_MOTOR(void)
{
    ADSCM00 = 0x8001 ;           /* Start AD0 */
    ADSCM10 = 0x8000 ;           /* Start AD1 */
}
/*****
/*      Motor control processing
*****/
void Motor_CONT(void)
{
    signed int    wrm, wre, trm, tre ;
    signed int    o_wre, we, o_iqap, o_iqa ;
    signed int    ida, iqa, o_vda1, o_vqa1 ;
    signed int    o_vd0, o_vq0, o_vda, o_vqa ;
    signed int    o_vua, o_vva, o_vwa, wiua, wiva ;
    signed int    s_time, wk ;
    signed short  now_enc, sa_enc ;
    /* */
    /*****
    /*      Calculation processing of speed and rotor position
    *****/
    now_enc = -TM10 ;
    sa_enc = now_enc - before_enc ;
    if ( abs( sa_enc ) > ( MAXPULSE / 2 ) ) {
        if ( sa_enc < 0 ) {
            sa_enc += MAXPULSE ;
        } else {
            sa_enc -= MAXPULSE ;
        }
    }
    before_enc = now_enc ;
    wrm = now_speed = (signed long)sa_enc * RAD / MAXPULSE; /* Set current speed */

    wre = wrm * P ;
    tre = ( trm * P + OFFSET ) % RAD ;
    /*****
    /*      Speed control processing
    *****/
    if ( ( stop_flag == OFF ) && ( error_flag == 0 ) ) {
        s_time = TM3 ;
        o_wre = object_speed * RPM_RADS * P / TH_U ; /* rpm -> radian conversion */
        we = o_wre - wre ;
        o_iqap = ( ( wre * KSP ) + ( we * KSP ) ) >> KSPGETA ;
        o_iqa = o_iqap + ( o_iqai >> KSIGETA ) ;

        if ( o_iqai > IQAMAX ) {
            o_iqai = IQAMAX ;

```

```

    } else if ( o_iqai < -IQAMAX ) {
        o_iqai = -IQAMAX ;
    } else {
        o_iqai += ( KSI * we ) ;
    }
}
/*****
/*    Current control processing
*****/
ida = ( ( ( iva * sin( tre ) ) - ( iua * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
iqa = ( ( ( iva * sin( tre + RAD/4 ) ) - ( iua * sin( tre + 11*RAD/12 ) ) ) ) >> SGETA ;

o_vda = ( KI * -ida ) >> KIGETA ;
o_vqa = ( KI * ( o_iqa - iqa ) ) >> KIGETA ;
/*****
/*    3-phase voltage conversion processing
*****/
if ( init_flag == 2 ) {
    o_trm += ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm > ( 2 * RAD ) ) {
        init_flag = 0;
    }
} else if ( init_flag == 3 ) {
    o_trm -= ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm < -( 2 * RAD ) ) {
        init_flag = 0;
    }
} else {
    o_trm = 0 ;
}

o_vua = ( ( ( o_vda * sin( tre + RAD/4 ) ) - ( o_vqa * sin( tre ) ) ) ) >> SGETA ;
o_vva = ( ( ( o_vda * sin( tre + 11*RAD/12 ) ) - ( o_vqa * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
o_vwa = -o_vua - o_vva ;

cont_time1 = ( TM3 - s_time ) * 10 / 16;
/*****
/*    PWM conversion output processing
*****/
OUT_data( WRESET, 0 ) ;
POERO = 0x3f ;
TUC00 = 0x02 ;
/*****
/* PWM counter value calculation output */
o_vua += ( PWM_DATA / 2 ) ;

```

```

o_vva += ( PWM_DATA / 2 ) ;
o_vwa += ( PWM_DATA / 2 ) ;

if ( o_vua <= 0 ) {
    o_vua = 1 ;
} else if ( o_vua >= PWM_DATA ) {
    o_vua = PWM_DATA - 1 ;
}
if ( o_vva <= 0 ) {
    o_vva = 1 ;
} else if ( o_vva >= PWM_DATA ) {
    o_vva = PWM_DATA - 1 ;
}
if ( o_vwa <= 0 ) {
    o_vwa = 1 ;
} else if ( o_vwa >= PWM_DATA ) {
    o_vwa = PWM_DATA - 1 ;
}

BFCM00 = o_vua ;
BFCM01 = o_vva ;
BFCM02 = o_vwa ;
} else {
    POER0 = 0 ;                               /* PWM output off */
    now_speed = 0;
    cont_time1 = 0;
}
}

```

4.2.8 10 mSEC interval interrupt processing function

```

/***** /
/*   Other timer interrupt processing (10 mSEC interval)   */
/***** /
__multi_interrupt
void int_ETC(void)
{
    unsigned short dummy ;
    /* Wait timer processing */
    if ( timer_count != 0 ) {
        timer_count -= 1 ;
    }
    /* Acceleration/deceleration timer processing */
    if ( accel_count != 0 ) {
        accel_count -= 1 ;
    }
    /* */
    if ( disp_co != 0 ) {

```



```

    d_speed += abs( now_speed ) ;
    disp_co -= 1 ;
}
}

```

4.2.9 A/D converter interrupt processing function

```

/***** /
/*      A/D converter interrupt processing for U-phase current and speed volume */
/***** /
__multi_interrupt
void  int_AD0(void)
{
    iua = (( ADCR00 & 0x3ff ) - 0x200) ;
    if ( abs(iua) > MAX_I ) {
        POER0 = 0 ;                               /* PWM output off */
        error_flag = ERR_NO1 ;                     /* Set error No. */
    }
    volume = 1023 - ( ADCR01 & 0x3ff ) ;          /* Set volume value */
    Motor_CONT() ;
    cont_time = TM3 * 10 / 16 ;                   /* Convert to uSEC */
}
/***** /
/*      A/D converter interrupt processing for V-phase current */
/***** /
__interrupt
void  int_AD1(void)
{
    iva = (( ADCR10 & 0x3ff ) - 0x200) ;
    if ( abs(iva) > MAX_I ) {
        POER0 = 0 ;                               /* PWM output off */
        error_flag = ERR_NO1 ;                     /* Set error No. */
    }
}
}

```

4.2.10 Hardware initialization processing function

```

/***** /
/*      Hardware (peripheral I/O) initialization */
/***** /
void  hinit( void )
{
    short  dummy ;
    /* Port mode register initialization */
    PMC1 = 0x3f ;                               /* ENC select */
    PMC2 = 0x07 ;
    PM2 = 0x07 ;
}

```

```

PM3 = 0xfe ;
PM4 = 0xf7 ;
PMDL = 0x0000 ;

OUT_data( LED11, 0xff ) ;          /* LED OFF */
OUT_data( LED12, 0xff ) ;
OUT_data( LED13, 0xff ) ;
OUT_data( LED14, 0xff ) ;
OUT_data( LED21, 0xff ) ;
OUT_data( LED22, 0xff ) ;
OUT_data( LED31, 0xff ) ;
OUT_data( LED32, 0xff ) ;
OUT_data( LED41, 0xff ) ;
OUT_data( LED42, 0xff ) ;
/* Set 10 mSEC timer TM2 */
STOPTE0 = 0x0000;
PRM02 = 0x01;                    /* Select fXX/2 */
CSE0 = 0x0028;                  /* Select fCLK/64 (3.2 uSEC) */
TCRE0 = 0x2000;                 /* Start timer */
CVSE50 = 1562*2 ;              /* 10 mSEC */
CMSE050 = 0x2400;
CC2IC5 = 0x06;
/* Set motor control interrupt timer TM3 */
PRM03 = 1 ;                    /* fCLK = fXX */
TMC30 = 0x51;                  /* fXX = 4MHz*10/64(1.6 uSEC) */
TMC31 = 0x09 ;
CC30 = TS * 10 / 16 ;          /* TS uSEC interval */
TMC30 = 0x53;                  /* Start timer */
CC3IC0 = 0x02;                 /* Reset interrupt mask */
/* TM10 initialization */
PRM02 = 1 ;                    /* fCLK = fXX/2 */
TUM0 = 0x80 ;                  /* Select UDC mode */
PRM10 = 0x07 ;                 /* Select operation mode 4 */
TMC10 = 0x40 ;                 /* Start count */
/* TM00 initialization */
PRM01 = 0 ;                    /* fCLK = fXX/2 */
SPEC0 = 0x0000 ;
TOMR0 = 0x80 ;                 /* Set output mode */
PSTO0 = 0x00 ;                 /* Disable real-time output */
BFCM00 = PWM_DATA / 2 ;        /* Set duty to 50 */
BFCM01 = PWM_DATA / 2 ;        /* Set duty to 50 */
BFCM02 = PWM_DATA / 2 ;        /* Set duty to 50 */
BFCM03 = PWM_DATA ;            /* Set PWM cycle */
DTRR0 = 40*3 ;                 /* Dead time 6 uSEC */
POER0 = 0x3f ;                 /* All phases active */
TMC00 = 0x8018 ;               /* Start TMPWM timer */
/* Set A/D */
ADSCM00 = 0x0001 ;

```

```

ADSCM10 = 0x0000 ;
ADIC0   = 0x03 ;
ADIC1   = 0x03 ;
}

```

4.2.11 Common area initialization processing function

```

/***** /
/*      Common area initialization                               */
/***** /
void  ainit( void )
{
/* Initialization of flags */
    error_flag = 0 ;                               /* Clear error flag */
    init_flag = OFF ;                               /* Initial flag off */
    disp_co = 100 ;
    d_speed = 0 ;
/* Motor control area initialization */
    stop_flag = ON ;                               /* Stop flag on */
    object_speed = 0 ;                             /* Target speed 0 */
    o_iqai = 0 ;                                   /* Speed integral value 0 */
    o_trm = 0 ;
    before_enc = -TM10;                           /* Set previous encoder value */
}

```

4.2.12 Revolution start initialization processing function

```

/***** /
/*      Revolution start initialization                         */
/***** /
void  start_init( void )
{
    int  i;
/* */
    for ( i = 0 ; i < 21 ; i++ ) before_posi[i][1] = 0;
    total_sa = 0 ;
    sum_speed = 0 ;
    speed_co = 100000 / TS ;
}

```

4.2.13 sin calculation processing function

```

/***** /
/*      sin x                                               */
/*      Data                                               */
/*      Radian unit                                         */
/*      Return value                                       */
/*      Sign value*16384                                    */

```

```

/***** /
int sin( int x )
{
    x = x % RAD ;
    if ( x < 0 ) x += RAD ;
    if ( x < (RAD/4) ){
        return sins( x ) ;
    } else if ( x < (RAD/2) ) {
        return sins( (RAD/2) - x ) ;
    } else if ( x < (RAD*3/4) ) {
        return -sins( x - (RAD/2) ) ;
    } else {
        return -sins( RAD - x ) ;
    }
}
/***** /
int sins( int x )
{
short z1, z2, z3, z4, z5 ;
/* */
    if ( x <= (RAD/8) ) {
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z3 = z1 * z2 >> SGETA ;
        z5 = z2 * z3 >> SGETA ;
        return ( (12868*z1) - (1322*z3) + (40*z5) ) >> SGETA ;
    } else {
        x = (RAD/4) - x ;
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z4 = z2 * z2 >> SGETA ;
        return ( (268432772) - (5050*z2) + (252*z4) ) >> SGETA ;
    }
}

```

4.2.14 Link directive file for V850E/IA2

```

/***** /
/*      Link directive file for V850E/IA2      */
/***** /
VECT_RESET: !LOAD ?RX V0x0000000 {
    .vect_RESET = $PROGBITS ?AX .vect_RESET;
};
ID_NO: !LOAD ?RX V0x0000070 {
    .id_NO = $PROGBITS ?AX .id_NO;
};
VECT_ETC: !LOAD ?RX V0x0000240 {
    .vect_ETC = $PROGBITS ?AX .vect_ETC;
};

```

```
};
VECT_MOTOR: !LOAD ?RX V0x0000260 {
    .vect_MOTOR = $PROGBITS ?AX .vect_MOTOR;
};
VECT_AD0: !LOAD ?RX V0x00003a0 {
    .vect_AD0 = $PROGBITS ?AX .vect_AD0;
};
VECT_AD1: !LOAD ?RX V0x00003b0 {
    .vect_AD1 = $PROGBITS ?AX .vect_AD1;
};

HANDLER: !LOAD ?RX V0x00001000 {
    .handler = $PROGBITS ?AX .handler;
};
TEXT: !LOAD ?RX {
    .text = $PROGBITS ?AX .text;
};

CONST : !LOAD ?R {
    .const = $PROGBITS ?A .const;
};

DATA : !LOAD ?RW V0x0fffc000 {
    .data = $PROGBITS ?AW ;
    .sdata = $PROGBITS ?AWG ;
    .sbss = $NOBITS ?AWG ;
    .bss = $NOBITS ?AW ;
};

__tp_TEXT @ %TP_SYMBOL;
__gp_DATA @ %GP_SYMBOL &__tp_TEXT{DATA};
__ep_DATA @ %EP_SYMBOL;
```

4.3 Program List (V850E/IA3)

4.3.1 Symbol definition

```

/***** /
/*      Common area                                          */
/***** /
unsigned char   ram_start ;
unsigned char   error_flag ;          /* Error flag */
unsigned char   init_flag ;          /* Initial flag */
unsigned short  cont_time ;           /* Interrupt control time uSEC */
unsigned short  cont_time1 ;         /* Vector operation time uSEC */
unsigned short  disp_co ;            /* Interrupt control time display timer */
unsigned short  volume ;             /* Volume value */
unsigned short  timer_count ;         /* Time wait counter */
unsigned short  accel_count ;        /* Acceleration/deceleration operation time counter */
unsigned char   stop_flag ;          /* Stop flag */
signed short    before_posi[21][2] ; /* Position buffer */
signed short    total_sa ;           /* Position total difference */
signed int      sum_speed ;
signed int      speed_co ;
signed int      now_speed ;          /* Present speed rms */
signed int      object_speed ;       /* Target speed rms */
unsigned int    d_speed ;            /* Display speed rms */
unsigned char   ram_end ;

#pragma section const begin
const unsigned short led_pat[10] = { 0xfc, 0x60, 0xda, 0xf2, 0x66, 0xb6, 0xbe, 0xe0, 0xfe,
                                     0xe6 } ;

#pragma section const end
/***** /
/*      Common flags                                          */
/***** /
extern unsigned char   ram_start ;
extern unsigned char   error_flag ;          /* Error flag */
extern unsigned char   init_flag ;          /* Initial flag */
extern unsigned short  cont_time ;           /* Interrupt control time uSEC */
extern unsigned short  cont_time1 ;         /* Vector operation time uSEC */
extern unsigned short  disp_co ;            /* Interrupt control time display timer */
extern unsigned short  volume ;             /* Volume value */
extern unsigned short  timer_count ;         /* Time wait counter */
extern unsigned short  accel_count ;        /* Acceleration/deceleration operation */
/* time counter */
extern unsigned char   stop_flag ;          /* Stop flag */
extern signed short    before_posi[21][2] ; /* Position buffer */
extern signed short    total_sa ;           /* Position total difference */
extern signed int      sum_speed ;
extern signed int      speed_co ;

```

```

extern signed int      now_speed ;           /* Present speed rms */
extern signed int      object_speed ;       /* Target speed rms */
extern unsigned int    d_speed ;           /* Display speed rms */
extern unsigned char   ram_end ;

#pragma section const begin
extern const unsigned short led_pat[] ;;
#pragma section const end

/*****
/*      Motor common definition
*****/

extern signed short    iua ;               /* U-phase current */
extern signed short    iva ;               /* V-phase current */
extern signed int      o_iqai ;           /* Speed integral value area */
extern signed int      o_trm ;            /* Target position for initialization */
extern signed int      base_position ;    /* Speed estimation value reference point */
extern unsigned int    sa_time ;          /* Speed measurement value */
extern unsigned short  timer_count ;      /* Time wait counter */
extern unsigned short  accel_count ;      /* Acceleration/deceleration operation */
/* time counter */
extern signed short    before_enc ;       /* Previous encoder value */

```

4.3.2 Constant definition

```

/*****
/*      I/O
*****/

#define BASE_IO        0xc200000
#define LED11          0x03
#define LED12          0x02
#define LED13          0x01
#define LED14          0x00
#define LED21          0x05
#define LED22          0x04
#define LED31          0x07
#define LED32          0x06
#define LED41          0x09
#define LED42          0x08

#define DIPSW          0x0f
#define SW             0x0e
#define DA1           0x0a
#define DA2           0x0b
#define DA3           0x0c
#define WRESET        0x0d
#define MODE          0x10

/*****
/*      Constant
*****/

```

```

/***** /
#define ON          1
#define OFF         0
#define CW          1          /* CW operation mode */
#define CCW         2          /* CCW operation mode */
#define STOP        0          /* Operation stop mode */
#define ERR_NO1     1          /* Overcurrent error */
#define ERR_NO2     2          /* Speed difference error */
/***** /
/*      Motor constant          */
/***** /
#define PAI          3.14159265 /*  $\pi$  */
#define TH_U         1000      /* Radian value jack-up constant */
#define RAD          (int)(2*PAI*TH_U) /* Radian value of one revolution */
#define OFFSET       1733     /* Original point OFFSET */
#define RPM_RADS     (int)((2*PAI*TH_U)/60) /* rpm -> radian conversion constant */
/* Motor constant */
#define KSP           500      /* Speed proportion constant */
#define KSI           50       /* Speed integral constant */
#define KI            1        /* Current conversion constant */
#define P             2        /* Number of poles */

#define KSPGETA      0         /* KSP jack-up constant */
#define KSIGETA      9         /* KSI jack-up constant */
#define KIGETA       9         /* KI jack-up constant */
#define SGETA        14        /* sin jack-up constant */

#define PWM_TS       80        /* PWM cycle */
#define PWM_DATA     (PWM_TS/0.03125) /* PWM set value */
#define SPEED_MAX    3000     /* Maximum speed rpm */
#define SPEED_MINI   600      /* Minimum speed rpm */
#define SA_SPEED_MAX 800      /* Maximum speed difference rpm */
#define IQAMAX       40000000 /* Maximum speed integral value */
#define MAX_I        800      /* Maximum current value */
#define TS           80       /* Motor control time interval uSEC */
#define WATCH_START  500     /* Speed monitor start time 10 mSEC */
#define ACCEL_VAL_1ST 50      /* Initial acceleration/deceleration */
/* time constant */
#define ACCEL_VAL    3         /* Acceleration/deceleration time constant */
#define ACCEL_SPD    50        /* Acceleration/deceleration constant */
#define MAXPULSE     10000    /* Number of pulses of one revolution */
/***** /
/*      Function constant          */
/***** /
void          fcalcu( signed int *wrm, signed int *trm );
void          OUT_data( unsigned short reg, unsigned short data );
unsigned short IN_data( int reg );
void          led_num( int no, long data );

```



```

/***** /
/*      Motor-related common area                               */
/***** /
signed short    iua ;          /* U-phase current */
signed short    iva ;          /* V-phase current */
signed int      o_iqai ;       /* Speed integral value area */
signed int      o_trm ;        /* Target position for initialization */
signed int      base_position ; /* Speed estimation value reference point */
unsigned int    sa_time ;      /* Speed measurement value */
unsigned short  timer_count ;  /* Time wait counter */
unsigned short  accel_count ;  /* Acceleration/deceleration operation time counter */
signed short    before_enc ;   /* Previous encoder value */

```

4.3.3 Interrupt handler setting

```

/***** /
/*      Interrupt symbol table                               */
/***** /

    .extern __start
    .extern _int_MOTOR
    .extern _int_AD0
    .extern _int_AD1
    .extern _int_ETC

    .globl V_RESET
    .globl V_ETC
    .globl V_MOTOR
    .globl V_AD0
    .globl V_AD1
#*****

    .section ".handler",text
V_RESET:
    jr    __start
V_ETC:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_ETC          -- Other timers
V_MOTOR:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_MOTOR       -- Speed control timer
V_AD0:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_AD0        -- A/D converter CH0
V_AD1:
    ld.w  [sp],r1
    add   4,sp

```

```

jr      _int_AD1                -- A/D converter CH1

.extern V_RESET
.extern V_ETC
.extern V_MOTOR
.extern V_AD0
.extern V_AD1
/***** /
/*      Interrupt jump table                                     */
/***** /

.section ".vect_RESET",text
mov     #V_RESET,r1
jmp     [r1]

.section ".id_NO",text
.byte  0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff

.section ".vect_ETC",text
add     -4,sp
st.w    r1,[sp]
mov     #V_ETC,r1
jmp     [r1]

.section ".vect_MOTOR",text
add     -4,sp
st.w    r1,[sp]
mov     #V_MOTOR,r1
jmp     [r1]

.section ".vect_AD0",text
add     -4,sp
st.w    r1,[sp]
mov     #V_AD0,r1
jmp     [r1]

.section ".vect_AD1",text
add     -4,sp
st.w    r1,[sp]
mov     #V_AD1,r1
jmp     [r1]

```

4.3.4 Startup routine setting

```

#=====
# DESCRIPTIONS:
#   This assembly program is a sample of start-up module for ca850.
#   If you modified this program, you must assemble this file, and
#   locate a given directory.

```



```

#-----
#   C program main function
#-----
    .extern _main

#-----
#   dummy data declaration for creating sbss section
#-----
    .sbss
    .lcomm __sbss_dummy, 0, 0

#-----
#   system stack
#-----
    .set    STACKSIZE, 0x400
    .bss
    .lcomm  __stack, STACKSIZE, 4

#-----
#   start up
#       pointers:  tp - text pointer
#                   gp - global pointer
#                   sp - stack pointer
#                   ep - element pointer
#   exit status is set to r10
#-----
    .text
    .align 4
    .globl __start
    .globl _exit
    .globl __exit
__start:
    mov     13,r10                -- 500 kHz to 64 MHz
    st.b   r10,VSWC[r0]          -- Set peripheral I/O wait

    mov     0x03,r10              -- PLL
    st.b   r10,PLLCTL[r0]

    mov     0x00,r10
    st.b   r10,PRCMD[r0]
    st.b   r10,PCC[r0]
    nop
    nop
    nop

```

```

        nop
        nop

        mov     #_ _tp_TEXT, tp           -- set tp register
        mov     #_ _gp_DATA, gp          -- set gp register offset
        add     tp, gp                    -- set gp register
        mov     #_ _stack+STACKSIZE, sp  -- set sp register
        mov     #_ _ep_DATA, ep          -- set ep register
#
        mov     #_ _ssbss, r13           -- clear sbss section
        mov     #_ _esbss, r12
        cmp     r12, r13
        jnl     .L11
.L12:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl      .L12
.L11:
#
        mov     #_ _sbss, r13            -- clear bss section
        mov     #_ _ebss, r12
        cmp     r12, r13
        jnl     .L14
.L15:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl      .L15
.L14:
#
        jarl    _main, lp                -- call main function
__exit:
        halt                    -- end of program
__startend:
        nop
#
#----- end of start up module -----#
#

```

4.3.5 Main processing function

```

#include     "Common.h"
#include     "Motor.h"
#pragma     ioreg                               /* Peripheral I/O register definition */

static int save_psw;
/*****

```

```

/*      3-phase motor control program                                          */
/***** /
void  main()
{
unsigned char   proc_no ;                /* Present processing number */
signed int     speed ;                  /* Indication speed rms */
signed int     accel_spd ;
int           sw, sw_mode ;
/* */

  hinit() ;                             /* Hardware initialization */
  ainit() ;                              /* Initialization of area used */
  proc_no = 0 ;
  __EI();
  while( 1 ) {
    accel_spd = ( SPEED_MAX - SPEED_MINI ) / 100;
    speed = ( ( SPEED_MAX - SPEED_MINI ) * volume / 1024 )
            + SPEED_MINI ;              /* Indication speed calculation by volume */
    sw = ~IN_data( SW ) & 0x07 ;       /* Read operation button */
    if ( sw == 1 ) {
      sw_mode = CW ;
    } else if ( sw == 2 ) {
      sw_mode = CCW ;
    } else if ( sw == 4 ) {
      sw_mode = STOP ;
    }
    switch( proc_no ) {
/* STOP processing */
      case 0 :
        if ( sw_mode == CW ) {
          __DI() ;
          object_speed = SPEED_MINI ; /* Set target speed to minimum value */
          stop_flag = OFF ;
          timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
          accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
          init_flag = 2 ;              /* CCW initial request */
          start_init() ;              /* Initialize revolution start */
          __EI() ;
          proc_no = 1 ;                /*Set next processing number */
        } else if ( sw_mode == CCW ) {
          __DI() ;
          stop_flag = OFF ;           /* Stop flag off */
          object_speed = -SPEED_MINI ; /* Set target speed to minimum value */
          timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
          accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
          init_flag = 3 ;            /* CCW initial request */
          start_init() ;             /* Initialize revolution start */
          __EI() ;
          proc_no = 4 ;              /* Set CCW processing number */

```

```

    }
    break ;
/* CW processing, acceleration */
    case 1 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;      /* Set acceleration/deceleration counter */
            if ( object_speed < speed ) {
                object_speed += accel_spd ;
                if ( object_speed > speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else if ( object_speed > speed ) {
                object_speed -= accel_spd ;
                if ( object_speed < speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                proc_no = 2 ;              /* Constant-speed processing */
            }
        }
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;                  /* Deceleration, set processing number */
        }
        break ;
/* CW processing, constant-speed */
    case 2 :
        object_speed = speed ;
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ;                  /* Deceleration, set processing number */
        }
        break ;
/* CW stop processing */
    case 3 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;      /* Set acceleration/deceleration counter */
            if ( object_speed > SPEED_MINI ) {
                object_speed -= accel_spd ;
                if ( object_speed < SPEED_MINI ) object_speed = SPEED_MINI;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                stop_flag = ON ;           /* Stop flag on */
                proc_no = 0 ;              /* Set stop processing number */
            }
        }
        break ;
/* CCW processing, acceleration */
    case 4 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ;      /* Set acceleration/deceleration counter */
            if ( object_speed < -speed ) {

```

```

        object_speed += accel_spd ;
        if ( object_speed > -speed ) object_speed = -speed;
        timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
    } else if ( object_speed > -speed ) {
        object_speed -= accel_spd ;
        if ( object_speed < -speed ) object_speed = -speed;
        timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
    } else {
        proc_no = 5 ;                /* Constant-speed processing */
    }
}
if ( (sw_mode == CW) || (sw_mode == STOP) ) {
    proc_no = 6 ;                /* Deceleration, set processing number */
}
break ;
/* CCW processing, constant-speed */
case 5 :
    object_speed = -speed ;
    if ( (sw_mode == CW) || (sw_mode == STOP) ) {
        proc_no = 6 ;                /* Deceleration, set processing number */
    }
    break ;
/* CCW stop processing */
case 6 :
    if ( accel_count == 0 ) {
        accel_count = ACCEL_VAL ;    /* Set acceleration/deceleration counter */
        if ( object_speed < -SPEED_MINI ) {
            object_speed += accel_spd ;
            if ( object_speed > -SPEED_MINI ) object_speed = -SPEED_MINI;
            timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
        } else {
            stop_flag = ON ;        /* Stop flag on /
            proc_no = 0 ;            /* Set stop processing number */
        }
    }
}
break ;
}

if ( ( proc_no == 2 ) || ( proc_no == 5 ) ) {
    if ( timer_count == 0 ) {
        if ( abs( object_speed - now_speed ) > SA_SPEED_MAX ) {
            error_flag = ERR_NO2 ;    /* Set error No. */
        }
    }
}

if ( disp_co == 0 ) {
    led_num(1, d_speed / 100 ) ;    /* Number of revolutions */
}

```



```

    OUT_data( LED21, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED22, ~led_pat[data%10]&0xff ) ;
} else if ( no == 3 ) {
    OUT_data( LED31, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED32, ~led_pat[data%10]&0xff ) ;
} else {
    OUT_data( LED41, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED42, ~led_pat[data%10]&0xff ) ;
}
}
/*****
/*   External I/O output subroutine                               */
/*       reg : Output register number                           */
/*       data : Output data                                     */
*****/
void OUT_data( unsigned short reg, unsigned short data )
{
    if ( reg == WRESET ) {
        P3.0 = 0;
        data = 1;          /* Dummy step */
        P3.0 = 1;
    } else {
        PDL = data | ( reg << 8 );
        PDL = reg | ( reg << 8 ) | 0x8000;
    }
}
/*****
/*   External I/O input subroutine                               */
/*       reg : Input register number                           */
*****/
unsigned short IN_data( int reg )
{
    unsigned char *po;
    /* */
    if ( reg == SW ) {
        return P4;
    } else {
        return 0;
    }
}

```

4.3.7 Motor control interrupt processing function

```

#include "Common.h"
#include "Motor.h"
#pragma ioreg          /* Peripheral I/O register definition */
/*****
/*   Motor control timer interrupt processing                   */
*****/

```

```

/***** /
__interrupt
void int_MOTOR(void)
{
    ADA0M0 = 0xB0 ;          /* Start AD0 */
    ADA1M0 = 0xA0 ;          /* Start AD1 */
}
/***** /
/* Motor control processing */
/***** /
void Motor_CONT(void)
{
    signed int wrm, wre, trm, tre ;
    signed int o_wre, we, o_iqap, o_iqa ;
    signed int ida, iqa, o_vda1, o_vqa1 ;
    signed int o_vd0, o_vq0, o_vda, o_vqa ;
    signed int o_vua, o_vva, o_vwa, wiua, wiva ;
    signed int s_time, wk ;
    signed short now_enc, sa_enc ;
    /* */
    /***** /
    /* Calculation processing of speed and rotor position */
    /***** /
    now_enc = -TMENC10 ;
    sa_enc = now_enc - before_enc ;
    if ( abs( sa_enc ) > ( MAXPULSE / 2 ) ) {
        if ( sa_enc < 0 ) {
            sa_enc += MAXPULSE ;
        } else {
            sa_enc -= MAXPULSE ;
        }
    }
    before_enc = now_enc ;
    wrm = now_speed = (signed long)sa_enc * RAD / MAXPULSE; /* Set current speed */

    wre = wrm * P ;
    tre = ( trm * P + OFFSET ) % RAD ;
    /***** /
    /* Speed control processing */
    /***** /
    if ( ( stop_flag == OFF ) && ( error_flag == 0 ) ) {
        s_time = TP1CNT ;
        o_wre = object_speed * RPM_RADS * P / TH_U ; /* rpm -> radian conversion */
        we = o_wre - wre ;
        o_iqap = ( ( wre * KSP ) + ( we * KSP ) ) >> KSPGETA ;
        o_iqa = o_iqap + ( o_iqai >> KSIGETA ) ;

        if ( o_iqai > IQAMAX ) {

```

```

    o_iqai = IQAMAX ;
} else if ( o_iqai < -IQAMAX ) {
    o_iqai = -IQAMAX ;
} else {
    o_iqai += ( KSI * we ) ;
}
/***** /
/*    Current control processing                                */
/***** /
ida = ( ( ( iva * sin( tre ) ) - ( iua * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
iqa = ( ( ( iva * sin( tre + RAD/4 ) ) - ( iua * sin( tre + 11*RAD/12 ) ) ) ) >> SGETA ;

o_vda = ( KI * -ida ) >> KIGETA ;
o_vqa = ( KI * ( o_iqa - iqa ) ) >> KIGETA ;
/***** /
/*    3-phase voltage conversion processing                    */
/***** /
if ( init_flag == 2 ) {                                     /* CW initial processing */
    o_trm += ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm > ( 2 * RAD ) ) {
        init_flag = 0;
    }
} else if ( init_flag == 3 ) {                             /* CCW initial processing */
    o_trm -= ( SPEED_MINI * TS / 20000 ) ;
    tre = ( o_trm * P ) % RAD ;
    o_vda = 0 ;
    o_vqa = 100 ;
    if ( o_trm < -( 2 * RAD ) ) {
        init_flag = 0;
    }
} else {
    o_trm = 0 ;
}
o_vua = ( ( ( o_vda * sin( tre + RAD/4 ) ) - ( o_vqa * sin( tre ) ) ) ) >> SGETA ;
o_vva = ( ( ( o_vda * sin( tre + 11*RAD/12 ) ) - ( o_vqa * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
o_vwa = -o_vua - o_vva ;

cont_time1 = ( TP1CNT - s_time ) ;                       /* Convert to uSEC */
/***** /
/*    PWM conversion output processing                        */
/***** /
OUT_data( WRESET, 0 ) ;                                   /* Reset watchdog timer */
HZA0CTL0 |= 0x04;                                        /* PWM output on */
/* PWM counter value calculation output */
o_vua += ( PWM_DATA / 2 ) ;

```

```

o_vva += ( PWM_DATA / 2 ) ;
o_vva += ( PWM_DATA / 2 ) ;

if ( o_vua <= 0 ) {
    o_vua = 1 ;
} else if ( o_vua >= PWM_DATA ) {
    o_vua = PWM_DATA - 1 ;
}
if ( o_vva <= 0 ) {
    o_vva = 1 ;
} else if ( o_vva >= PWM_DATA ) {
    o_vva = PWM_DATA - 1 ;
}
if ( o_vwa <= 0 ) {
    o_vwa = 1 ;
} else if ( o_vwa >= PWM_DATA ) {
    o_vwa = PWM_DATA - 1 ;
}

TQ0CCR1 = o_vua ;
TQ0CCR2 = o_vva ;
TQ0CCR3 = o_vwa ;
} else {
    HZA0CTL0 |= 0x08;          /* PWM output off */
    now_speed = 0;
    cont_time1 = 0;
}
}

```

4.3.8 10 mSEC interval interrupt processing function

```

/***** /
/*   Other timer interrupt processing (10 mSEC interval)   */
/***** /
__multi_interrupt
void int_ETC(void)
{
/* Wait timer processing */
    if ( timer_count != 0 ) {
        timer_count -= 1 ;
    }
/* Acceleration/deceleration timer processing */
    if ( accel_count != 0 ) {
        accel_count -= 1 ;
    }
/* */
    if ( disp_co != 0 ) {
        d_speed += abs( now_speed ) ;
    }
}

```

```

    disp_co -= 1 ;
}
}

```

4.3.9 A/D converter interrupt processing function

```

/***** /
/*   A/D converter interrupt processing for U-phase current and speed volume */
/***** /
__multi_interrupt
void int_AD0(void)
{
    iua = ( ( ADA0CR0 >> 6 ) & 0x3ff ) - 0x200 ) ;
    if ( abs(iua) > MAX_I ) {
        HZA0CTL0 |= 0x08 ;           /* PWM output off */
        error_flag = ERR_NO1 ;     /* Set error No. */
    }
    volume = 1023 - ( ( ADA0CR1 >> 6 ) & 0x3ff ) ; /* Set volume value */
    Motor_CONT() ;
    cont_time = TP1CNT;           /* Convert to uSEC */
}
/***** /
/*   A/D converter interrupt processing for volume */
/***** /
__interrupt
void int_AD1(void)
{
    iva = ( ( ADA1CR0 & 0x3ff ) - 0x200 ) ;
    if ( abs(iva) > MAX_I ) {
        HZA0CTL0 |= 0x08 ;           /* PWM output off */
        error_flag = ERR_NO1 ;     /* Set error No. */
    }
}
}

```

4.3.10 Hardware initialization processing function

```

/***** /
/*   Hardware (peripheral I/O) initialization */
/***** /
void hinit( void )
{
/* Port mode register initialization */
    PM3 = 0xfe ;
    PM4 = 0xff ;
    PMDL = 0x0000 ;

    OUT_data( LED11, 0xff ) ; /* LED OFF */
    OUT_data( LED12, 0xff ) ;
}

```

```

OUT_data( LED13, 0xff ) ;
OUT_data( LED14, 0xff ) ;
OUT_data( LED21, 0xff ) ;
OUT_data( LED22, 0xff ) ;
OUT_data( LED31, 0xff ) ;
OUT_data( LED32, 0xff ) ;
OUT_data( LED41, 0xff ) ;
OUT_data( LED42, 0xff ) ;
/* Set 10 mSEC timer TMP0 */
TP0CTL0 = 0x05 ;          /* Select fXX/64 */
TP0CTL1 = 0x00 ;          /* Select interval timer mode */
TP0CCR0 = 10000 ;         /* 10 mSEC */
TP0CTL0 |= 0x80 ;         /* Start timer */
TP0CCIC0= 0x06;
/* Set motor control interrupt timer TMP1 */
TP1CTL0 = 0x05 ;          /* Select fXX/64 */
TP1CTL1 = 0x00 ;          /* Select interval timer mode */
TP1CCR0 = TS ;           /* TS uSEC */
TP1CTL0 |= 0x80 ;         /* Start timer */
TP1CCIC0= 0x01;
/* TMENC10 initialization */
TUM10 = 0x80 ;           /* Select UDC mode */
PRM10 = 0x07 ;           /* Select operation mode 4 */
TMC10 = 0x40 ;           /* Start count */
/* TMQ0 initialization */
TQ0CTL0 = 0x00;           /* fXX/2 (64 MHz/2 = 32 MHz) */
TQ0CTL1 = 0x07;           /* Select 6-phase PWM output mode */
TQ0IOC0 = 0x55;           /* Positive phase normal output, output enabled */
TQ0IOC1 = 0x00;           /* TIQ00 to TIQ03, EVTQ0, and TRGQ0 pins of TMQ0 */
TQ0IOC2 = 0x00;           /* are not used */
TQ0OPT0 = 0x00;           /* Select comparison mode */
TQ0CCR0 = PWM_DATA ;      /* Carrier wave cycle 20 kHz */
TQ0CCR1 = PWM_DATA /2;    /* Set U-phase duty to 50 */
TQ0CCR2 = PWM_DATA /2;    /* Set V-phase duty to 50 */
TQ0CCR3 = PWM_DATA /2;    /* Set W-phase duty to 50 */
TQ0DTC = 180;             /* Dead time 6 uSEC */
TQ0OPT1 = 0x00;           /* No culling, no crest and valley interrupts are used */

TQ0OPT2 = 0x04;           /* • No culling between reloads */
                           /* • Clear and re-count dead time counter */
                           /* • Output A/D trigger output of INTTP0CC0 */
                           /* interrupt during counting up */
                           /* • A/D trigger output of INTTP0CC0 interrupt enabled */

TQ0IOC3 = 0xfc;           /* Negative phase inverted output, output enabled */
PMC1 = 0x3F;              /* Alternate-function mode */
PFCE1 = 0x00;            /* Select TOQ0T1 to TOQ0T3 or TOQ0B1 to TOQ0B3 output */
PFC1 = 0x00;

```

```

HZA0CTL0 = 0x00;
HZA0CTL0 = 0xD0;          /* High-impedance operation enabled */
                          /* TOQ0OFF pin rising edge valid */
HZA2CTL0 = 0x00;          /* High-impedance off due to analog input */
TQ0CTL0 |= 0x80;          /* Start 6-phase PWM output mode */
/* Set A/D */
ADA0M0 = 0x30 ;           /* ANI00, ANI01 */
ADA0M1 = 0x01 ;
ADA0S  = 0x01 ;
OP0CTL0 = 0x00 ;          /* Operational amplifier invalid */
OP0CTL1 = 0x00 ;          /* Comparator invalid */
AD0IC  = 0x03 ;

ADA1M0 = 0x20 ;           /* ANI10 */
ADA1M1 = 0x01 ;
ADA1S  = 0x00 ;
OP1CTL0 = 0x00 ;          /* Operational amplifier invalid */
OP1CTL1 = 0x00 ;          /* Comparator invalid */
AD1IC  = 0x03 ;
PIC4   = 0x01 ;
}

```

4.3.11 Common area initialization processing function

```

/***** /
/*      Common area initialization                               */
/***** /
void    ainit( void )
{
/* Initialization of flags */
    error_flag = 0 ;           /* Clear error flag */
    init_flag = OFF ;          /* Initial flag off */
    disp_co = 100 ;
    d_speed = 0 ;

/* Motor control area initialization */
    stop_flag  = ON ;           /* Stop flag on */
    object_speed = 0 ;          /* Target speed 0 */
    o_iqai = 0 ;               /* Speed integral value 0 */
    o_trm = 0 ;
    before_enc = -TMENC10 ;     /* Set previous encoder value */
}

```

4.3.12 Revolution start initialization processing function

```

/***** /
/*      Revolution start initialization                           */
/***** /

```



```

void start_init( void )
{
    int i;
/* */
    for ( i = 0 ; i < 21 ; i++ ) before_posi[i][1] = 0;
    total_sa = 0 ;
    sum_speed = 0 ;
    speed_co = 100000 / TS ;
}

```

4.3.13 sin calculation processing function

```

/***** /
/*      sin x                                     */
/*      Data                                     */
/*      Radian unit                             */
/*      Return value                            */
/*      Sign value*16384                        */
/***** /
int sin( int x )
{
    x = x % RAD ;
    if ( x < 0 ) x += RAD ;
    if ( x < (RAD/4) ){
        return sins( x ) ;
    } else if ( x < (RAD/2) ) {
        return sins( (RAD/2) - x ) ;
    } else if ( x < (RAD*3/4) ) {
        return -sins( x - (RAD/2) ) ;
    } else {
        return -sins( RAD - x ) ;
    }
}

/***** /
int sins( int x )
{
    short z1, z2, z3, z4, z5 ;
/* */
    if ( x <= (RAD/8) ) {
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z3 = z1 * z2 >> SGETA ;
        z5 = z2 * z3 >> SGETA ;
        return ( (12868*z1) - (1322*z3) + (40*z5) ) >> SGETA ;
    } else {
        x = (RAD/4) - x ;
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;

```

```

    z4 = z2 * z2 >> SGETA ;
    return ( (268432772) - (5050*z2) + (252*z4) ) >> SGETA ;
}
}

```

4.3.14 Link directive file for V850E/IA3

```

/***** /
/*      Link directive file for V850E/IA3      */
/***** /
VECT_RESET: !LOAD ?RX V0x00000000 {
    .vect_RESET = $PROGBITS ?AX .vect_RESET;
};
ID_NO: !LOAD ?RX V0x00000070 {
    .id_NO = $PROGBITS ?AX .id_NO;
};
VECT_ETC: !LOAD ?RX V0x00000250 {
    .vect_ETC = $PROGBITS ?AX .vect_ETC;
};
VECT_MOTOR: !LOAD ?RX V0x00000280 {
    .vect_MOTOR = $PROGBITS ?AX .vect_MOTOR;
};
VECT_AD0: !LOAD ?RX V0x00000400 {
    .vect_AD0 = $PROGBITS ?AX .vect_AD0;
};
VECT_AD1: !LOAD ?RX V0x00000410 {
    .vect_AD1 = $PROGBITS ?AX .vect_AD1;
};

HANDLER: !LOAD ?RX V0x00001000 {
    .handler = $PROGBITS ?AX .handler;
};
TEXT: !LOAD ?RX {
    .text = $PROGBITS ?AX .text;
};

CONST : !LOAD ?R {
    .const = $PROGBITS ?A .const;
};

DATA : !LOAD ?RW V0xffffd800 {
    .data = $PROGBITS ?AW ;
    .sdata = $PROGBITS ?AWG ;
    .sbss = $NOBITS ?AWG ;
    .bss = $NOBITS ?AW ;
};

__tp_TEXT @ %TP_SYMBOL;

```

```
_ _gp_DATA @ %GP_SYMBOL &_ _tp_TEXT{DATA};  
_ _ep_DATA @ %EP_SYMBOL;
```

4.4 Program List (V850E/IA4)

4.4.1 Symbol definition

```

/***** /
/*      Common area                                          */
/***** /
unsigned char   ram_start ;
unsigned char   error_flag ;          /* Error flag */
unsigned char   init_flag ;          /* Initial flag */
unsigned short  cont_time ;          /* Interrupt control time uSEC */
unsigned short  cont_time1 ;        /* Vector operation time uSEC */
unsigned short  disp_co ;           /* Interrupt control time display timer */
unsigned short  volume ;            /* Volume value */
unsigned short  timer_count ;       /* Time wait counter */
unsigned short  accel_count ;       /* Acceleration/deceleration operation time counter */
unsigned char   stop_flag ;        /* Stop flag */
signed short    before_posi[21][2] ; /* Position buffer */
signed short    total_sa ;         /* Position total difference */
signed int      sum_speed ;
signed int      speed_co ;
signed int      now_speed ;        /* Present speed rms */
signed int      object_speed ;     /* Target speed rms */
unsigned int    d_speed ;          /* Display speed rms */
unsigned char   ram_end ;

#pragma section const begin
const unsigned short led_pat[10] = { 0xfc, 0x60, 0xda, 0xf2, 0x66, 0xb6, 0xbe, 0xe0,
                                     0xfe, 0xe6 } ;

#pragma section const end
/***** /
/*      Common flags                                          */
/***** /
extern unsigned char   ram_start ;
extern unsigned char   error_flag ;          /* Error flag */
extern unsigned char   init_flag ;          /* Initial flag */
extern unsigned short  cont_time ;          /* Interrupt control time uSEC */
extern unsigned short  cont_time1 ;        /* Vector operation time uSEC */
extern unsigned short  disp_co ;           /* Interrupt control time display timer */
extern unsigned short  volume ;            /* Volume value */
extern unsigned short  timer_count ;       /* Time wait counter */
extern unsigned short  accel_count ;       /* Acceleration/deceleration operation */
/* time counter */
extern unsigned char   stop_flag ;        /* Stop flag */
extern signed short    before_posi[21][2] ; /* Position buffer */
extern signed short    total_sa ;         /* Position total difference */
extern signed int      sum_speed ;
extern signed int      speed_co ;

```

```

extern signed int      now_speed ;          /* Present speed rms */
extern signed int      object_speed ;      /* Target speed rms */
extern unsigned int    d_speed ;          /* Display speed rms */
extern unsigned char   ram_end ;

#pragma section const begin
extern const unsigned short led_pat[] ;;
#pragma section const end
/*****
/*      Motor common definition
*****/
extern signed short    iua ;              /* U-phase current */
extern signed short    iva ;              /* V-phase current */
extern signed int      o_iqai ;          /* Speed integral value area */
extern signed int      o_trm ;           /* Target position for initialization */
extern signed int      base_position ;    /* Speed estimation value reference point */
extern unsigned int    sa_time ;         /* Speed measurement value */
extern unsigned short  timer_count ;     /* Time wait counter */
extern unsigned short  accel_count ;     /* Acceleration/deceleration operation */
/* time counter */
extern signed short    before_enc ;      /* Previous encoder value */

```

4.4.2 Constant definition

```

/*****
/*      I/O
*****/
#define BASE_IO        0xc20000
#define LED11          0x03
#define LED12          0x02
#define LED13          0x01
#define LED14          0x00
#define LED21          0x05
#define LED22          0x04
#define LED31          0x07
#define LED32          0x06
#define LED41          0x09
#define LED42          0x08

#define DIPSW          0x0f
#define SW             0x0e
#define DA1            0x0a
#define DA2            0x0b
#define DA3            0x0c
#define WRESET         0x0d
#define MODE           0x10
/*****
/*      Constant
*****/

```

```

/***** /
#define ON          1
#define OFF         0
#define CW          1          /* CW operation mode */
#define CCW         2          /* CCW operation mode */
#define STOP        0          /* Operation stop mode */
#define ERR_NO1     1          /* Overcurrent error */
#define ERR_NO2     2          /* Speed difference error */
/***** /
/*      Motor constant          */
/***** /
#define PAI         3.14159265 /*  $\pi$  */
#define TH_U        1000      /* Radian value jack-up constant */
#define RAD         (int)(2*PAI*TH_U) /* Radian value of one revolution */
#define OFFSET      1733     /* Original point OFFSET */
#define RPM_RADS    (int)((2*PAI*TH_U)/60) /* rpm -> radian conversion constant */
/* Motor constant */
#define KSP         500      /* Speed proportion constant */
#define KSI         50       /* Speed integral constant */
#define KI          1        /* Current conversion constant */
#define P           2        /* Number of poles */

#define KSPGETA     0        /* KSP jack-up constant */
#define KSIGETA     9        /* KSI jack-up constant */
#define KIGETA      9        /* KI jack-up constant */
#define SGETA       14      /* sin jack-up constant */

#define PWM_TS      80       /* PWM cycle */
#define PWM_DATA    (PWM_TS/0.03125) /* PWM set value */
#define SPEED_MAX   3000    /* Maximum speed rpm */
#define SPEED_MINI  600     /* Minimum speed rpm */
#define SA_SPEED_MAX 800    /* Maximum speed difference rpm */
#define IQAMAX      4000000 /* Maximum speed integral value */
#define MAX_I       800     /* Maximum current value */
#define TS          80      /* Motor control time interval uSEC */
#define WATCH_START 500    /* Speed monitor start time 10 mSEC */
#define ACCEL_VAL_1ST 50    /* Initial acceleration/deceleration */
/* time constant */
#define ACCEL_VAL   3        /* Acceleration/deceleration time constant */
#define ACCEL_SPD   50       /* Acceleration/deceleration constant */
#define MAXPULSE    10000   /* Number of pulses of one revolution */
/***** /
/*      Function constant          */
/***** /
void          fcalcu( signed int *wrm, signed int *trm );
void          OUT_data( unsigned short reg, unsigned short data );
unsigned short IN_data( int reg );
void          led_num( int no, long data );

```

```

/***** /
/*      Motor-related common area                                */
/***** /
signed short   iua ;          /* U-phase current */
signed short   iva ;          /* V-phase current */
signed int     o_iqai ;       /* Speed integral value area */
signed int     o_trm ;        /* Target position for initialization */
signed int     base_position ; /* Speed estimation value reference point */
unsigned int   sa_time ;      /* Speed measurement value */
unsigned short timer_count ;  /* Time wait counter */
unsigned short accel_count ;  /* Acceleration/deceleration operation time counter */
signed short   before_enc ;   /* Previous encoder value */

```

4.4.3 Interrupt handler setting

```

/***** /
/*      Interrupt symbol table                                  */
/***** /

    .extern _ _start
    .extern _int_MOTOR
    .extern _int_AD0
    .extern _int_AD1
    .extern _int_ETC

    .globl V_RESET
    .globl V_ETC
    .globl V_MOTOR
    .globl V_AD0
    .globl V_AD1
#*****

    .section ".handler",text
V_RESET:
    Jr    _ _start
V_ETC:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_ETC          -- Other timers
V_MOTOR:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_MOTOR        -- Speed control timer
V_AD0:
    ld.w  [sp],r1
    add   4,sp
    jr    _int_AD0         -- A/D converter CH0
V_AD1:
    ld.w  [sp],r1
    add   4,sp

```

```

jr      _int_AD1                -- A/D converter CH1

.extern V_RESET
.extern V_ETC
.extern V_MOTOR
.extern V_AD0
.extern V_AD1
/*****
/*      Interrupt jump table                                     */
*****/

.section ".vect_RESET",text
mov     #V_RESET,r1
jmp     [r1]

.section ".id_NO",text
.byte   0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff,0xff

.section ".vect_ETC",text
add     -4,sp
st.w    r1,[sp]
mov     #V_ETC,r1
jmp     [r1]

.section ".vect_MOTOR",text
add     -4,sp
st.w    r1,[sp]
mov     #V_MOTOR,r1
jmp     [r1]

.section ".vect_AD0",text
add     -4,sp
st.w    r1,[sp]
mov     #V_AD0,r1
jmp     [r1]

.section ".vect_AD1",text
add     -4,sp
st.w    r1,[sp]
mov     #V_AD1,r1
jmp     [r1]

```

4.4.4 Startup routine setting

```

#=====
# DESCRIPTIONS:
#   This assembly program is a sample of start-up module for ca850.
#   If you modified this program, you must assemble this file, and
#   locate a given directory.

```



```

#-----
#   C program main function
#-----
    .extern _main

#-----
#   dummy data declaration for creating sbss section
#-----
    .sbss
    .lcomm  _ _sbss_dummy, 0, 0

#-----
#   system stack
#-----
    .set    STACKSIZE, 0x400
    .bss
    .lcomm  _ _stack, STACKSIZE, 4

#-----
#   start up
#       pointers:  tp - text pointer
#                   gp - global pointer
#                   sp - stack pointer
#                   ep - element pointer
#   exit status is set to r10
#-----
    .text
    .align 4
    .globl  _ _start
    .globl  _ _exit
    .globl  _ _exit
_ _start:
    mov     13,r10                -- 500 kHz to 64 MHz
    st.b    r10,VSWC[r0]         -- Set peripheral I/O wait

    mov     0x03,r10             -- PLL
    st.b    r10,PLLCTL[r0]

    mov     0x00,r10
    st.b    r10,PRCMD[r0]
    st.b    r10,PCC[r0]
    nop
    nop
    nop

```

```

        nop
        nop

        mov     #_ _tp_TEXT, tp           -- set tp register
        mov     #_ _gp_DATA, gp         -- set gp register offset
        add     tp, gp                   -- set gp register
        mov     #_ _stack+STACKSIZE, sp -- set sp register
        mov     #_ _ep_DATA, ep         -- set ep register
#
        mov     #_ _sbss, r13           -- clear sbss section
        mov     #_ _ebss, r12
        cmp     r12, r13
        jnl    .L11
.L12:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl     .L12
.L11:
#
        mov     #_ _sbss, r13           -- clear bss section
        mov     #_ _ebss, r12
        cmp     r12, r13
        jnl    .L14
.L15:
        st.w    r0, [r13]
        add     4, r13
        cmp     r12, r13
        jl     .L15
.L14:
#
        jarl    _main, lp               -- call main function
_ _exit:
        halt                    -- end of program
_ _startend:
        nop
#
#----- end of start up module -----#
#

```

4.4.5 Main processing function

```

#include "Common.h"
#include "Motor.h"
#pragma ioreg /* Peripheral I/O register definition */

static int save_psw;
/***** /

```

```

/*      3-phase motor control program                                     */
/***** /
void    main()
{
unsigned char    proc_no ;                /* Present processing number */
signed int      speed ;                  /* Indication speed rms */
signed int      accel_spd ;
int             sw, sw_mode ;
/* */

    hinit() ;                            /* Hardware initialization */
    ainit() ;                             /* Initialization of area used */
    proc_no = 0 ;
    _ _EI();
    while( 1 ) {
        accel_spd = ( SPEED_MAX - SPEED_MINI ) / 100;
        speed = ( ( SPEED_MAX - SPEED_MINI ) * volume / 1024 )
                + SPEED_MINI ;           /* Indication speed calculation by volume */
        sw = ~IN_data( SW ) & 0x07 ;     /* Read operation button */
        if ( sw == 1 ) {
            sw_mode = CW ;
        } else if ( sw == 2 ) {
            sw_mode = CCW ;
        } else if ( sw == 4 ) {
            sw_mode = STOP ;
        }
        switch( proc_no ) {
/* STOP processing */
        case 0 :
            if ( sw_mode == CW ) {
                _ _DI() ;
                object_speed = SPEED_MINI ; /* Set target speed to minimum value */
                stop_flag = OFF ;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
                accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
                init_flag = 2 ;              /* CCW initial request */
                start_init() ;             /* Initialize revolution start */
                _ _EI() ;
                proc_no = 1 ;              /* Set next processing number */
            } else if ( sw_mode == CCW ) {
                _ _DI() ;
                stop_flag = OFF ;          /* Stop flag off */
                object_speed = -SPEED_MINI ; /* Set target speed to minimum value */
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
                accel_count = ACCEL_VAL_1ST ; /* Set acceleration/deceleration counter */
                init_flag = 3 ;           /* CCW initial request */
                start_init() ;           /* Initialize revolution start */
                _ _EI() ;
                proc_no = 4 ;            /* Set CCW processing number */
            }
        }
    }
}

```

```

    }
    break ;
/* CW processing, acceleration */
    case 1 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ; /* Set acceleration/deceleration counter */
            if ( object_speed < speed ) {
                object_speed += accel_spd ;
                if ( object_speed > speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else if ( object_speed > speed ) {
                object_speed -= accel_spd ;
                if ( object_speed < speed ) object_speed = speed;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                proc_no = 2 ; /* Constant-speed processing */
            }
        }
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ; /* Deceleration, set processing number */
        }
        break ;
/* CW processing, constant-speed */
    case 2 :
        object_speed = speed ;
        if ( (sw_mode == CCW) || (sw_mode == STOP) ) {
            proc_no = 3 ; /* Deceleration, set processing number */
        }
        break ;
/* CW stop processing */
    case 3 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ; /* Set acceleration/deceleration counter */
            if ( object_speed > SPEED_MINI ) {
                object_speed -= accel_spd ;
                if ( object_speed < SPEED_MINI ) object_speed = SPEED_MINI;
                timer_count = WATCH_START ; /* Set speed monitor start time to 5 SEC */
            } else {
                stop_flag = ON ; /* Stop flag on */
                proc_no = 0 ; /* Set stop processing number */
            }
        }
        break ;
/* CCW processing, acceleration */
    case 4 :
        if ( accel_count == 0 ) {
            accel_count = ACCEL_VAL ; /* Set acceleration/deceleration counter */
            if ( object_speed < -speed ) {

```

```

        object_speed += accel_spd ;
        if ( object_speed > -speed ) object_speed = -speed;
        timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
    } else if ( object_speed > -speed ) {
        object_speed -= accel_spd ;
        if ( object_speed < -speed ) object_speed = -speed;
        timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
    } else {
        proc_no = 5 ;           /* Constant-speed processing */
    }
}
if ( (sw_mode == CW) || (sw_mode == STOP) ) {
    proc_no = 6 ;           /* Deceleration, set processing number */
}
break ;
/* CCW processing, constant-speed */
case 5 :
    object_speed = -speed ;
    if ( (sw_mode == CW) || (sw_mode == STOP) ) {
        proc_no = 6 ;           /* Deceleration, set processing number */
    }
    break ;
/* CCW stop processing */
case 6 :
    if ( accel_count == 0 ) {
        accel_count = ACCEL_VAL ;    /* Set acceleration/deceleration counter */
        if ( object_speed < -SPEED_MINI ) {
            object_speed += accel_spd ;
            if ( object_speed > -SPEED_MINI ) object_speed = -SPEED_MINI;
            timer_count = WATCH_START ;/* Set speed monitor start time to 5 SEC */
        } else {
            stop_flag = ON ;         /* Stop flag on */
            proc_no = 0 ;           /* Set stop processing number */
        }
    }
    break ;
}

if ( ( proc_no == 2 ) || ( proc_no == 5 ) ) {
    if ( timer_count == 0 ) {
        if ( abs( object_speed - now_speed ) > SA_SPEED_MAX ) {
            error_flag = ERR_NO2 ;    /* Set error No. */
        }
    }
}

if ( disp_co == 0 ) {
    led_num(1, d_speed / 100 );      /* Number of revolutions */
}

```

```

d_speed = 0 ;
disp_co = 100 ;
if ( abs(now_speed) == 0 ) {
    disp_co = 0;
}
led_num(2, 1000/PWM_TS );          /* Carrier frequency */
led_num(3, cont_time );           /* Overall processing time */
led_num(4, cont_time1 );         /* Vector operation processing time */
}
if ( error_flag ) {
    while( 1 ) {
        OUT_data( LED41, ~0x00 ) ;      /* LED display off */
        OUT_data( LED42, ~0x00 ) ;
        timer_count = 50 ;
        while( timer_count ) ;
        if ( error_flag == ERR_NO1 ) {
            OUT_data( LED41, ~0x9e ) ; /* E1 display */
            OUT_data( LED42, ~0x60 ) ;
        } else if ( error_flag == ERR_NO2 ) {
            OUT_data( LED41, ~0x9e ) ; /* E2 display */
            OUT_data( LED42, ~0xda ) ;
        } else {
            OUT_data( LED41, ~0x9e ) ; /* E3 display */
            OUT_data( LED42, ~0xf2 ) ;
        }
        timer_count = 50 ;
        while( timer_count ) ;
    }
}
}
}
}

```

4.4.6 LED display function

```

/***** /
/*     LED value display subroutine                               */
/*         no   : Display area number (1 to 4)                   */
/*         data : Display data (0 to 99)                         */
/***** /
void led_num( int no, long data )
{
    if ( no == 1 ) {
        data = data % 10000;
        OUT_data( LED11, ~led_pat[data/1000]&0xff ) ;
        OUT_data( LED12, ~led_pat[(data%1000)/100]&0xff ) ;
        OUT_data( LED13, ~led_pat[(data%100)/10]&0xff ) ;
        OUT_data( LED14, ~led_pat[data%10]&0xff ) ;
    } else if ( no == 2 ) {

```

```

    OUT_data( LED21, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED22, ~led_pat[data%10]&0xff ) ;
} else if ( no == 3 ) {
    OUT_data( LED31, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED32, ~led_pat[data%10]&0xff ) ;
} else {
    OUT_data( LED41, ~led_pat[(data%100)/10]&0xff ) ;
    OUT_data( LED42, ~led_pat[data%10]&0xff ) ;
}
}
/*****
/*   External I/O output subroutine                               */
/*       reg : Output register number                           */
/*       data : Output data                                     */
*****/
void OUT_data( unsigned short reg, unsigned short data )
{
    if ( reg == WRESET ) {
        P3.0 = 0;
        data = 1;          /* Dummy step */
        P3.0 = 1;
    } else {
        PDL = data | ( reg << 8 );
        PDL = reg | ( reg << 8 ) | 0x8000;
    }
}
/*****
/*   External I/O input subroutine                               */
/*       reg : Input register number                           */
*****/
unsigned short IN_data( int reg )
{
    unsigned char *po;
    /* */
    if ( reg == SW ) {
        return P4;
    } else {
        return 0;
    }
}

```

4.4.7 Motor control interrupt processing function

```

#include "Common.h"
#include "Motor.h"
#pragma ioreg          /* Peripheral I/O register definition */
/*****
/*   Motor control timer interrupt processing                   */

```



```

/***** /
_ _interrupt
void  int_MOTOR(void)
{
    ADA0M0 = 0xB0 ;          /* Start AD0 */
    ADA1M0 = 0xA0 ;          /* Start AD1 */
}
/***** /
/*    Motor control processing                                */
/***** /
void  Motor_CONT(void)
{
    signed int   wrm, wre, trm, tre ;
    signed int   o_wre, we, o_iqap, o_iqa ;
    signed int   ida, iqa, o_vda1, o_vqa1 ;
    signed int   o_vd0, o_vq0, o_vda, o_vqa ;
    signed int   o_vua, o_vva, o_vwa, wiua, wiva ;
    signed int   s_time, wk ;
    signed short now_enc, sa_enc ;
    /* */
/***** /
/*    Calculation processing of speed and rotor position      */
/***** /
    now_enc = -TMENC10 ;
    sa_enc = now_enc - before_enc ;
    if ( abs( sa_enc ) > ( MAXPULSE / 2 ) ) {
        if ( sa_enc < 0 ) {
            sa_enc += MAXPULSE ;
        } else {
            sa_enc -= MAXPULSE ;
        }
    }
    before_enc = now_enc ;
    wrm = now_speed = (signed long)sa_enc * RAD / MAXPULSE; /* Set current speed */

    wre = wrm * P ;
    tre = ( trm * P + OFFSET ) % RAD ;
/***** /
/*    Speed control processing                                */
/***** /
    if ( ( stop_flag == OFF ) && ( error_flag == 0 ) ) {
        s_time = TP1CNT ;
        o_wre = object_speed * RPM_RADS * P / TH_U ;      /* rpm -> radian conversion */
        we      = o_wre - wre ;
        o_iqap  = ( ( wre * KSP ) + ( we * KSP ) ) >> KSPGETA ;
        o_iqa   = o_iqap + ( o_iqai >> KSIGETA ) ;

        if ( o_iqai > IQAMAX ) {

```

```

    o_iqai = IQAMAX ;
} else if ( o_iqai < -IQAMAX ) {
    o_iqai = -IQAMAX ;
} else {
    o_iqai += ( KSI * we ) ;
}
/***** /
/*    Current control processing                                */
/***** /
    ida = ( ( ( iva * sin( tre ) ) - ( iua * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
    iqa = ( ( ( iva * sin( tre + RAD/4 ) ) - ( iua * sin( tre + 11*RAD/12 ) ) ) ) >> SGETA ;

    o_vda = ( KI * -ida ) >> KIGETA ;
    o_vqa = ( KI * ( o_iqa - iqa ) ) >> KIGETA ;
/***** /
/*    3-phase voltage conversion processing                    */
/***** /
    if ( init_flag == 2 ) {                                     /* CW initial processing */
        o_trm += ( SPEED_MINI * TS / 20000 ) ;
        tre = ( o_trm * P ) % RAD ;
        o_vda = 0 ;
        o_vqa = 100 ;
        if ( o_trm > ( 2 * RAD ) ) {
            init_flag = 0;
        }
    } else if ( init_flag == 3 ) {                             /* CCW initial processing */
        o_trm -= ( SPEED_MINI * TS / 20000 ) ;
        tre = ( o_trm * P ) % RAD ;
        o_vda = 0 ;
        o_vqa = 100 ;
        if ( o_trm < -( 2 * RAD ) ) {
            init_flag = 0;
        }
    } else {
        o_trm = 0 ;
    }
    o_vua = ( ( ( o_vda * sin( tre + RAD/4 ) ) - ( o_vqa * sin( tre ) ) ) ) >> SGETA ;
    o_vva = ( ( ( o_vda * sin( tre + 11*RAD/12 ) ) - ( o_vqa * sin( tre + 2*RAD/3 ) ) ) ) >> SGETA ;
    o_vwa = -o_vua - o_vva ;

    cont_time1 = ( TP1CNT - s_time ) ;                        /* Convert to uSEC */
/***** /
/*    PWM conversion output processing                        */
/***** /
    OUT_data( WRESET, 0 ) ;                                   /* Reset watchdog timer */
    HZA0CTL0 |= 0x04;                                        /* PWM output on */
/* PWM counter value calculation output */
    o_vua += ( PWM_DATA / 2 ) ;

```

```

o_vva += ( PWM_DATA / 2 ) ;
o_vva += ( PWM_DATA / 2 ) ;

if ( o_vua <= 0 ) {
    o_vua = 1 ;
} else if ( o_vua >= PWM_DATA ) {
    o_vua = PWM_DATA - 1 ;
}
if ( o_vva <= 0 ) {
    o_vva = 1 ;
} else if ( o_vva >= PWM_DATA ) {
    o_vva = PWM_DATA - 1 ;
}
if ( o_vwa <= 0 ) {
    o_vwa = 1 ;
} else if ( o_vwa >= PWM_DATA ) {
    o_vwa = PWM_DATA - 1 ;
}

TQ0CCR1 = o_vua ;
TQ0CCR2 = o_vva ;
TQ0CCR3 = o_vwa ;
} else {
    HZA0CTL0 |= 0x08;                /* PWM output off */
    now_speed = 0;
    cont_time1 = 0;
}
}

```

4.4.8 10 mSEC interval interrupt processing function

```

/***** /
/*   Other timer interrupt processing (10 mSEC interval)   */
/***** /
_ _multi_interrupt
void  int_ETC(void)
{
/* Wait timer processing */
    if ( timer_count != 0 ) {
        timer_count -= 1 ;
    }
/* Acceleration/deceleration timer processing */
    if ( accel_count != 0 ) {
        accel_count -= 1 ;
    }
/* */
    if ( disp_co != 0 ) {
        d_speed += abs( now_speed ) ;
    }
}

```

```

    disp_co -= 1 ;
}
}

```

4.4.9 A/D converter interrupt processing function

```

/***** /
/*      A/D converter interrupt processing for U-phase current and speed volume */
/***** /
_ _multi_interrupt
void  int_AD0(void)
{
    iua = ( ( ADA0CR0 >> 6 ) & 0x3ff ) - 0x200 ) ;
    if ( abs(iua) > MAX_I ) {
        HZA0CTL0 |= 0x08 ;                /* PWM output off */
        error_flag = ERR_NO1 ;          /* Set error No. */
    }
    volume = 1023 - ( ( ADA0CR1 >> 6 ) & 0x3ff ) ; /* Set volume value */
    Motor_CONT() ;
    cont_time = TP1CNT;                  /* Convert to uSEC */
}
/***** /
/*      A/D converter interrupt processing for volume */
/***** /
_ _interrupt
void  int_AD1(void)
{
    iva = ( ( ADA1CR0 & 0x3ff ) - 0x200 ) ;
    if ( abs(iva) > MAX_I ) {
        HZA0CTL0 |= 0x08 ;                /* PWM output off */
        error_flag = ERR_NO1 ;          /* Set error No. */
    }
}
}

```

4.4.10 Hardware initialization processing function

```

/***** /
/*      Hardware (peripheral I/O) initialization */
/***** /
void  hinit( void )
{
/* Port mode register initialization */
    PM3 = 0xfe ;
    PM4 = 0xff ;
    PMDL = 0x0000 ;

    OUT_data( LED11, 0xff ) ; /* LED OFF */
    OUT_data( LED12, 0xff ) ;
}

```

```

OUT_data( LED13, 0xff ) ;
OUT_data( LED14, 0xff ) ;
OUT_data( LED21, 0xff ) ;
OUT_data( LED22, 0xff ) ;
OUT_data( LED31, 0xff ) ;
OUT_data( LED32, 0xff ) ;
OUT_data( LED41, 0xff ) ;
OUT_data( LED42, 0xff ) ;
/* Set 10 mSEC timer TMP0 */
TP0CTL0 = 0x05 ;          /* Select fXX/64 */
TP0CTL1 = 0x00 ;          /* Select interval timer mode */
TP0CCR0 = 10000 ;         /* 10 mSEC */
TP0CTL0 |= 0x80 ;        /* Start timer */
TP0CCIC0= 0x06;
/* Set motor control interrupt timer TMP1 */
TP1CTL0 = 0x05 ;          /* Select fXX/64 */
TP1CTL1 = 0x00 ;          /* Select interval timer mode */
TP1CCR0 = TS ;           /* TS uSEC */
TP1CTL0 |= 0x80 ;        /* Start timer */
TP1CCIC0= 0x01;
/* TMENC10 initialization */
TUM10 = 0x80 ;           /* Select UDC mode */
PRM10 = 0x07 ;           /* Select operation mode 4 */
TMC10 = 0x40 ;           /* Start count */
/* TMQ0 initialization */
TQ0CTL0 = 0x00;          /* fXX/2 (64 MHz/2 = 32 MHz) */
TQ0CTL1 = 0x07;          /* Select 6-phase PWM output mode */
TQ0IOC0 = 0x55;          /* Positive phase normal output, output enabled */
TQ0IOC1 = 0x00;          /* TIQ00 to TIQ03, EVTQ0, and TRGQ0 pins of TMQ0 */
TQ0IOC2 = 0x00;          /* are not used */
TQ0OPT0 = 0x00;          /* Select comparison mode */
TQ0CCR0 = PWM_DATA ;     /* Carrier wave cycle 20 kHz */
TQ0CCR1 = PWM_DATA /2;   /* Set U-phase duty to 50 */
TQ0CCR2 = PWM_DATA /2;   /* Set V-phase duty to 50 */
TQ0CCR3 = PWM_DATA /2;   /* Set W-phase duty to 50 */
TQ0DTC = 180;            /* Dead time 6 uSEC */
TQ0OPT1 = 0x00;          /* No culling, no crest and valley interrupts are used */

TQ0OPT2 = 0x04;          /* • No culling between reloads */
                        /* • Clear and re-count dead time counter */
                        /* • Output A/D trigger output of INTTP0CC0 interrupt */
                        /*   during counting up */
                        /* • A/D trigger output of INTTP0CC0 interrupt enabled */

TQ0IOC3 = 0xfc;          /* Negative phase inverted output, output enabled */
PMC1 = 0x3F;             /* Alternate-function mode */
PFCE1 = 0x00;           /* Select TQ0T1 to TQ0T3 or TQ0B1 to TQ0B3 output */
PFC1 = 0x00;

```

```

HZA0CTL0 = 0x00;
HZA0CTL0 = 0xD0;          /* High-impedance operation enabled */
                          /* TOQ0OFF pin rising edge valid */
HZA2CTL0 = 0x00;          /* High-impedance off due to analog input */
TQ0CTL0 |= 0x80;          /* Start 6-phase PWM output mode */
/* Set A/D */
ADA0M0 = 0x30 ;           /* ANI00, ANI01 */
ADA0M1 = 0x01 ;
ADA0S  = 0x01 ;
OP0CTL0 = 0x00 ;          /* Operational amplifier invalid */
OP0CTL1 = 0x00 ;          /* Comparator invalid */
AD0IC  = 0x03 ;

ADA1M0 = 0x20 ;           /* ANI10 */
ADA1M1 = 0x01 ;
ADA1S  = 0x00 ;
OP1CTL0 = 0x00 ;          /* Operational amplifier invalid */
OP1CTL1 = 0x00 ;          /* Comparator invalid */
AD1IC  = 0x03 ;
}

```

4.4.11 Common area initialization processing function

```

/***** /
/*      Common area initialization                               */
/***** /
void  ainit( void )
{
/* Initialization of flags */
  error_flag = 0 ;          /* Clear error flag */
  init_flag = OFF ;        /* Initial flag off */
  disp_co = 100 ;
  d_speed = 0 ;
/* Motor control area initialization */
  stop_flag  = ON ;          /* Stop flag on */
  object_speed = 0 ;        /* Target speed 0 */
  o_iqai = 0 ;              /* Speed integral value 0 */
  o_trm = 0 ;
  before_enc = -TMENC10 ;   /* Set previous encoder value */
}

```

4.4.12 Revolution start initialization processing function

```

/***** /
/*      Revolution start initialization                           */
/***** /
void  start_init( void )

```

```

{
    int i;
/* */
    for ( i = 0 ; i < 21 ; i++ ) before_posi[i][1] = 0;
    total_sa = 0 ;
    sum_speed = 0 ;
    speed_co = 100000 / TS ;
}

```

4.4.13 sin calculation processing function

```

/***** /
/*      sin x                                     */
/*      Data                                     */
/*      Radian unit                             */
/*      Return value                             */
/*      Sign value*16384                         */
/***** /
int sin( int x )
{
    x = x % RAD ;
    if ( x < 0 ) x += RAD ;
    if ( x < (RAD/4) ){
        return sins( x ) ;
    } else if ( x < (RAD/2) ) {
        return sins( (RAD/2) - x ) ;
    } else if ( x < (RAD*3/4) ) {
        return -sins( x - (RAD/2) ) ;
    } else {
        return -sins( RAD - x ) ;
    }
}
/***** /
int sins( int x )
{
    short z1, z2, z3, z4, z5 ;
/* */
    if ( x <= (RAD/8) ) {
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z3 = z1 * z2 >> SGETA ;
        z5 = z2 * z3 >> SGETA ;
        return ( (12868*z1) - (1322*z3) + (40*z5) ) >> SGETA ;
    } else {
        x = (RAD/4) - x ;
        z1 = (x << SGETA) / (RAD/8) ;
        z2 = z1 * z1 >> SGETA ;
        z4 = z2 * z2 >> SGETA ;

```

```

    return ( (268432772) - (5050*z2) + (252*z4) ) >> SGETA ;
}
}

```

4.4.14 Link directive file for V850E/IA4

```

/***** /
/*      Link directive file for V850E/IA4      */
/***** /
VECT_RESET: !LOAD ?RX V0x00000000 {
    .vect_RESET = $PROGBITS ?AX .vect_RESET;
};
ID_NO: !LOAD ?RX V0x00000070 {
    .id_NO = $PROGBITS ?AX .id_NO;
};
VECT_ETC: !LOAD ?RX V0x00000250 {
    .vect_ETC = $PROGBITS ?AX .vect_ETC;
};
VECT_MOTOR: !LOAD ?RX V0x00000280 {
    .vect_MOTOR = $PROGBITS ?AX .vect_MOTOR;
};
VECT_AD0: !LOAD ?RX V0x00000400 {
    .vect_AD0 = $PROGBITS ?AX .vect_AD0;
};
VECT_AD1: !LOAD ?RX V0x00000410 {
    .vect_AD1 = $PROGBITS ?AX .vect_AD1;
};

HANDLER: !LOAD ?RX V0x00001000 {
    .handler = $PROGBITS ?AX .handler;
};
TEXT: !LOAD ?RX {
    .text = $PROGBITS ?AX .text;
};

CONST : !LOAD ?R {
    .const = $PROGBITS ?A .const;
};

DATA : !LOAD ?RW V0xffffd800 {
    .data = $PROGBITS ?AW ;
    .sdata = $PROGBITS ?AWG ;
    .sbss = $NOBITS ?AWG ;
    .bss = $NOBITS ?AW ;
};

__tp_TEXT @ %TP_SYMBOL;
__gp_DATA @ %GP_SYMBOL &__tp_TEXT{DATA};

```



```
_ _ep_DATA @ %EP_SYMBOL;
```