RZ/T2H Group

Dual Encoder Sample Program

Summary

This application note explains a sample program that simultaneously connects two different encoders, one compliant with the A-format™ version 2.0 communication protocol specification (“A-format™ v2 Specification”) and the other with the EnDat 2.2 Specification. This sample program acquires and displays information for each by using the RZ/T2H Encoder interface.

The major features of the program are listed below.
・Simultaneous connection of encoders compliant with the A-format™ v2 specification and encoders compliant with the EnDat 2.2 specification.
・Supports A-format™ v2 command codes.
・Obtains angle information, etc. from an encoder conforming to the A-format™ v2 specification (MAR-M50A from Nikon).
・Supports the mode command and the MRS codes used in EnDat 2.2.
・Obtains angle information, etc. from an encoder (EQN1035 from HEIDENHAIN) compliant with EnDat 2.2 specifications.

Target Device

RZ/T2H

When applying the sample program covered in this application note to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

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1. Specifications

Table 1.1 lists the peripheral modules to be used and their applications and Figure 1.1 shows the operating environment when the sample code is being executed.

Table 1.1 Peripheral Modules and Applications

Peripheral Module	Application
Multi-Protocol Encoder I/F	RZ/T2H has 16 channels of encoder interface. The encoder interface communicates the respective encoder by selecting a module with A-format v2 specification and a module with EnDat 2.2 specification for each channel.
Interrupt controller (ICU)	Multi-Protocol Encoder I/F interrupt control
General PWM Timer (GPT)	Generation of event cycles to be input to ELC
Event Link Controller (ELC)	Link events output by GPT to Multi-Protocol Encoder I/F
Serial Communication Interface (SCI) UART	Asynchronous communications of the SCI are used for COM port communications by using USB interface. It is used for console interface of the sample program.

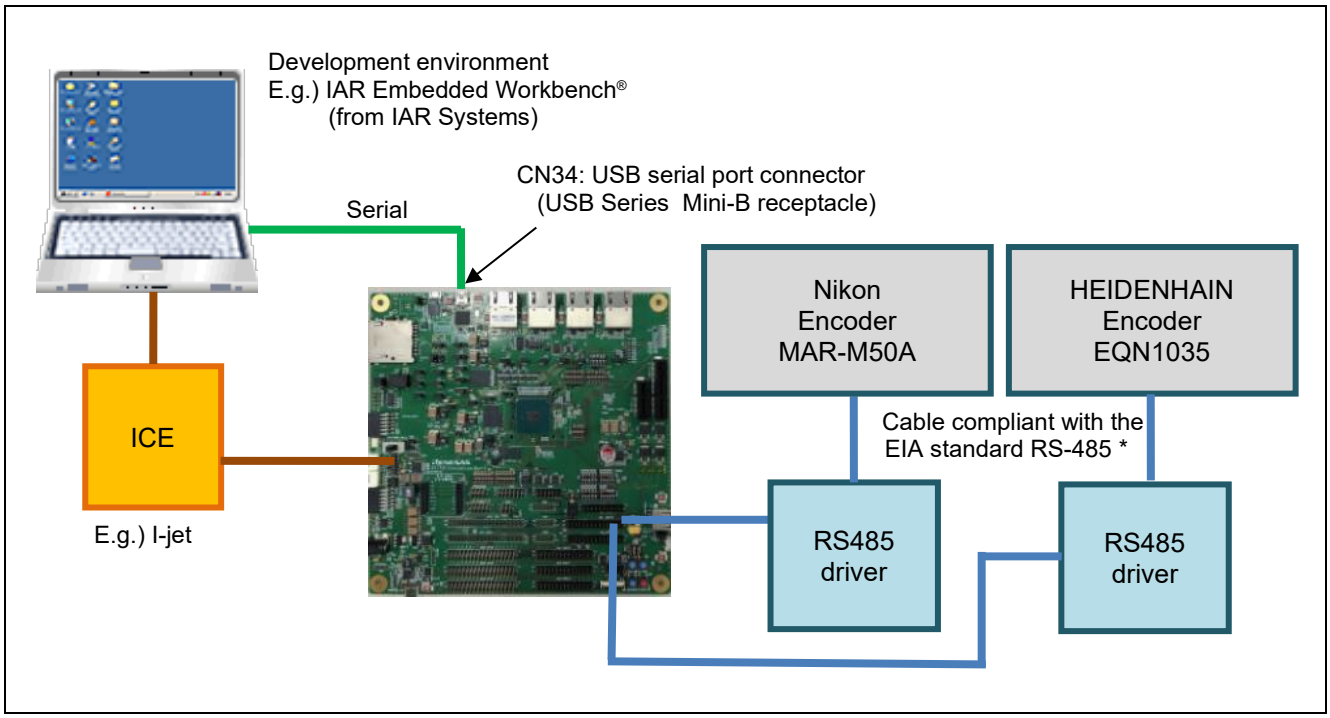


Figure 1.1 Operating Environment

Note: Contact the encoder manufacturer for the cable length that can transmit and receive.

2. Operating Environment

The sample code covered in this application note is for the environment below.

Table 2.1 Operating Environment

Item		Description
MCU		RZ/T2H Group
Operating frequency *1	CR52 ver.	CPUCLK = 1000 MHz (Cortex®-R52 CPU0)
	CA55 ver.	CPUCLK = 1200 MHz (Cortex®-A55 Core0)
Operating voltage		0.8 V (Core) / 1.1 V (DDR) / 1.8 V (PLL, etc.) / 3.3 V (I/O)
Integrated development environment *2		IAR Systems: IAR Embedded Workbench® for Arm® RENESAS: e² studio
Board		RZ/T2H Evaluation Board (RTK9RZT2Hxxxxxxxxx)
Devices (function to be used on the board)		None

Note 1. This sample program has a CR52 version that runs on the CPU core Cortex®-R52 and a CA55 version that runs on the CPU core Cortex®-A55. CR52 ver. and CA55 ver. are descriptions of the respective version.

Note 2. Refer to the RZ/T2H Group Encoder I/F Dual sample program Release Note to check the version number of the integrated development environment.

3. Peripheral Modules

The basics of the peripheral modules, operating modes, and registers are described in the “RZ/T2H Group User’s Manual: Hardware”.

3.1 Pins

Table 3.1 lists the pins used and their functions.

Table 3.1 Used Pins and Their Functions *

Channel	Pin Name	I/O Port	Input/ Output	Voltage Domain	Description
AFMT0	ENCIFOE00 (D/R)	P14_3	Output	VDD3	Data output enable
	ENCIFDO00 (REQ)	P14_4	Output	VDD33	Data output
	ENCIFDI00 (SDAT)	P14_5	Input	VDD33	Data input
ENDAT_CH1	ENCIFCK1 (TCLK1)	P33_2	Output	VDD1833_3	Clock output
	ENCIFOE1 (DE1)	P33_3	Output	VDD1833_3	Data output enable
	ENCIFDO1 (DATA_DV1)	P33_4	Output	VDD1833_3	Data output
	ENCIFDI1 (DATA_RC1)	P33_5	Input	VDD1833_3	Data input

Note: How to change A-format channel and EnDat 2.2 channel is written in “4.15.11 Procedure of Channel Changing”.

4. Software

4.1 A-format Driver Function

The functions of the A-format driver are listed below.

1 Initial settings
2 Transmission of command codes
3 Acquisition of reception data

4.2 EnDat Driver Function

The functions of the EnDat driver are listed below.

1) Initial settings
   A) Initialization of the encoder (Encoder with battery unit is not supported)
   B) Settings of propagation delay compensation
2) Transmission of the following request information
   A) Mode command
   B) MRS Code
   C) Parameters
3) Reception of the encoder data
   A) Positional value
   B) Parameters
   C) Additional information *

Note: In this document, “additional information” represents the additional data 1 and 2. For details, see the “EnDat Specification” which is available from HEIDENHAIN GmbH on request.

4.3 File Structures

For the file structure, refer to the release note for the RZ/T2H Group Encoder I/F Dual Encoder sample program.

4.4 Functions

Table 4.1 lists the functions for A-format. Table 4.2 lists the functions for EnDat.

Table 4.1 A-format Functions

Table 4.2 EnDat Functions

4.5 Specifications of A-format API Functions

4.5.1 R_A_AS_Open

R_A_AS_Open	
Synopsis	Starts controlling operation of the encoder.
Header	r_a_as_rzt2_if.h
Declaration	int32_t R_A_AS_Open(const int32_t id, r_a_as_info_t* p_info);
Description	This function is used for the following initial settings of the AFMT module. 1. Release A-format Interface from the module-stop state 2. Setting of the encoder interface 3. Setting of the communication parameters (for BRSEL register) 4. Setting for enabling interrupts.
Argument	id : Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.) R_A_AS0_ID : Specifies channel 0. R_A_AS1_ID : Specifies channel 1. : : R_A_AS15_ID : Specifies channel 15. Others : Setting is not allowed. p_info : Sets information about the encoder Designate the address of the structure r_a_as_info_t where encoder information is stored.
Return value	R_A_AS_SUCCESS: Normal termination R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id or p_info member variable of the structure r_a_as_info_t is not specified.) R_A_AS_ERR_ACCESS: Abnormal termination (The channel is already opened.)
Note	This function configures the encoder interface. If this function is executed after power for the encoder has been switched on, send CDF8 eight consecutive times to clear the status flag after executing this function. Calling this API function from within a callback function is not allowed.

4.5.2 R_A_AS_Close

R_A_AS_Close	
Synopsis	Stops controlling operation of the encoder
Header	r_a_as_rzt2_if.h
Declaration	int32_t R_A_AS_Close(const int32_t id);
Description	This function stops controlling operation of the encoder on the designated channel.
Argument	id : Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.) R_A_AS0_ID : Specifies channel 0 R_A_AS1_ID : Specifies channel 1 : : R_A_AS15_ID : Specifies channel 15. Others : Setting is not allowed.
Return Value	R_A_AS_SUCCESS: Normal termination R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id is not specified.) R_A_AS_ERR_ACCESS: Abnormal termination (A request is being transmitted.)
Note	Calling this API function from within a callback function is not allowed.

4.5.3 R_A_AS_GetVersion

R_A_AS_GetVersion	
Synopsis	Acquire the version number of the encoder interface driver.
Header	r_a_as_rzt2_if.h
Declaration	uint32_t R_A_AS_GetVersion(const r_a_as_type_t type);
Description	This function acquires the version number of the A-format driver.
Argument	type : Designate R_A_AS_A_FORMAT.
Return value	A major part of the version number is stored in the sixteen MSBs and the minor part of the version number is stored in the sixteen LSBs.
Supplement	If the other type is designated, 0xFFFFFFFF will be returned.
Note	Calling this API function from within a callback function is not allowed.

4.5.4 R_A_AS_Control

R_A_AS_Control	
Synopsis	Controlling operation of the encoder.
Header	r_a_as_rzt2_if.h
Declaration	int32_t R_A_AS_Control(const int32_t id, const r_a_as_cmd_t cmd, void *const p_buf);
Description	This function controls operations of the encoder by using the cmd argument. See “4.5.5 A-format Control Commands” for the operation of the control commands.
Argument	id : Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.) R_A_AS0_ID : Specifies channel 0. R_A_AS1_ID : Specifies channel 1. : : R_A_AS15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Command For the list of the commands, see “Table 4.10 Control Commands of the R_A_AS_Control Function”. p_buf : Arguments corresponding to each cmd.
Return value	R_A_AS_SUCCESS: Normal termination R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id or cmd is not specified.) See “4.5.5, A-format Control Commands” and “Table 4.10 Control Commands of the R_A_AS_Control Function” for other returned values.
Note	Be sure to call R_A_AS_Open before calling this function. Calling this API function from within a callback function is not allowed.

4.5.5 A-format Control Commands

(1) R_A_AS_CMD_SET_PARAM

R_A_AS_CMD_SET_PARAM		
Synopsis	Sets request information	
Header	r_a_as_rzt2_if.h	
Declaration	int32_t R_A_AS_Control(const int32_t id, const r_a_as_cmd_t cmd, void *const p_buf);	
Description	This function sets request information.	
Argument	id	: Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.)
		R_A_AS0_ID : Specifies channel 0.
		R_A_AS1_ID : Specifies channel 1.
		: :
		R_A_AS15_ID : Specifies channel 15.
		Others : Setting is not allowed.
	cmd	: Designate R_A_AS_CMD_SET_PARAM.
	p_buf	: Request information Designate the pointer to the structure r_a_as_req_t where the request information is stored. See section “4.14.1(2) r_a_as_req_t” for details.
Return value	R_A_AS_SUCCESS: Normal termination R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id is not specified, p_buf is null, or structure r_a_as_req_t member of the p_buf is not specified.) R_A_AS_ERR_ACCESS: Abnormal termination (The channel is not started.)	
Note	This control command is utilized only for setting request information. Transmission of commands to the encoder proceeds by using the following control commands. ・R_A_AS_CMD_TX_TRG ・R_A_AS_CMD_TX_ELC Calling this control command from within a callback function is not allowed.	

(2) R_A_AS_CMD_ELC_DISABLE

R_A_AS_CMD_ELC_DISABLE		
Synopsis	Disables input of the ELC event triggers	
Header	r_a_as_rzt2_if.h	
Declaration	int32_t R_A_AS_Control(const int32_t id, const r_a_as_cmd_t cmd, void *const p_buf);	
Description	This function disables event input triggers from the ELC.	
Arguments	id	: Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.)
		R_A_AS0_ID : Specifies channel 0.
		R_A_AS1_ID : Specifies channel 1.
		: :
		R_A_AS15_ID : Specifies channel 15.
		Others : Setting is not allowed.
	cmd	: Designate R_A_AS_CMD_ELC_DISABLE.
	p_buf	: Not used. (Designate NULL.)
Return value	R_A_AS_SUCCESS: Input of the ELC event trigger is disabled. R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id is not specified.) R_A_AS_ERR_ACCESS: Abnormal termination (The ELC event trigger is not in progress or the channel is not started.)	
Note	Calling this control command from within a callback function is not allowed.	

(3) R_A_AS_CMD_TX_TRG

R_A_AS_CMD_TX_TRG	
Synopsis	Starts transmission of requests to the encoder
Header	r_a_as_rzt2_if.h
Declaration	int32_t R_A_AS_Control(const int32_t id, const r_a_as_cmd_t cmd, void *const p_buf);
Description	This function starts transmission of requests to the encoder. In normal reception, a callback function which corresponds to the interrupt source being enabled is called every time a transmission of request is made. See section “4.6.1 a_as_txerr_callback” to “4.6.3 a_as_rxend_callback”.
Arguments	id : Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.) R_A_AS0_ID : Specifies channel 0. R_A_AS1_ID : Specifies channel 1. : : R_A_AS15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Designate R_A_AS_CMD_TX_TRG. p_buf : Not used. (Designate NULL.)
Return value	R_A_AS_SUCCESS: Normal termination. R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id is not specified.) R_A_AS_ERR_BUSY: Abnormal termination (Transfer is in progress.) R_A_AS_ERR_ACCESS: Abnormal termination (The channel is not started.)
Note	This control command is utilized only for starting transmission of requests to the encoder. Use this command after setting request information by using control command R_A_AS_CMD_SET_PARAM. Calling this control command from within a callback function is not allowed.

(4) R_A_AS_CMD_TX_ELC

R_A_AS_CMD_TX_ELC	
Synopsis	Starts transmission of requests to the encoders in response to the input of an ELC event trigger.
Header	r_a_as_rzt2_if.h
Declaration	int32_t R_A_AS_Control(const int32_t id, const r_a_as_cmd_t cmd, void *const p_buf);
Description	This function enables input of the ELC event trigger, and starts the transmission of requests to the encoder. In normal reception, a callback function which corresponds to the interrupt source being enabled is called every time a transmission of request is made. See section “4.6.1 a_as_txerr_callback” to “4.6.3 a_as_rxend_callback” An error code R_A_AS_ERR_BUSY is returned if this control command is executed while the ELC event trigger is in progress.
Argument	id : Designates the ID code to be used. (It is defined in r_a_as_rzt2_dat.h.) R_A_AS0_ID : Specifies channel 0. R_A_AS1_ID : Specifies channel 1. : : R_A_AS15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Designate R_A_AS_CMD_TX_ELC. p_buf : Not used. (Designate NULL.)
Return value	R_A_AS_SUCCESS: Normal termination R_A_AS_ERR_INVALID_ARG: Abnormal termination (The id is not specified.) R_A_AS_ERR_BUSY: Abnormal termination (Transfer or the ELC event trigger is in progress.) R_A_AS_ERR_ACCESS: Abnormal termination (The channel is not started.)
Note	This control command is utilized only for starting transmission of requests to the encoder. Use this command after setting request information by using control command R_A_AS_CMD_SET_PARAM. Calling this control command from within a callback function is not allowed.

4.6 Specification of A-format User-defined Functions

4.6.1 a_as_txerr_callback

a_as_txerr_callback	
Synopsis	Callback function that conveys the result of transmission and reception when a timeout error is generated in normal reception.
Header	-
Declaration	void a_as_txerr_callback (r_a_as_result_t * p_result);
Description	This is a callback function to be registered by the function R_A_AS_Control (R_A_AS_CMD_SET_PARAM). This function conveys the result of transmission and reception in normal reception. This function is called when an interrupt request is generated in response to a timeout error (AFMTi_TMOUT). After this function is processed, the function a_as_rxend_callback() is called, too. This function is the context of the interrupt handler. To ensure interrupt responsiveness, return quickly. The function name is an example and can be set freely.
Argument	p_result : Result of transmission and reception This is the pointer to the array where the result of transmission and reception declared by the structure r_a_as_result_t is stored. See “Table 4.3 Result of Transmission and Reception Stored in Each Array Element” for each element. The result of transmission and reception for the encoder address specified by the function R_A_AS_Control(R_A_AS_CMD_SET_PARAM) is updated. See “Table 4.4 Results of Transmission and Reception” for details.
Return value	None
Note	If the ELC event trigger is enabled, the result of transmission and reception should be acquired within the timer interval. Depending on the timing of response from the encoder, this callback function may be called even if the function R_A_AS_Close, or R_A_AS_Control (R_A_AS_CMD_ELC_DISABLE) have been executed.

4.6.2 a_as_rxset_callback

a_as_rxset_callback	
Synopsis	Callback function that conveys the result of transmission and reception when the setting of received data is complete in normal reception.
Header	-
Declaration	void a_as_rxset_callback(r_a_as_result_t * p_result);
Description	This is a callback function to be registered by the function R_A_AS_Control(R_A_AS_CMD_SET_PARAM). This function conveys the result of transmission and reception in normal reception. This function is called when an interrupt request is generated in response to completion of the data reception (AFMTi_EOF). After this function is processed, the function a_as_rxend_callback() is called, too. This function is the context of the interrupt handler. To ensure interrupt responsiveness, return quickly. The function name is an example and can be set freely.
Argument	p_result : Result of transmission and reception This is the pointer to the array where the result of transmission and reception declared by the structure r_a_as_result_t is stored. See “Table 4.3 Result of Transmission and Reception Stored in Each Array Element” for the contents of each element. The result of transmission and reception for the encoder address specified by the function R_A_AS_Control(R_A_AS_CMD_SET_PARAM) is updated. See “Table 4.4 Results of Transmission and Reception” for details.
Return value	None
Note	If the ELC event trigger is enabled, the result of transmission and reception should be acquired within the timer interval. Depending on the timing of response from the encoder, this callback may be called even if the function R_A_AS_Close or R_A_AS_Control(R_A_AS_CMD_ELC_DISABLE) has been executed.

4.6.3 a_as_rxend_callback

a_as_rxend_callback	
Synopsis	Callback function that conveys the result of transmission and reception when the reception of data has been completed in normal reception.
Header	-
Declaration	void a_as_rxend_callback (r_a_as_result_t * p_result);
Description	This is a callback function to be registered by the function R_A_AS_Control (R_A_AS_CMD_SET_PARAM). This function conveys the result of transmission and reception in normal reception. When a timeout error interrupt (AFMTi_TMOUT) or a completion of the data reception interrupt (AFMTi_EOF) is generated, it is called following the function a_as_txerr_callback() or the function a_as_rxset_callback(). This function is the context of the interrupt handler. To ensure interrupt responsiveness, return quickly. The function name is an example and can be set freely.
Argument	p_result : Result of transmission and reception This is the pointer to the array where the result of transmission and reception declared by the structure r_a_as_result_t is stored. See “Table 4.3 Result of Transmission and Reception Stored in Each Array Element” for the contents of each element. The result of transmission and reception for the encoder address specified by the function R_A_AS_Control(R_A_AS_CMD_SET_PARAM) is updated. See “Table 4.4 Results of Transmission and Reception”.
Return value	None
Note	If the ELC event trigger is enabled, the result of transmission and reception should be acquired within the timer interval. Depending on the timing of response from the encoder, this callback may be called even if the function R_A_AS_Close or R_A_AS_Control(R_A_AS_CMD_ELC_DISABLE) has been executed.

4.6.4 a_as_elctimer_callback

a_as_elctimer_callback	
Synopsis	Callback function that conveys the result of transmission and reception when the data reception is complete in continuous operation of the ELC event trigger.
Header	-
Declaration	void a_as_elctimer_callback(r_a_as_result_t * p_result);
Description	This is a callback function to be registered by the function R_A_AS_Control (R_A_AS_CMD_SET_PARAM). This function conveys the result of transmission and reception in normal reception. This function is called every time when an interrupt request is generated in response to completion of the data reception (AFMTi_EOF). This function is the context of the interrupt handler. To enure interrupt responsiveness, return quickly. The function name is an example and can be set freely.
Argument	p_result : Result of transmission and reception This is the pointer to the array where the result of transmission and reception declared by the structure r_a_as_result_t is stored. See “Table 4.3 Result of Transmission and Reception Stored in Each Array Element” for the contents of each element. The result of transmission and reception for the encoder address specified by the function R_A_AS_Control(R_A_AS_CMD_SET_PARAM) is updated. See “Table 4.4 Results of Transmission and Reception” for details.
Return value	None
Note	If the ELC event trigger is enabled, the result of transmission and reception should be acquired within the timer interval. Depending on the timing of response from the encoder, this callback may be called even if the function R_A_AS_Close or R_A_AS_Control(R_A_AS_CMD_ELC_DISABLE) has been executed.

Table 4.3 Result of Transmission and Reception Stored in Each Array Element

Array Number	Content
p_result[0]	Result of transmission and reception for the encoder section ENC1.
p_result[1]	Result of transmission and reception for the encoder section ENC2.
p_result[2]	Result of transmission and reception for the encoder section ENC3.
p_result[3]	Result of transmission and reception for the encoder section ENC4.
p_result[4]	Result of transmission and reception for the encoder section ENC5.
p_result[5]	Result of transmission and reception for the encoder section ENC6.
p_result[6]	Result of transmission and reception for the encoder section ENC7.
p_result[7]	Result of transmission and reception for the encoder section ENC8.

Table 4.4 Results of Transmission and Reception

Interrupt Source	Results of Transmission and Reception (Member variables of p_result)		
	Result	Data	Status
Timeout error (AFMTi_TMOUT) *1	Only valid when used in the callback functions	Invalid	Only valid when used in the callback functions.
Completion of the data reception (AFMTi_EOF) *1	Only valid when used in the callback functions.	Valid *2	Only valid when used in the callback functions.

Note: 1. i = 00 to 15
2. If the ELC event trigger is disabled, the data reception results are valid until next request.
If the ELC event trigger is enabled, the data reception results are valid until next AFMTi_EOF interrupt is generated.

4.7 A-format Interrupt Handlers

4.7.1 a_as0_int_isr

a_as0_int_isr	
Synopsis	Interrupt handler for AFMT0_EOF
Header	-
Declaration	void a_as0_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 0 data reception.
Argument	None
Return value	None

4.7.2 a_as1_int_isr

a_as1_int_isr	
Synopsis	Interrupt handler for AFMT1_EOF
Header	-
Declaration	void a_as1_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 1 data reception. *
Argument	None
Return value	None

4.7.3 a_as2_int_isr

a_as2_int_isr	
Synopsis	Interrupt handler for AFMT2_EOF
Header	-
Declaration	void a_as2_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 2 data reception. *
Argument	None
Return value	None

4.7.4 a_as3_int_isr

a_as3_int_isr	
Synopsis	Interrupt handler for AFMT3_EOF
Header	-
Declaration	void a_as3_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 3 data reception. *
Argument	None
Return value	None

4.7.5 a_as4_int_isr

a_as4_int_isr	
Synopsis	Interrupt handler for AFMT4_EOF
Header	-
Declaration	void a_as4_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 4 data reception. *
Argument	None
Return value	None

4.7.6 a_as5_int_isr

a_as5_int_isr	
Synopsis	Interrupt handler for AFMT5_EOF
Header	-
Declaration	void a_as5_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 5 data reception. *
Argument	None
Return value	None

4.7.7 a_as6_int_isr

a_as6_int_isr	
Synopsis	Interrupt handler for AFMT6_EOF
Header	-
Declaration	void a_as6_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 6 data reception. *
Argument	None
Return value	None

4.7.8 a_as7_int_isr

a_as7_int_isr	
Synopsis	Interrupt handler for AFMT7_EOF
Header	-
Declaration	void a_as7_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 7 data reception. *
Argument	None
Return value	None

4.7.9 a_as8_int_isr

a_as8_int_isr	
Synopsis	Interrupt handler for AFMT8_EOF
Header	-
Declaration	void a_as8_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 8 data reception. *
Argument	None
Return value	None

4.7.10 a_as9_int_isr

a_as9_int_isr	
Synopsis	Interrupt handler for AFMT9_EOF
Header	-
Declaration	void a_as9_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 9 data reception. *
Argument	None
Return value	None

4.7.11 a_as10_int_isr

a_as10_int_isr	
Synopsis	Interrupt handler for AFMT10_EOF
Header	-
Declaration	void a_as10_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 10 data reception. *
Argument	None
Return value	None

4.7.12 a_as11_int_isr

a_as11_int_isr	
Synopsis	Interrupt handler for AFMT11_EOF
Header	-
Declaration	void a_as11_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 11 data reception. *
Argument	None
Return value	None

4.7.13 a_as12_int_isr

a_as12_int_isr	
Synopsis	Interrupt handler for AFMT12_EOF
Header	-
Declaration	void a_as12_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 12 data reception. *
Argument	None
Return value	None

4.7.14 a_as13_int_isr

a_as13_int_isr	
Synopsis	Interrupt handler for AFMT13_EOF
Header	-
Declaration	void a_as13_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 13 data reception. *
Argument	None
Return value	None

4.7.15 a_as14_int_isr

a_as14_int_isr	
Synopsis	Interrupt handler for AFMT14_EOF
Header	-
Declaration	void a_as14_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 14 data reception. *
Argument	None
Return value	None

4.7.16 a_as15_int_isr

a_as15_int_isr	
Synopsis	Interrupt handler for AFMT15_EOF
Header	-
Declaration	void a_as15_int_isr(void);
Description	This is the interrupt handler for the completion of A_AS channel 15 data reception. *
Argument	None
Return value	None

Note: This interrupt handler is not used in the initial channel configuration. When the channel is changed, the interrupt handler corresponding channel is used.

4.7.17 a_as_err_isr

a_as_err_isr	
Synopsis	Interrupt handler for PERI_ERR0
Header	-
Declaration	void a_as_err_isr(void);
Description	This is the interrupt handler for the timeout of A_AS channel 0 to 15.
Argument	None
Return value	None

4.8 Specifications of EnDat API Functions

4.8.1 R_ENDAT_Open

R_ENDAT_Open	
Synopsis	Starting control of the encoder
Header	r_endat_rzt2_if.h
Declaration	r_endat_err_t R_ENDAT_Open(const int32_t id, r_endat_info_t* p_info);
Description	EnDat Driver initializes following initial settings. 1. Initialization of the encoder (Encoder with a battery unit is not supported) 2. Settings of propagation delay compensation Execute this function 1.3 seconds after the encoder is turned on. The propagation delay of the cable is automatically measured, but if any of the R_ENDAT_CABLE_DELAY measurements fail, the number of measurements is reduced by that amount. If all measurements fail, the value ENDAT_ERR_DRV is returned.
Arguments	id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.) R_ENDAT0_ID : Specifies channel 0. R_ENDAT1_ID : Specifies channel 1. : : R_ENDAT15_ID : Specifies channel 15. Others : Setting is not allowed. p_info : Specifies encoder information. Specify the address of the structure r_endat_info_t that contains the encoder information.
Return value	ENDAT_SUCCESS : Normal termination ENDAT_ERR_INVALID_ARG : Abnormal termination (The id or r_endat_info_t structure member of the p_info is not specified.) ENDAT_ERR_ACCESS : Abnormal termination (The channel is already open.) ENDAT_ERR_DRV : Abnormal termination (The initialization failed.)
Note	The encoder initialization process includes sending the mode command "Encoder receive reset", reading Word 13: "Number of clocks", clearing Word 0 "Error messages", and clearing Word 1: "Warning messages". When initializing the encoder with a battery unit, add the required procedures to the encoder after executing this function by referring to the "Power-on procedure" in the HEIDENHAIN application note (v03).

4.8.2 R_ENDAT_Close

R_ENDAT_Close	
Synopsis	Ending control of the EnDat encoder
Header	r_endat_rzt2_if.h
Declaration	r_endat_err_t R_ENDAT_Close(const int32_t id);
Description	This function handles ending of the encoder interface driver.
Arguments	id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.) R_ENDAT0_ID : Specifies channel 0. R_ENDAT1_ID : Specifies channel 1. : : R_ENDAT15_ID : Specifies channel 15. Others : Setting is not allowed.
Return value	ENDAT_SUCCESS : Normal termination ENDAT_ERR_INVALID_ARG : Abnormal termination (The id Is not specified.) ENDAT_ERR_ACCESS : Abnormal termination (Transfer is in progress.)

4.8.3 R_ENDAT_GetVersion

R_ENDAT_GetVersion	
Synopsis	Acquiring the version number of the encoder interface driver
Header	r_endat_rzt2_if.h
Declaration	uint32_t R_ENDAT_GetVersion(void);
Description	This function acquires the version number of the EnDat driver.
Arguments	None
Return value	Version information : The major and minor parts of the version number are stored in the sixteen MSBs and sixteen LSBs, respectively. Ex.) For ver.1.2, the value returned is 0x00010002

4.8.4 R_ENDAT_Control

R_ENDAT_Control	
Synopsis	Controlling the EnDat encoder
Header	r_endat_rzt2_if.h
Declaration	r_endat_err_t R_ENDAT_Control(const int32_t id, const r_endat_cmd_t cmd, void *const p_buf);
Description	Use the argument cmd to control the EnDat encoder. See "4.8.5 EnDat Control Commands" for the operation of the control commands.
Arguments	id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.) R_ENDAT0_ID : Specifies channel 0. R_ENDAT1_ID : Specifies channel 1. : : R_ENDAT15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Command For details, see section “4.14.6(2) r_endat_cmd_t”. p_buf : Arguments for each cmd
Return value	ENDAT_SUCCESS : Normal termination ENDAT_ERR_INVALID_ARG : Abnormal termination (The id or cmd is not specified.) For other return values, see "4.8.5 EnDat Control Commands".
Note	Be sure to execute R_ENDAT_Open before executing this function.

4.8.5 EnDat Control Commands

(1) ENDAT_CMD_REQ

ENDAT_CMD_REQ	
Synopsis	Sends requests to the EnDat encoder
Header	r_endat_rzt2_if.h
Declaration	r_endat_err_t R_ENDAT_Control(const int32_t id, const r_endat_cmd_t cmd, void *const p_buf);
Description	Sends requests to the EnDat encoder. The endat_callback function is called once for each request sent. If the Continuous mode setting is enabled, the endat_poscon_callback function is repeatedly called until ENDAT_CMD_POS_STOP is executed and the endat_rdst_callback function is called. If the ELC mode setting is enabled, the request is repeatedly sent in synchronize with ELC events until ENDAT_CMD_POS_STOP is executed and the endat_rdst_callback function is called. Each time a request is sent, the endat_poscon_callback function is called.
Arguments	id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.) R_ENDAT0_ID : Specifies channel 0. R_ENDAT1_ID : Specifies channel 1. : : R_ENDAT15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Designate ENDAT_CMD_REQ. p_buf : Request information Specifies the pointer to the r_endat_req_t structure which holds the request information. For details of the r_endat_req_t structure, see section “4.14.4(3) r_endat_req_t”.
Return value	R_ENDAT_SUCCESS : Normal termination R_ENDAT_ERR_INVALID_ARG : Abnormal termination (The id or cmd is not specified, p_buf is NULL, or the structure r_endat_req_t member of the p_buf is not specified.) R_ENDAT_ERR_BUSY : Abnormal termination (Transfer is in progress or STATR register RDY4STRB bit is 0.) R_ENDAT_ERR_ACCESS : Abnormal termination (The channel is not started.)

(2) ENDAT_CMD_POS_STOP

ENDAT_CMD_POS_STOP	
Synopsis	Stop continuous acquisiton of position values
Header	r_endat_rzt2_if.h
Declaration	r_endat_err_t R_ENDAT_Control(const int32_t id, const r_endat_cmd_t cmd, void *const p_buf);
Description	Disables the Continuous mode setting during reception processing in Continuous mode, and disables the ELC mode setting during event-synchronized send/receive processing in ELC mode, thus continuous reception of position values from the EnDat encoder is stopped. An error is returned if there is no continuous reception processing of position values.
Arguments	id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.) R_ENDAT0_ID : Specifies channel 0. R_ENDAT1_ID : Specifies channel 1. : : R_ENDAT15_ID : Specifies channel 15. Others : Setting is not allowed. cmd : Designate ENDAT_CMD_POS_STOP. p_buf : Not used. (Designate NULL.)
Return value	R_ENDAT_SUCCESS : Normal termination R_ENDAT_ERR_INVALID_ARG : Abnormal termination (The id or cmd is not specified.) R_ENDAT_ERR_ACCESS : Abnormal termination (Continuous mode or ELC mode request is not sent.)

4.9 Specifications of EnDat User-defined Functions

4.9.1 enc_init_tclk_wait_callback

enc_init_tclk_wait_callback	
Synopsis	Function to generate wait time after activating TCLK pin output
Header	-
Declaration	void enc_init_reset_wait_callback(void);
Description	Callback function to be registered with the R_ENDAT_Open function. Initialization process of the connected encoder generates the time to wait after activating TCLK pin output. Set 100 us waiting time or longer. The function name is an example and can be freely set.
Arguments	None
Return value	None

4.9.2 enc_init_reset_wait_callback

enc_init_reset_wait_callback	
Synopsis	Function to generate wait time after encoder reset
Header	-
Declaration	void enc_init_reset_wait_callback(void);
Description	Callback function to be registered with the R_ENDAT_Open function. Initialization process of the connected encoder generates the time to wait after the encoder reset process. Set 60 ms waiting time or longer. The function name is an example and can be freely set.
Arguments	None
Return value	None

4.9.3 enc_init_mem_wait_callback

enc_init_mem_wait_callback	
Synopsis	Function to generate wait time for detecting memory area selection timeout
Header	-
Declaration	void enc_init_mem_wait_callback(void);
Description	Callback function to be registered with the R_ENDAT_Open function. Generates a wait time used for detecting a timeout error in the process of selecting a memory area in the initialization process of the connected encoder. Set 743 us* waiting time or longer. The function name is an example and can be freely set. Note: This value is based on the assumption of (2 clock cycles + mode command(6 clock cycles) + MRS code(8 clock cycles) + 16 clock cycles + 2T(2 clock cycles) + maximum 7 clock cycles +Start(1 clock cycle) + MRS code(8 clock cycles) + 16 clock cycles + CRC(5 clock cycles))×(1/100 kHz) + t_m(30 us) + t_R(0.5 us) + t_D(1.7 us) = 742.2 us. The transmission clock frequency is set to 100kHz in the driver during the encoder initialization process. The delay time t_D assumes a cable length of 150 m. Users are required to adjust the waiting time according to the encoder and the cable length.
Arguments	None
Return value	None

4.9.4 enc_init_pram_wait_callback

enc_init_pram_wait_callback	
Synopsis	Function to generate wait time for detecting parameter transmission timeout
Header	-
Declaration	void enc_init_pram_wait_callback(void);
Description	Callback function to be registered with the R_ENDAT_Open function. Generates a wait time for the initialization process of the connected encoder to detect timeout errors in the process of sending and receiving parameters by the encoder. Set 13 ms* waiting time or longer. The function name is an example and can be freely set. Note: Assumes memory access time (12 ms) + (Start(1 clock cycle) + Address(8 clock cycles) + Parameters(16 clock cycles) + CRC(5 clock cycles))×(1/100 kHz) + t_m(30 us) + t_R(0.5 us) + t_D(1.7 us) = 12.33 ms. During the encoder initialization process, the transmission clock frequency is set to 100 kHz in the driver. The delay time t_D assumes a cable length of 150 m. Users are required to adjust the waiting time according to the encoder and the cable length.
Arguments	None
Return value	None

4.9.5 enc_init_cable_wait_callback

enc_init_cable_wait_callback	
Synopsis	Function to generate wait time for detecting propagation delay measurement timeout
Header	-
Declaration	void enc_init_cable_wait_callback(void);
Description	Callback function to be registered with the R_ENDAT_Open function. Generates a wait time used for detecting a timeout error in the process of measuring cable propagation delay in the initialization process of the connected encoder. Set 588 us* waiting time or longer. The function name is an example and can be freely set. Note: Assumes t_{cal}(5 us) + (Start(1 clock cycle) + Error(1 clock cycle) + maximum number of bits of main received data (48 bits) + number of CRC bits (5 bits))×(1/100 kHz) + t_m(30 us) + t_R(0.5 us) + t_D(1.7 us) = 587.2us. During the encoder initialization process, the transmission clock frequency is set to 100 kHz in the driver. The delay time t_D assumes a cable length of 150 m. Users are required to adjust the waiting time according to the encoder and the cable length.
Arguments	None
Return value	None

4.9.6 endat_callback

endat_callback	
Synopsis	Data reception result notification function for sending requests
Header	-
Declaration	void endat_callback(r_endat_result_t * p_result, r_endat_protocol_err_t *p_err);
Description	This callback function is registered with the R_ENDAT_Control(ENDAT_CMD_REQ) function This function is the context of the interrupt handler. To ensure interrupt responsiveness, return immediately. The function name is an example and can be freely set.
Argument	p_result : Result of sending/receiving Pointer to structure r_endat_result_t that stores the result of sending/receiving data. The data reception result is valid until the next request is sent. p_err : Error information Pointer to the structure r_endat_protocol_err_t that contains the results of sending and receiving. The data reception result is valid until the next request is sent.
Return value	None

4.9.7 endat_poscon_callback

endat_poscon_callback	
Synopsis	Data reception result notification function for sending requests (Continuous mode, ELC mode)
Header	-
Declaration	void endat_poscon_callback(r_endat_result_t * p_result, endat_protocol_err_t *p_err);
Description	This callback function is registered with the R_ENDAT_Control (ENDAT_CMD_REQ) function when data transmission is performed in Continuous mode or ELC mode. This function notifies the result of data reception in response to a request. This function is the context of the interrupt handler. To ensure interrupt responsiveness, return immediately. The function name is an example and can be freely set.
Arguments	p_result : Result of sending/receiving Pointer to the structure r_endat_result_t that stores the result of sending/receiving data. The data reception result is valid until the next request is sent/received. p_err : Error information Pointer to the structure r_endat_protocol_err_t that stores the results of sending and receiving. The data reception result is valid until the next request is sent/received.
Return value	None

4.9.8 endat_rdst_callback

endat_rdst_callback	
Synopsis	Callback function to notify that the next data communication is ready to start
Header	-
Declaration	void endat_rdst_callback(void);
Description	This callback function is registered with the R_ENDAT_Control(ENDAT_CMD_REQ) function. It is called after the endat_callback function when an interrupt occurs with setting RDY bit of STATR register. While operating in Continuous mode or ELC mode, this function is called after the endat_poscon_callback function each time data reception is completed. This function is the context for the interrupt handler. To ensure interrupt responsiveness, return immediately. The function name is an example and can be freely set.
Arguments	None
Return value	None

4.10 EnDat Interrupt Handlers

4.10.1 endat0_rx_int_isr

endat0_rx_int_isr	
Synopsis	Channel 0 Data reception completion interrupt handler
Header	-
Declaration	void endat0_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 0. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.2 endat1_rx_int_isr

endat1_rx_int_isr	
Synopsis	Channel 1 Data reception completion interrupt handler
Header	-
Declaration	void endat1_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 1. 1. ERR1, IERR2 interrupts 2. WTDG interrupts 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.3 endat2_rx_int_isr

endat2_rx_int_isr	
Synopsis	Channel 2 Data reception completion interrupt handler
Header	-
Declaration	void endat2_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 2. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.4 endat3_rx_int_isr

endat3_rx_int_isr	
Synopsis	Channel 3 Data reception completion interrupt handler
Header	-
Declaration	void endat3_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 3. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.5 endat4_rx_int_isr

endat4_rx_int_isr	
Synopsis	Channel 4 Data reception completion interrupt handler
Header	-
Declaration	void endat4_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 4. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.6 endat5_rx_int_isr

endat5_rx_int_isr	
Synopsis	Channel 5 Data reception completion interrupt handler
Header	-
Declaration	void endat5_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 5. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.7 endat6_rx_int_isr

endat6_rx_int_isr	
Synopsis	Channel 6 Data reception completion interrupt handler
Header	-
Declaration	void endat6_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 6. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.8 endat7_rx_int_isr

endat7_rx_int_isr	
Synopsis	Channel 7 Data reception completion interrupt handler
Header	-
Declaration	void endat7_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 7. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.9 endat8_rx_int_isr

endat8_rx_int_isr	
Synopsis	Channel 8 Data reception completion interrupt handler
Header	-
Declaration	void enda8_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 8. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.10 endat9_rx_int_isr

endat9_rx_int_isr	
Synopsis	Channel 9 Data reception completion interrupt handler
Header	-
Declaration	void endat9_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 9. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.11 endat10_rx_int_isr

endat10_rx_int_isr	
Synopsis	Channel e0 Data reception completion interrupt handler
Header	-
Declaration	void endat10_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 10. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.12 endat11_rx_int_isr

endat11_rx_int_isr	
Synopsis	Channel 11 Data reception completion interrupt handler
Header	-
Declaration	void endat11_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 11. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.13 endat12_rx_int_isr

endat12_rx_int_isr	
Synopsis	Channel 12 Data reception completion interrupt handler
Header	-
Declaration	void endat12_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 12. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.14 endat13_rx_int_isr

endat13_rx_int_isr	
Synopsis	Channel 13 Data reception completion interrupt handler
Header	-
Declaration	void endat13_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 13. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.15 endat14_rx_int_isr

endat14_rx_int_isr	
Synopsis	Channel 14 Data reception completion interrupt handler
Header	-
Declaration	void endat14_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 14. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.10.16 endat15_rx_int_isr

endat15_rx_int_isr	
Synopsis	Channel 15 Data reception completion interrupt handler
Header	-
Declaration	void endat15_rx_int_isr(void);
Description	Interrupt handler for the following interrupt factors on EnDat channel 15. * 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

Note: This interrupt handler is not used in the initial channel configuration. When the channel is changed, the interrupt handler corresponding channel is used.

4.11 Interrupts

Table 4.5 lists the interrupt for the Dual Encoder driver. If the channels are changed, the ID will also change along with the interrupt channel change for the A-format and EnDat encoders.

Table 4.5 Interrupt for the Dual Encoder Driver

Interrupt	ID *		Outline
	CR52 ver.	CA55 ver.	
ENCIF_ERR0	388	417	This is generated in response to the timeout of channel 0 to 15.
ENCIF00_INT0	389	716	This is generated in response to the completion of channel 0 reception of the A-format encoder.
ENCIF01_INT0	390	720	This is generated by the following interrupt factors of the Ch1 EnDat encoder. 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts

Note: This sample program has a CR52 version that runs on the CPU core Cortex-R52 and a CA55 version that runs on the CPU core Cortex-A55. CR52 ver. and CA55 ver. are descriptions of the respective version.

4.12 Constant and Error Code

Table 4 6 lists the constant/error code definition tables. For each definition, refer to the respective table. For EnDat error codes, see "4.14.6(1) r_endat_err_t".

Table 4.6 Constant/error code definition tables

Table number	Contents
Table 4.7	User-defined constants used by the A-format driver (r_a_as_rzt2_config.h)
Table 4.8	A-format Driver Type
Table 4.9	Methods of Connection between A_AS and Encoders
Table 4.10	Control Commands of the R_A_AS_Control Function
Table 4.11	A-format Bitrate
Table 4.12	A-format Encoder Addresses
Table 4.13	A-format Commands
Table 4.14	A-format Error Codes
Table 4.15	User-defined Constants to be Used in the EnDat Driver (r_endat_rzt2_config.h)
Table 4.16	EnDat 2.2 Mode Commands
Table 4.17	EnDat Transmission Clock Frequencies
Table 4.18	EnDat Watchdog Timer Time Units
Table 4.19	EnDat Low-level Period at the Start of Data Transmission
Table 4.20	EnDat MRS Codes

Table 4.7 User-defined constants used by the A-format driver (r_a_as_rzt2_config.h)

Constant Name	Setting	Description
R_A_AS_T2_ONE_2500KBPS	0x0000	The value set in the BRSEL register TM bit when the connection is one-to-one, and the bit rate is 2.5 Mbps. *
R_A_AS_T2_ONE_4MBPS	0x0000	The value set in the BRSEL register TM bit when the connection is one-to-one, and the bit rate is 4 Mbps. *
R_A_AS_T2_ONE_6670KBPS	0x0000	The value set in the BRSEL register TM bit when the connection is one-to-one, and the bit rate is 6.67 Mbps. *
R_A_AS_T2_ONE_8MBPS	0x0000	The value set in the BRSEL register TM bit when the connection is one-to-one, and the bit rate is 8 Mbps. *
R_A_AS_T2_BUS_2500KBPS	0x001A	The value set in the BRSEL register TM bit when the connection is a bus connection, and the bit rate is 2.5 Mbps. *
R_A_AS_T2_BUS_4MBPS	0x0010	The value set in the BRSEL register TM bit when the connection is a bus connection, and the bit rate is 4 Mbps. *
R_A_AS_T2_BUS_6670KBPS	0x0009	The value set in the BRSEL register TM bit when the connection is a bus connection, and the bit rate is 6.67 Mbps. *
R_A_AS_T2_BUS_8MBPS	0x0008	The value set in the BRSEL register TM bit when the connection is a bus connection, and the bit rate is 8 Mbps. *

Note: In this sample program, the values set in each register are the recommended values.

Table 4.8 A-format Driver Type

Constant Name	Setting	Description
R_A_AS_A_FORMAT	0	Designates the A-format driver.

Table 4.9 Methods of Connection between A_AS and Encoders

Constant Name	Setting	Description
R_A_AS_ONE_FOR_ONE	0	One-to-one connection
R_A_AS_BUS	1	Bus connection

Table 4.10 Control Commands of the R_A_AS_Control Function

Constant Name	Setting	Description
R_A_AS_CMD_SET_PARAM	0xAF000000	Sets requests information
R_A_AS_CMD_ELC_DISABLE	0xAF000002	Disable input of the ELC event trigger
R_A_AS_CMD_TX_TRG	0xAF000003	Starts transmission of a command by timer operation.
R_A_AS_CMD_TX_ELC	0xAF000005	Starts transmission of a command by input of the ELC event trigger

Table 4.11 A-format Bitrate

Constant Name	Setting	Description
R_A_AS_2500KBPS	0	2.5 Mbps
R_A_AS_4MBPS	1	4 Mbps
R_A_AS_6670KBPS	2	6.67 Mbps
R_A_AS_8MBPS	3	8 Mbps

Table 4.12 A-format Encoder Addresses

Constant Name	Setting	Description
R_A_AS_ECN1	0	The address of the encoder section ENC1.
R_A_AS_ECN2	1	The address of the encoder section ENC2.
R_A_AS_ECN3	2	The address of the encoder section ENC3.
R_A_AS_ECN4	3	The address of the encoder section ENC4.
R_A_AS_ECN5	4	The address of the encoder section ENC5.
R_A_AS_ECN6	5	The address of the encoder section ENC6.
R_A_AS_ECN7	6	The address of the encoder section ENC7.
R_A_AS_ECN8	7	The address of the encoder section ENC8.

Table 4.13 A-format Commands

Constant Name	Setting	Description
R_A_AS_CDF0	0	The value defined for the command data frame CDF0.
R_A_AS_CDF1	1	The value defined for the command data frame CDF1.
R_A_AS_CDF2	2	The value defined for the command data frame CDF2.
R_A_AS_CDF3	3	The value defined for the command data frame CDF3.
R_A_AS_CDF4	4	The value defined for the command data frame CDF4.
R_A_AS_CDF5	5	The value defined for the command data frame CDF5.
R_A_AS_CDF6	6	The value defined for the command data frame CDF6.
R_A_AS_CDF7	7	The value defined for the command data frame CDF7.
R_A_AS_CDF8	8	The value defined for the command data frame CDF8.
R_A_AS_CDF9	9	The value defined for the command data frame CDF9.
R_A_AS_CDF10	10	The value defined for the command data frame CDF10.
R_A_AS_CDF11	11	The value defined for the command data frame CDF11.
R_A_AS_CDF12	12	The value defined for the command data frame CDF12.
R_A_AS_CDF13	13	The value defined for the command data frame CDF13.
R_A_AS_CDF14	14	The value defined for the command data frame CDF14.
R_A_AS_CDF15	15	The value defined for the command data frame CDF15.
R_A_AS_CDF16	16	The value defined for the command data frame CDF16.
R_A_AS_CDF17	17	The value defined for the command data frame CDF17.
R_A_AS_CDF18	18	The value defined for the command data frame CDF18.
R_A_AS_CDF19	19	The value defined for the command data frame CDF19.
R_A_AS_CDF21	21	The value defined for the command data frame CDF21.
R_A_AS_CDF22	22	The value defined for the command data frame CDF22.
R_A_AS_CDF27	27	The value defined for the command data frame CDF27.
R_A_AS_CDF28	28	The value defined for the command data frame CDF28.
R_A_AS_CDF29	29	The value defined for the command data frame CDF29.
R_A_AS_CDF30	30	The value defined for the command data frame CDF30.

Table 4.14 A-format Error Codes

Constant Name	Setting	Description
R_A_AS_SUCCESS	0	Normal termination
R_A_AS_ERR_INVALID_ARG	-1	Argument error
R_A_AS_ERR_BUSY	-2	The API cannot be executed.
R_A_AS_ERR_ACCESS	-3	API execution order error.

Table 4.15 User-defined Constants to be Used in the EnDat Driver (r_endat_rzt2_config.h)

Constant	Set value	Content
R_ENDAT_CABLE_DELAY	5	The number of times the propagation delay is automatically measured. Set it to 5 to 255 times.
R_ENDAT_ADD_NUM	0u	Number of additional information to receive

Table 4.16 EnDat 2.2 Mode Commands

Constant	Value	Content
R_ENDAT_POS	0x07u	“Encoder send position values” command
R_ENDAT_MEM	0x0Eu	“Selection of memory area” command
R_ENDAT_RX_PARAM	0x1Cu	“Encoder receive parameter” command
R_ENDAT_PARAM	0x23u	“Encoder send parameter” command
R_ENDAT_RESET	0x2Au	“Encoder receive reset” command
R_ENDAT_POS_ADD_DATA	0x38u	“Encoder send position values with additional data” command
R_ENDAT_POS_MEM	0x09u	“Encoder send position values and selection of the memory area” command
R_ENDAT_POS_RX_PARAM	0x1Bu	“Encoder send position values and receive parameter” command
R_ENDAT_POS_PARAM	0x24u	“Encoder send position values and send parameter” command
R_ENDAT_POS_RX_ERR_RESET	0x2Du	“Encoder send position values and receiver error reset” command

Note: For details, refer to the "EnDat Specification" which is available from HEIDENHAIN on request.

Table 4.17 EnDat Transmission Clock Frequencies

Constant	value	content
R_ENDAT_FTCLK_16670	0x3u	16.67 MHz *
R_ENDAT_FTCLK_8330	0x6u	8.33 MHz *
R_ENDAT_FTCLK_4160	0xBu	4.16 MHz *
R_ENDAT_FTCLK_4000	0x8u	4 MHz *
R_ENDAT_FTCLK_2000	0xCu	2 MHz
R_ENDAT_FTCLK_1000	0xDu	1 MHz
R_ENDAT_FTCLK_200	0xEu	0.2 MHz
R_ENDAT_FTCLK_100	0xFu	0.1 MHz

Note: Propagation delay compensation should be enabled (delay_comp=true).

Table 4.18 EnDat Watchdog Timer Time Units

Constant	value	content
R_ENDAT_WD_RANGE_US	0x00u	Watchdog Timer time unit is microseconds
R_ENDAT_WD_RANGE_MS	0x80u	Watchdog Timer time unit is milliseconds

Table 4.19 EnDat Low-level Period at the Start of Data Transmission

Constant	value	content
R_ENDAT_TST_HALF_TCLK	0x00u	1/2 TCLK
R_ENDAT_TST_500NS	0x01u	0.5 us *
R_ENDAT_TST_1US	0x02u	1 us *
R_ENDAT_TST_1500NS	0x03u	1.5 us *
R_ENDAT_TST_2US	0x04u	2 us *
R_ENDAT_TST_4US	0x05u	4 us *
R_ENDAT_TST_8US	0x06u	8 us *
R_ENDAT_TST_10US	0x07u	10 us *

Note The low-level period has a margin of error. See the hardware manual for details.

Table 4.20 EnDat MRS Codes

Constant	value	content
R_ENDAT_MRS_INFO1_NOP	0x40u	Send additional info 1 without data contents (NOP)
R_ENDAT_MRS_DIA	0x41u	Send diagnostic values
R_ENDAT_MRS_POS2_LSB	0x42u	Send position value 2, word 1 LSB
R_ENDAT_MRS_POS2_CENTER	0x43u	Send position value 2, word 2
R_ENDAT_MRS_POS2_MSB	0x44u	Send position value 2, word 3 MSB
R_ENDAT_MRS_MEM_LSB	0x45u	Acknowledge memory content LSB
R_ENDAT_MRS_MEM_MSB	0x46u	Acknowledge memory content MSB
R_ENDAT_MRS_MRS_CODE	0x47u	Acknowledge MRS code
R_ENDAT_MRS_TEST_SMD	0x48u	Acknowledge test command
R_ENDAT_MRS_TEST_LSB	0x49u	Send test values, word 1 LSB
R_ENDAT_MRS_TEST_CENTER	0x4Au	Send test values, word 2
R_ENDAT_MRS_TEST_MSB	0x4Bu	Send test values, word 3 MSB
R_ENDAT_MRS_TEMP1	0x4Cu	Send temperature 1
R_ENDAT_MRS_TEMP2	0x4Du	Send temperature 2
R_ENDAT_MRS_ADD_SEN	0x4Eu	Additional sensors
R_ENDAT_MRS_NOT_INFO1	0x4Fu	Stop sending additional datum 1
R_ENDAT_MRS_INFO2_NOP	0x50u	Send additional datum 2 without data contents
R_ENDAT_MRS_COM	0x51u	Send commutation
R_ENDAT_MRS_ACC	0x52u	Send acceleration
R_ENDAT_MRS_COM_ACC	0x53u	Send commutation & acceleration
R_ENDAT_MRS_LIM_POS	0x54u	Send limit position signals
R_ENDAT_MRS_LIM_POS_ACC	0x55u	Send limit position signals & acceleration
R_ENDAT_MRS_ASY_POS_LSB	0x56u	Asynchronous position value, word 1 LSB
R_ENDAT_MRS_ASY_POS_CENTER	0x57u	Asynchronous position value, word 2
R_ENDAT_MRS_ASY_POS_MSB	0x58u	Asynchronous position value, word 3 MSB
R_ENDAT_MRS_OPE_STA_ERR	0x59u	Operating status error sources
R_ENDAT_MRS_TIM_STA	0x5Bu	Timestamp
R_ENDAT_MRS_NOT_INFO2	0x5Fu	Stop sending additional datum 2
R_ENDAT_MRS_OPE_STAT	0xB9u	Operating status
R_ENDAT_MRS_ENC_MANU1	0xA1u	Parameters of the encoder manufacturer 1
R_ENDAT_MRS_ENC_MANU2	0xA3u	Parameters of the encoder manufacturer 2
R_ENDAT_MRS_ENC_MANU3	0xA5u	Parameters of the encoder manufacturer 3
R_ENDAT_MRS_OPE_PARAM	0xA7u	Operating parameters
R_ENDAT_MRS_OEM1	0xA9u	Parameters of the OEM 1
R_ENDAT_MRS_OEM2	0xABu	Parameters of the OEM 2
R_ENDAT_MRS_OEM3	0xADu	Parameters of the OEM 3
R_ENDAT_MRS_OEM4	0xAFu	Parameters of the OEM 4
R_ENDAT_MRS_COMP_VAL1	0xB1u	Compensation Values of the encoder manufacturer 1
R_ENDAT_MRS_COMP_VAL2	0xB3u	Compensation Values of the encoder manufacturer 2
R_ENDAT_MRS_COMP_VAL3	0xB5u	Compensation Values of the encoder manufacturer 3
R_ENDAT_MRS_COMP_VAL4	0xB7u	Compensation Values of the encoder manufacturer 4
R_ENDAT_MRS_PARAM_ENDAT22	0xBDu	Parameters of the encoder manufacturer for EnDat 2.2
R_ENDAT_MRS_PARAM_SEC2	0xBFu	Parameters of the section 2 memory area
R_ENDAT_MRS_OPE_PARAM2	0xBBu	Operating parameters 2

Note: For details, refer to the "EnDat Specification" which is available from HEIDENHAIN on request.

4.13 Fixed-width Integer Types

Table 4.21 lists the fixed-width integers for the sample code. These fixed-width integers are defined in the standard libraries.

Table 4.21 Fixed-width Integers for the Sample Program

Symbol	Description
int8_t	8-bit signed integer (defined in the standard libraries)
int16_t	16-bit signed integer (defined in the standard libraries)
int32_t	32-bit signed integer (defined in the standard libraries)
int64_t	64-bit signed integer (defined in the standard libraries)
uint8_t	8-bit unsigned integer (defined in the standard libraries)
uint16_t	16-bit unsigned integer (defined in the standard libraries)
uint32_t	32-bit unsigned integer (defined in the standard libraries)
uint64_t	64-bit unsigned integer (defined in the standard libraries)

4.14 Structures, Unions, and Enumerated Types

4.14.1 A-format Structures

(1) r_a_as_info_t

Initialization information of the A_AS control unit,

```
typedef struct
{
    uint8_t     connect;    Connection method
                            Designate the method of connection between A_AS and the
                            encoders. See “Table 4.9  Methods of Connection between A_AS
                            and Encoders” for the values to be designated.
                            Note: This setting is reflected in the BRSEL registers.
    uint8_t     bitrate;    Bit rate
                            Designate the bit rate for communications with the encoder. See
                            “Table 4.11  A-format Bitrate” for the values to be designated.
                            Note: This setting is reflected in the BRSEL registers.
    uint16_t    ifmg;       Margin value
                            Note: This is reserved for driver interface compatibility with RZ/T2M
                            group A-format driver. This setting value is not used for RZ/T2H.
} r_a_as_info_t
```

(2) r_a_as_req_t

Information of requests to be sent to the encoders.

```
typedef struct
{
```

uint8_t	encadr;	Encoder address Designate the encoder address. See “Table 4.12 A-format Encoder Addresses” for the value to be designated. This setting is reflected in the XEA bit of the COMMAND register.
uint8_t	cmd;	Command Designate the command code to be sent to the encoder. See “Table 4.13 A-format Commands” for the value to be designated. If the value is not listed in the said table and exceeds 0x20, an error with the error code R_A_AS_ERR_INVALID_ARG is generated. Some commands are not available depending on the connection method.
uint8_t	memadr;	Memory address Designate the address of the memory in the encoder. Set this value only in the following cases: cmd = R_A_AS_CDF13 cmd = R_A_AS_CDF14 Note: For the command R_A_AS_CDF13, the accessible address range is between 0x00 and 0xFF. For the command R_A_AS_CDF14, the accessible address range is between 0x00 and 0xEF.
uint16_t	memdat;	Data to be written to the memory Designate the data to be written to the memory. Set this value only in the following case: cmd = R_A_AS_CDF14
uint32_t	encid;	Recognition code Designate the 24-bit recognition code. Set this value only in the following cases: cmd = R_A_AS_CDF18 cmd = R_A_AS_CDF19
r_a_as_result_cb_t	cbadr_txerr	The pointer to the callback function *1 to be called in response to PERI_ERR0 interrupt request. See “4.6.1 a_as_txerr_callback” for details.
r_a_as_result_cb_t	cbadr_rxset;	The pointer to the callback function *1 to be called in response to an AFMTi_EOF (i = 0 to 15) interrupt request. See “4.6.2 a_as_rxset_callback” for details.
r_a_as_result_cb_t	cbadr_rxend;	The pointer to the callback function *1 to be called following the cbadr_txerr() function or cbadr_rxset() function in response to PERI_ERR0 interrupt or AFMTi_EOF (i = 0 to 15) interrupt request. See “4.6.3 a_as_rxend_callback” for details.
bool	pre;	Set true in this variable to set request information while transmission and reception of data by the ELC event trigger is in progress. Set false to set request information in other cases. (true: Set request information while transmission and reception of data by the ELC event trigger is in progress)

```
} r_a_as_req_t
```

Note 1. Callback function will not be run if the pointer is NULL.

(3) r_a_as_result_t

Result of transmission and reception in normal reception

```
typedef struct
{
    r_a_as_req_err_t    result;     Result of transmission and reception
                                    See the enumerated type “4.14.3(1) r_a_as_req_err_t” for
                                    details.
    r_a_as_data_t       data;       Reception data
                                    See the structure “4.14.1(4) r_a_as_data_t” for details.
    r_a_as_status_t     status;     State of the A_AS
                                    See the structure “4.14.1(5) r_a_as_status_t” for details.
} r_a_as_result_t
```

(4) r_a_as_data_t

Data received in normal reception

```
typedef struct
{
    uint32_t            rxi;        ENCnRXDATA0 register value
                                    The value of the ENCnRXDATA0 register is stored here.
    uint32_t            rxd0;       ENCnRXDATA1 register value
                                    The value of the ENCnRXDATA1 register is stored here.
    uint32_t            rxd1;       ENCnRXDATA2 register value
                                    The value of the ENCnRXDATA2 register is stored here.
} r_a_as_data_t
```

(5) r_a_as_status_t

State of the A_AS on transmission or reception

```
typedef struct
{
    bool     iwdgerr;    Indicates IF watchdog error. Corresponds to timeout error.
    bool     dwdgerr;    Indicates DF watchdog error. Corresponds to timeout error.
    bool     starterr;   Indicates start bit errors. Corresponds to CA[1] FORM status flag.
    bool     stoperr;    Indicates stop bit errors. Corresponds to CA[1] FORM status flag.
    bool     syncerr;    Indicates sync code errors. Corresponds to CA[2] SYNC status flag.
    bool     rxeaerr;    Indicates received encoder address error. Corresponds to CA[0] CMD status
                         flag.
    bool     crcerr;     Indicates CRC error. Corresponds to CA[3] CRC status flag.
    bool     rxccerr;    Indicates received command code error. Corresponds to CA[0] CMD status
                         flag.
    bool     mdaterr;    Indicates EEPROM data error. *1
    bool     madrerr;    Indicates EEPROM address error. *1
    bool     rxdzerr;    Indicates ID code error. *1
    bool     fd1err;     Indicates fixed-data (1) error. *1
    bool     fd2err;     Indicates fixed-data (2) error. *1
    bool     fd3err;     Indicates fixed-data (3) error. *1
    bool     fd5err;     Indicates fixed-data (5) error. *1
    bool     elcin;      Information in response to ELCIN input is being stored. *1
    uint8_t  txcc;       Transmission command code is stored.
                         (0: CDF0 to 19 and 23 to 30, 1: CDF21, 2: CDF22)
    bool     rxset;      This value indicates whether the setting of received data is complete.
                         (true: Ready to read; false: Not ready to read)
    bool     timer;      Indicates whether the timer is operating or not. *1
    bool     txerr;      Indicates transmission error. *1
    bool     rxend;      Indicates completion of reception. (true: Received; false: Not received)
} r_a_as_status_t
```

Note: 1. This is reserved for driver interface compatibility with RZ/T2M group A-format encoder driver. This is not used in the driver for RZ/T2H.

4.14.2 A-format Unions

Unions are not used in this sample program.

4.14.3 A-format Enumerated Types

(1) r_a_as_req_err_t

Result of reception from the encoder

```
typedef enum
{
    R_A_AS_REQ_SUCCESS = 0,   Normal termination of data transmission and reception
    R_A_AS_REQ_ERR            An error occurred in data transmission or reception.
                              This error code is generated even if one of the error indicators
                              (excluding timer, rxend, rxset, elcin, and txcc) of the structure
                              “4.14.1(5) r_a_as_status_t” is "true".
    R_A_AS_REQ_BP_ERR         The reception FIFO buffer is full.
                              This error code is generated only in bypass reception.
} r_a_as_req_err_t
```

4.14.4 EnDat Structures

(1) r_endat_info_t

Initialization information of the EnDat control unit

```
typedef struct
{
```

uint8_t	ftclk;	Transmission clock frequency setting See "Table 4.17 EnDat Transmission Clock Frequencies". This setting is reflected in the FTCLK bit of the KONFR1 register.
bool	filter;	Noise filter settings (true: enabled, false: disabled) Note: This is reserved for driver interface compatibility with RZ/T2M group EnDat driver. This setting value is not used for RZ/T2H.
bool	delay_comp;	Propagation delay correction (true: valid, false: invalid) This setting is reflected in the DELAYCMP bit of the KONFR1 register.
uint8_t	tst;	Set the Low period at the start of data transmission See "Table 4.19 EnDat Low-level Period at the Start of Data Transmission". This setting is reflected in the RCVTIME bit of the KONFR2 register.
endat_wait_cb_t	pecn_init_tclk_wait;	A pointer to a callback function that generates the wait time after activating TCLK pin output. See “4.9.1 enc_init_tclk_wait_callback” for details. Do not set NULL.
endat_wait_cb_t	p_enc_init_reset_wait;	A pointer to a callback function that generates the wait time after an encoder reset See "4.9.2 enc_init_reset_wait_callback" for details. Do not set NULL.
endat_wait_cb_t	p_enc_init_mem_wait;	Pointer to callback function that generates wait time for encoder memory area selection timeout error detection. See "4.9.3 enc_init_mem_wait_callback" for details. Do not set NULL.
endat_wait_cb_t	p_enc_init_pram_wait;	Encoder parameter Send / receive timeout Error detection function pointer to generate wait time See "4.9.4 enc_init_pram_wait_callback" for details. Do not set NULL.
endat_wait_cb_t	p_enc_init_cable_wait;	A pointer to a function that produces a wait time for time-out error detection for cable propagation delay measurements. If propagation delay compensation is disabled (delay_comp = false), the setting can be omitted. See "4.9.5 enc_init_cable_wait_callback" for details. Do not set NULL when propagation delay compensation is enabled.

```
} r_endat_info_t
```

(2) r_endat_watchdog_t

Watchdog Timer setting time

```
typedef struct
{
    uint8_t     range;    Set the unit of time for the Watchdog Timer
                          See "Table 4.18 EnDat Watchdog Timer Time Units"
    uint8_t     time;     Set the Watchdog Timer time
                          See "Table 4.22  EnDat Watchdog Timer Table"
} r_endat_watchdog_t
```

Table 4.22 EnDat Watchdog Timer Table

Value of time	Time of the Watchdog Timer	
	range = R_ENDAT_WD_RANGE_US	range = R_ENDAT_WD_RANGE_MS
0	Stop	Stop
1	2 us	0.2 ms
2	4 us	0.4 ms
3	6 us	0.6 ms
:	:	:
10	20 us	2.0 ms
:	:	:
127	254 us	25.4 ms

Note: Except for the stop time, there is a margin of error. Refer to the hardware manual for details.

(3) r_endat_req_t

Request information to be sent to the EnDat2.2 compliant encoder. The mode command, MRS code, address and port address are combined and sent to the encoder. The combinations are shown in "Table 4.23 Mode Command Combination Table".

```
typedef struct
{
```

uint8_t	mode_cmd;	EnDat 2.2 Mode Command See “Table 4.16 EnDat 2.2 Mode Commands”.
bool	dt;	Continuous mode setting (true: enabled, false: disabled) This setting is valid only if mode_cmd = R_ENDAT_POS.
uint8_t	mrs;	MRS code See “Table 4.20 EnDat MRS Codes”. The setting is valid only if the mode command combined with the MRS code in the “Table 4.23 Mode Command Combination Table” is designated as the mode_cmd.
uint8_t	addr;	Address (0x00 to 0xFF) The setting is valid only if the mode command combined with the address in the “Table 4.23 Mode Command Combination Table” is designated as the mode_cmd.
uint16_t	param_instruction;	Parameters to be written to memory area of the encoder The setting is valid only if the mode command combined with the parameters or block address in the “Table 4.23 Mode Command Combination Table” is designated as the mode_cmd.
r_endat_watchdog_t	watchdog;	Setting time of watchdog timer See “4.14.4(2) r_endat_watchdog_t”. When sending a request for the following settings, set it to disabled (time =0). mode_cmd=R_ENDAT_POS and dt=true mode_cmd=R_ENDAT_RESET mode_cmd=R_ENDAT_RX_PARAM mode_cmd=R_ENDAT_PARAM This setting is reflected in the KONFR2 register WTDOG bit.
bool	elc;	ELC mode setting (true: enabled, false: disabled) This setting is valid only if mode_cmd=R_ENDAT_POS and dt=false.
r_endat_isr_result_cb_t	pisr_result;	Pointer to a callback function that conveys the result of the request. See “4.9.6 endat_callback” and “4.9.7 endat_poscon_callback” for details. Do not set NULL.
r_endat_isr_rdst_cb_t	pisr_rdst;	Pointer to a callback function that conveys that the next data communication is ready. See “4.9.8 endat_rdst_callback” for detail. Do not set NULL.

```
} r_endat_req_t
```

Table 4.23 Mode Command Combination Table

mode_cmd	Command value	mrs / addr	param_instruction
R_ENDAT_POS	0x07u	--	--
R_ENDAT_MEM	0x0Eu	MRS Code	--
R_ENDAT_RX_PARAM	0x1Cu	Address	Parameters *1
R_ENDAT_PARAM	0x23u	Address	--
R_ENDAT_RESET	0x2Au	Address	--
R_ENDAT_POS_ADD_DATA	0x38u	--	--
R_ENDAT_POS_MEM	0x09u	MRS Code	Block address *2
R_ENDAT_POS_RX_PARAM	0x1Bu	Address	Parameters *1
R_ENDAT_POS_PARAM	0x24u	Address	--
R_ENDAT_POS_RX_ERR_RESET	0x2Du	Address	--

Note 1. Consider the setting value according to the address.
2. Use only when the MRS code is R_ENDAT_MRS_PARAM_SEC2

(4) r_endat_result_t

Send/receive results

```
typedef struct
{
    r_endat_req_err_t    result;    Results of sending and receiving requests
                                    See “4.14.6(3) r_endat_req_err_t”.
    r_endat_data_t       data;      Received data
                                    See “4.14.4(5) r_endat_data_t”.
    r_endat_status_t     status;    Encoder Status
                                    See “4.14.4(6) r_endat_status_t”.
} r_endat_result_t
```

(5) r_endat_data_t

Received data

```
typedef struct
{
    uint64_t     pos;          Received positional value or test value
                               The RDATA_L bit in the EMPFR1_L register is
                               stored in the lower 32 bits. The RDATA_H bit in the
                               EMPFR1_H register is stored in the upper 32 bits.
    Uint32_t     add_datum1;   Additional data 1
                               Stores the D bit value of the EMPFR3 register.
    Uint32_t     add_datum2;   Additional data 2
                               Stores the D bit value of the EMPFR2 register.
} r_endat_data_t
```

(6) r_endat_status_t

Encoder Status

```
typedef struct
{
    bool        busy;       Encoder internal memory status
                            (true: accessing, false: accessible)
    bool        rm;         Increment encoder origin status
                            (true: origin detection, false: origin undetected)
    bool        wrn;        Warning status inside the encoder
                            (true: with warning, false: no warning)
} r_endat_status_t
```

(7) r_endat_protocol_err_t

EnDat I/F and encoder error information

```
typedef struct
{
    bool        err1;       Error1 bit status (true: occurred, false: not occurred)
    bool        crc1;       CRC check error for positional value (true: occurred, false: not
                            occurred)
    bool        ftype1;     EnDat TYPE1 error (true: occurred, false: not occurred)
    bool        ftype2;     EnDat TYPE2 error (true: occurred, false: not occurred)
    bool        msadr;      Address error in EnDat TYPE2 error (true: occurred, false: not
                            occurred)
    bool        err2;       Error2 bit status (true: occurred, false: not occurred)
    bool        crc3;       CRC check error for Additional data 1 (true: occurred, false: not
                            occurred)
    bool        crc2;       CRC check error for Additional data 2 (true: occurred, false: not
                            occurred)
    bool        wdg;        Watchdog error (true: occurred, false: not occurred)
    bool        ftype3;     EnDat TYPE3 error (true: occurred, false: not occurred)
    bool        modeerr;    Mode command transmission error (This bit is not used. It is always
                            false.) *
} r_endat_protocol_err_t
```

Note This is reserved for driver interface compatibility with RZ/T2M group EnDat encoder driver.
This is not used in the driver for RZ/T2H.

4.14.5 EnDat Unions

No unions are used.

4.14.6 EnDat Enumerated Types

(1) r_endat_err_t

Error codes of the encoder interface

```
typedef enum
{
    ENDAT_SUCCESS            =0,   Normal termination
    ENDAT_ERR_INVALID_ARG    ,     Argument error
    ENDAT_ERR_BUSY           ,     API is not executable
    ENDAT_ERR_ACCESS         ,     Error in the execution order of APIs
    ENDAT_ERR_DRV                  Internal error in driver
} r_endat_err_t
```

(2) r_endat_cmd_t

Command settings when the R_ENDAT_Control function is used

```
typedef enum
{
    ENDAT_CMD_REQ          ,   Send command to the encoder
    ENDAT_CMD_POS_STOP         Stop continuous reception of positional values from the
                               encoder
} r_endat_cmd_t
```

(3) r_endat_req_err_t

Result of sending and receiving requests

```
typedef enum
{
    ENDAT_REQ_SUCCESS    =0,   Normal completion of data transmission and reception
    ENDAT_REQ_ERR              Data transmission/reception control error occurs
} r_endat_rx_err_t
```

4.15 Description of the Sample Program

4.15.1 Operation Outline

This sample program supports bus connection of up to eight encoders compliant with the A-format specification (Nikon MAR-M50A) and the EnDat 2.2 compliant encoder "EQN1035". This sample program performs the following processes.

A-format

1) Request information input from the console is sent to the encoder (normal sending/receiving by writing to the TXTRG register).

2) Display data received from the encoder on the console

3) Send and receive commands using the ELC event input trigger function of AFMT. (GPT events are linked as input events. For an example of input event settings, see "Figure 4.6 Flowchart of a_as_elctimer function.")

EnDat

1) Send requests input from the debugger's terminal I/O to the EnDat encoder (EQN1035)

2) Display data received from the EnDat encoder (EQN1035) on the debugger's terminal I/O

3) Send and receive commands using the ELC event input trigger function of the EnDat I/F. (GPT events are linked as input events.)

(1) Dual Encoder System Block Diagram

Figure 4.1 shows a block diagram of the system.

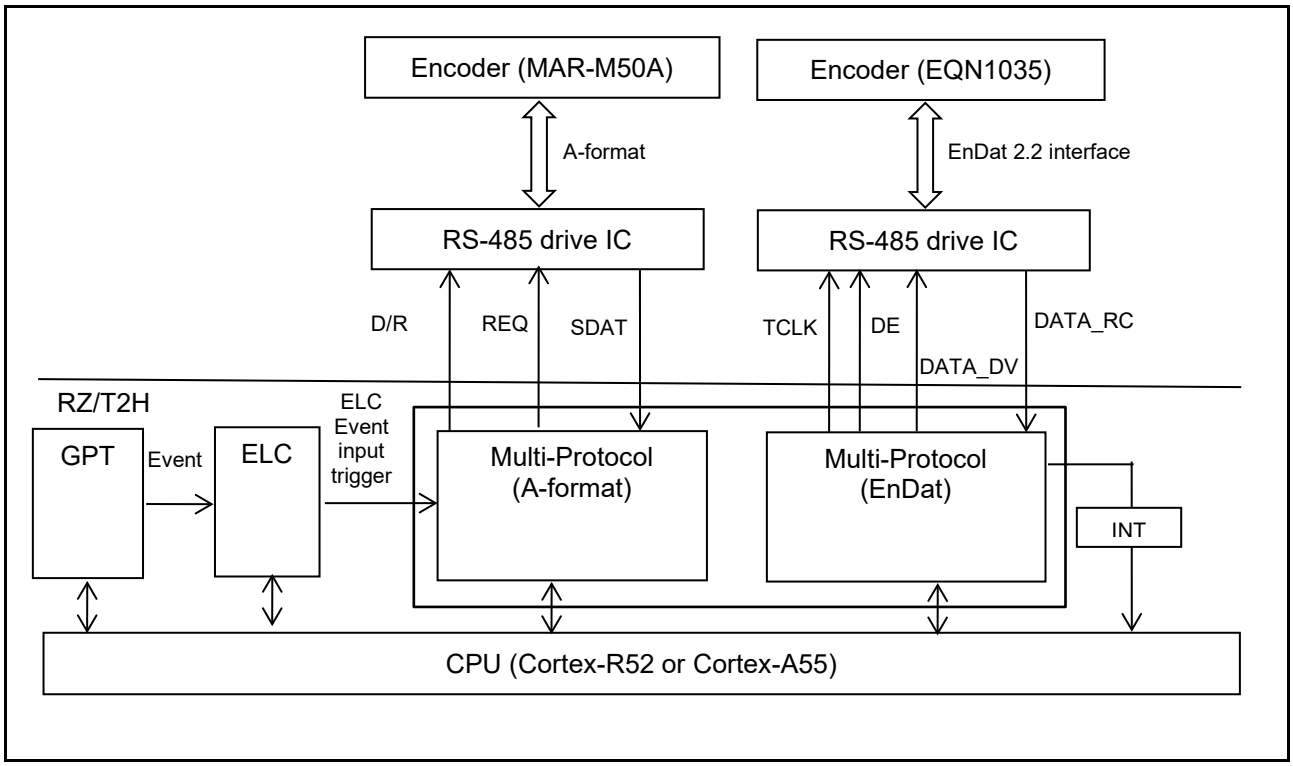


Figure 4.1 System Block Diagram

(2) Software Structure

Figure 4.2 shows the structure of the software.

The A-format driver has the opening process part consisting of the R_A_AS_Open function, the closing process part consisting of the R_A_AS_Close function, the sending requests part consisting of the R_A_AS_Control function, and the data reception part (interrupt handler) consisting of callback functions.

The EnDat driver has the opening process part consisting of the R_ENDAT_Open function, the closing process part consisting of the R_ENDAT_Close function, the sending requests part consisting of the R_ENDAT_Control function, and the data reception part (interrupt handler) consisting of callback functions.

The sample program has the A-format driver control part that controls the A-format driver and sends requests, and the A-format result indication part (callback) that displays the results of data reception, the EnDat driver control part that controls the EnDat driver and sends requests, and the EnDat result indication part (callback) that displays the results of data reception.

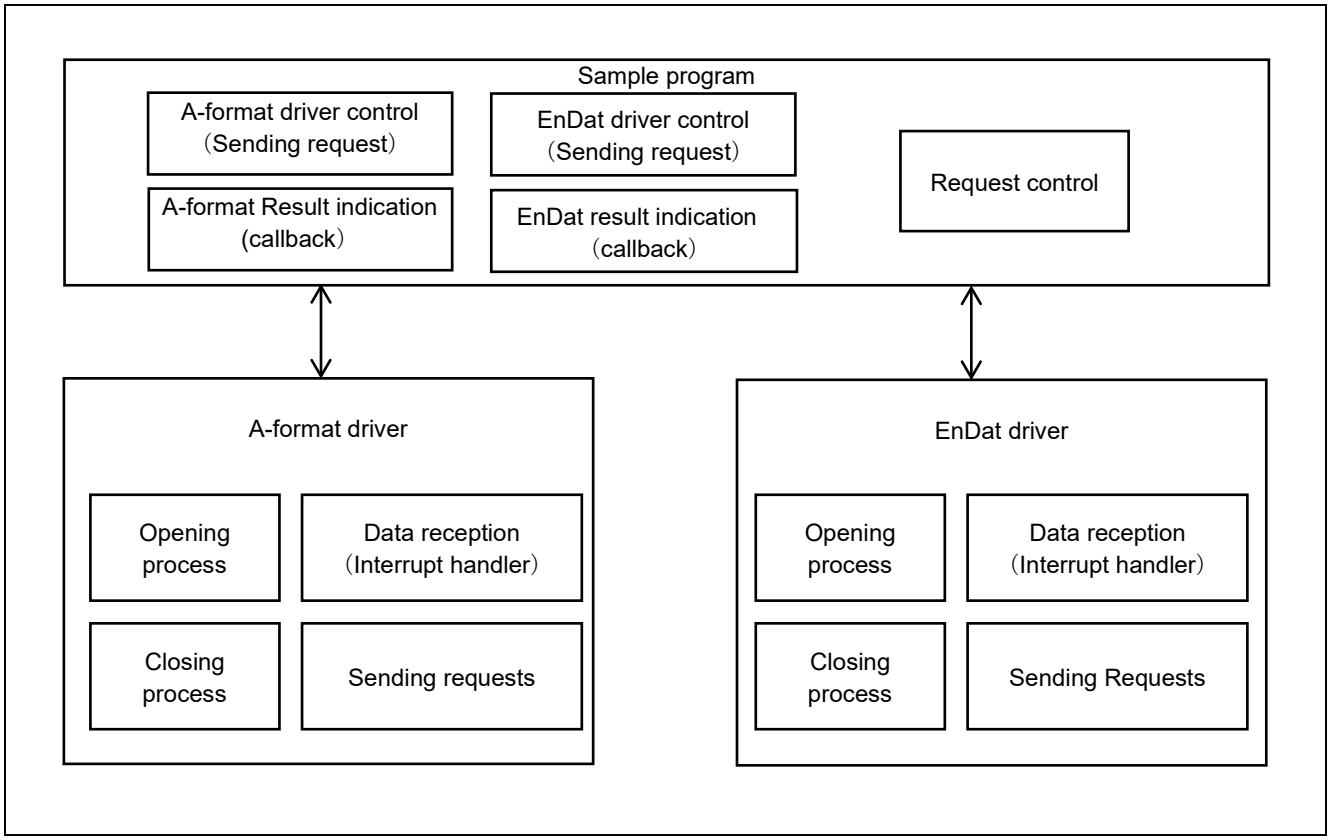


Figure 4.2 Dual Encoder Software Structure

4.15.2 Sample Program Functions

Table 4.24 lists the major functions of the sample program.

Table 4.24 Major Functions of the Sample Program

Function Type	Function Name	Page Number	
		Specification	Flowchart
Common Function	hal_entry	55	-
	enc_main	55	66
	dual_cmd_control	55	67
	get_cmd	55	-
	cmd_exit	56	-
	timer_start	56	-
	timer_stop	56	-
A-format Function	a_as_enc_init	56	-
	a_as_req	57	68
	a_as_elctimer	57	69
	a_as_elcstop	57	70
	a_as_txerr_callback	57	70
	a_as_rxset_callback	58	71
	a_as_rxend_callback	58	71
	a_as_elctimer_callback	58	72
EnDat Function	endat_power_on_wait	58	-
	enc_init_tclk_wait_callback	59	-
	enc_init_reset_wait_callback	59	-
	enc_init_mem_wait_callback	59	-
	enc_init_pram_wait_callback	59	-
	enc_init_cable_wait_callback	60	-
	endat_pos	60	73
	endat_poscon	60	74
	endat_elctimer	60	75
	endat_stop	61	76
	endat_temp	61	77
	endat_callback	61	78
	endat_poscon_callback	61	79
	endat_rdst_callback	62	79
	endat_result_display	62	-

4.15.3 Specifications of Sample Program Functions

(1) Common Functions

(a) hal_entry

hal_entry	
Synopsis	Entry function of the Dual Encoder sample program
Header	-
Declaration	void hal_entry(void);
Description	This is the entry function of the Dual Encoder sample program. From here, the function enc_main () is called.
Arguments	None
Return value	None

(b) enc_main

enc_main	
Synopsis	Main function of the Dual Encoder sample program
Header	-
Declaration	int32_t enc_main(void);
Description	This is the main function of the Dual Encoder sample program. For details, see section “4.15.8(1) Flowchart of enc_main”.
Arguments	None
Return value	0 : Normal termination Others : Abnormal termination (error code of the encoder interface)

(c) dual_cmd_control

dual_cmd_control	
Synopsis	Dual Encoder driver control function
Header	-
Declaration	static void dual_cmd_control(void);
Description	This function performs console command input processing.
Arguments	None
Return value	None

(d) get_cmd

get_cmd	
Synopsis	Function to get command from console
Header	-
Declaration	static uint32_t get_cmd(char_t *p_arg[], const uint32_t arg_max);
Description	Get the command from the console
Arguments	p_arg : Pointer to an array console that stores commands acquired from the console arg_max : Maximum number of strings to acquire
Return value	Number of strings acquired from console

(e) cmd_exit

cmd_exit	
Synopsis	End display function of the Dual Encoder sample program
Header	-
Declaration	static void cmd_exit(uint32_t arg_num, char_t *p_arg[]);
Description	Function executed when the console command exit is entered, indicating on the console that the sample program has terminated.
Arguments	arg_num : Number of strings entered from console (not used) *p_arg[] : First address of string entered from console (not used)
Return value	None

(f) timer_start

timer_start	
Synopsis	GPT cycle setting/startup function
Header	-
Declaration	static void timer_start(uint32_t ch, uint32_t us);
Description	Set the timer cycle in GPT corresponding to the encoder of designated channel to start the timer. If an unused channel is designated, do nothing and return.
Arguments	ch : Encoder channel number us : Timer cycle [us]
Return value	None

(g) timer_stop

timer_stop	
Synopsis	GPT timer stop
Header	-
Declaration	static void timer_stop(uint32_t ch);
Description	Stop the GPT timer corresponding to the encoder of designated channel. If an unused channel is designated, do nothing and return.
Arguments	ch : Encoder channel number
Return value	None

(2) A-format Functions

(a) a_as_enc_init

a_as_enc_init	
Synopsis	Initializing the encoder
Header	-
Declaration	static int32_t a_as_enc_init(int32_t id);
Description	This function is for initializing the encoder. The command data frame CDF8 is transmitted eight times consecutively to clear the status flag.
Argument	id : Encoder ID R_A_AS0_ID: Specify channel 0 encoder ID R_A_AS1_ID: Specify channel 1 encoder ID : R_A_AS15_ID: Specify channel 15 encoder ID
Return value	0: Normal termination Others: Abnormal termination (error code of the encoder interface)

(b) a_as_req

a_as_req	
Synopsis	Console command “req” function
Header	-
Declaration	static void a_as_req(uint32_t arg_num, char_t *p_arg[]);
Description	This function is exeuted when the console command "req" is input. See section “4.15.8(3) Flowchart of a_as_req“and section “4.15.10 Console Commands” for details.
Argument	arg_num : The number of character strings input through the console. *p_arg[] : The starting address where the character strings are stored.
Return value	None

(c) a_as_elctimer

a_as_elctimer	
Synopsis	Console command “elctimer” function
Header	-
Declaration	static void a_as_elctimer (uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command “elctimer” is input. See section “4.15.8(4) Flowchart of a_as_elctimer” and section “4.15.10 Console Commands” for details.
Arguments	arg_num : The number of character strings input through the console. *p_arg[] : The starting address where the character strings are stored.
Return value	None

(d) a_as_elcstop

a_as_elcstop	
Synopsis	Console command “elcstop” function
Header	-
Declaration	static void a_as_elcstop (uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command "elcstop" is input. See section “4.15.8(5) Flowchart of a_as_elcstop” and section “4.15.10 Console Commands” for details.
Argument	arg_num : The number of character strings input through the console. *p_arg[] : The starting address where the character strings are stored.
Return calue	None

(e) a_as_txerr_callback

a_as_txerr_callback	
Synopsis	Callback for the console command “req” when a transmission error is generated
Header	-
Declaration	static void a_as_txerr_callback(r_a_as_result_t *p_result);
Description	This is a callback function that is executed when the console command "req" is input. It holds a pointer to the result of transmitted A-format request in normal reception in the variable a_as_result and indicates that a timeout error is generated. See section “4.15.8(6) Flowchart a_as_txerr_callback” for details.
Argument	*p_result : The address in the RAM where the result of transmission of the request and reception starts.
Return value	None

(f) a_as_rxset_callback

a_as_rxset_callback	
Synopsis	Callback for the console command “req” when the setting of received data is complete.
Header	-
Declaration	static void a_as_rxset_callback(r_a_as_result_t *p_result);
Description	This is a callback function that is executed when the console command "req" is input. It holds a pointer to the result of the transmitted an A-format request and received data in response in normal reception in the variable a_as_result and indicates completion of the setting of received data. See section “4.15.8(7) Flowchart of a_as_rxset_callback” for details.
Argument	*p_result : The address in the RAM where the result of transmission of the request and reception starts.
Return value	

(g) a_as_rxend_callback

a_as_rxend_callback	
Synopsis	Callback for the console command “req” when reception of the data has been completed.
Header	-
Declaration	static void a_as_rxend_callback(r_a_as_result_t *p_result);
Description	This is a callback function that is executed when the console command "req" is input. It indicates completion of the reception of data in response to the A-format request in normal reception. See section “4.15.8(8) Flowchart of a_as_rxend_callback” for details.
Argument	*p_result : The address in the RAM where the result of transmission of the request and reception starts.
Return value	None

(h) a_as_elctimer_callback

a_as_elctimer_callback	
Synopsis	Callback for the console command "elctimer".
Header	-
Declaration	static void a_as_elctimer_callback(r_a_as_result_t * p_result);
Description	This is a callback function that is executed when the console command "elctimer" is input. It holds the result of the transmitted request and received data in the variables a_as_ti_result and a_as_ti_data. See section “4.15.8(9) Flowchart of a_as_elctimer_callback” for details.
Argument	*p_result : The address in the RAM where the result of transmission of the request and reception starts.
Return value	None

(3) EnDat functions

(a) endat_power_on_wait

endat_power_on_wait	
Synopsis	Waiting time generation function after encoder power-on
Header	-
Declaration	static void endat_power_on_wait(void);
Description	This callback function generates the required 1.3s standby time after the encoder is turned on.
Arguments	None
Return value	None

(b) enc_init_tclk_wait_callback

enc_init_tclk_wait_callback	
Synopsis	Waiting time generation function after activating TCLK pin output
Header	-
Declaration	static void enc_init_tclk_wait_callback(void);
Description	This callback function generates a waiting time of 100 us after activating TCLK pin output. See “4.9.1 enc_init_tclk_wait_callback”.
Arguments	None
Return value	None

(c) enc_init_reset_wait_callback

enc_init_reset_wait_callback	
Synopsis	Waiting time generation function after encoder reset
Header	-
Declaration	static void enc_init_reset_wait_callback(void);
Description	This callback function generates a waiting time of 60 ms after the encoder reset process in the initialization process of the connected encoder. See “4.9.2 enc_init_reset_wait_callback”.
Arguments	None
Return value	None

(d) enc_init_mem_wait_callback

enc_init_mem_wait_callback	
Synopsis	Waiting time generation function for encoder memory area selection process
Header	-
Declaration	static void enc_init_mem_wait_callback(void);
Description	This callback function generates a waiting time of 743 us for detecting a timeout error in the process of selecting a memory area in the initialization process of the connected encoder. See “4.9.3 enc_init_mem_wait_callback”.
Arguments	None
Return value	None

(e) enc_init_pram_wait_callback

enc_init_pram_wait_callback	
Synopsis	Waiting time generation function for encoder parameter sending/receiving process
Header	-
Declaration	static void enc_init_pram_wait_callback(void);
Description	This callback function generates a waiting time of 13 ms for detecting a timeout error in the initialization process of the connected encoder, during which the encoder sends and receives parameters. See “4.9.4 enc_init_pram_wait_callback”.
Arguments	None
Return value	None

(f) enc_init_cable_wait_callback

enc_init_cable_wait_callback	
Synopsis	Wait time generation function for encoder cable propagation delay measurement process
Header	-
Declaration	static void enc_init_cable_wait_callback(void);
Description	Callback function to generate a waiting time of 588 us for detecting a timeout error in the process of measuring the cable propagation delay in the initialization process of the connected encoder. See “4.9.5 enc_init_cable_wait_callback”
Arguments	None
Return value	None

(g) endat_pos

endat_pos	
Synopsis	Function to get a positional value from the encoder
Header	-
Declaration	static void endat_pos(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command pos is entered. It acquires a positional value from the encoder.
Arguments	arg_num : Number of strings entered from the console (Not used) *p_arg[] : First address of string entered from console (Not used)
Return value	None

(h) endat_poscon

endat_poscon	
Synopsis	Function to get positional values continuously from the encoder
Header	-
Declaration	static void endat_poscon(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command poscon is entered to continuously acquire position values from the encoder using Continuous mode.
Argumetns	arg_num : Number of strings entered from the console (Not used) *p_arg[] : First address of string entered from console (Not used)
Return value	None

(i) endat_elctimer

endat_elctimer	
Synopsis	Function to get positional values continuously from the encoder synchronously with the ELC events
Header	-
Declaration	static void endat_elctimer(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command elctimer is entered. It acquires positional values continuously from the encoder synchronously with the ELC events.
Arguments	arg_num : Number of strings entered from the console *p_arg[] : First address of string entered from console
Return value	None

(j) endat_stop

endat_stop	
Synopsis	Function to stop continuous acquisition positional values from the encoder
Header	-
Declaration	static void endat_stop(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command stop is entered. It stops the continuous transmission of positional values from the encoder when it is operating in Continuous mode. While operating in ELC mode, this function cancels ELC mode operation and stops issuing continuous positional value acquisition commands. After the continuous positional value transmission from the encoder is stopped, the last 10 positional values are displayed.
Arguments	arg_num : Number of strings entered from the console (Not used) *p_arg[] : First address of string entered from console (Not used)
Return value	None

(k) endat_temp

endat_temp	
Synopsis	Function to get temperature information from the encoder
Header	-
Declaration	static void endat_temp(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command temp is entered. It acquires temperature information from the encoder
Arguments	arg_num : Number of strings entered from the console (Not used) *p_arg[] : First address of string entered from console (Not used)
Return value	None

(l) endat_callback

endat_callback	
Synopsis	Callback function that conveys the result of the request transmission to the encoder
Header	-
Declaration	static void endat_callback(r_endat_result_t *p_result, r_endat_protocol_err_t *p_err);
Description	This function stores the result in memory.
Arguments	p_result : Result of the request transmission p_err : EnDat I/F and encoder error information
Return value	None

(m) endat_poscon_callback

endat_poscon_callback	
Synopsis	Callback function that conveys the result of the request transmission to the encoder
Header	-
Declaration	static void endat_poscon_callback (r_endat_result_t *p_result, r_endat_protocol_err_t *p_err);
Description	This function stores the continuously acquired results in memory
Arguments	p_result : Result of the request transmission p_err : EnDat I/F and encoder error information
Return value	None

(n) endat_rdst_callback

endat_rdst_callback	
Synopsis	Callback function to convey that the next data transmission is ready to start
Header	-
Declaration	static void endat_rdst_callback(void);
Description	This function conveys that the data reception completes and the next data communication is ready. It is called each time data reception is completed while operating in continuous mode or in ELC mode. This function sets the acquisition completion flag.
Arguments	None
Return value	None

(o) endat_result_display

endat_result_display		
Synopsis	Function to display the result of data reception	
Header	-	
Declaration	static void result_display(r_endat_result_t *p_result, r_endat_protocol_err_t *p_err);	
Description	This function indicates the result of data reception in response to a request sent to the encoder.	
Arguments	p_result	: Result of the request transmission
	p_err	: EnDat I/F and encoder error information
Return value	None	

4.15.4 Variables Used in the A-format Sample Program

The major static variables used in the sample program are listed below.

Table 4.25 Static Variables Used in the A-format Sample Program

Type	Variable Name	Description
bool	a_as_flg	Transmission and reception completion flag. (true: transmission and reception completed; false: transmission and reception in progress)
r_a_as_result_t	a_as_result[A_AS_ENC_NUM]	The results of acquisition are stored.
bool	a_as_elc_flg	ELC event input trigger flag (true: ELC event input trigger operation is in progress; false: ELC event input trigger operation is stopped)
bool	elc_trans_flg	The flag that indicates the state of transmission and reception of data from the ELC event input trigger. (true: Transmission and reception in progress, false: Transmission and reception completed)
r_a_as_req_t	a_as_req_elc	Holds the request information while ELC event input trigger operation is in progress.

4.15.5 Constants Used in the A-format Sample Program

The major constants used in the sample program are listed below.

Table 4.26 Major Constants Used in the A-format Sample Program

Constant	Setting	Description
A_AS_ENC_NUM	8	The number of connected encoders.

4.15.6 Variables of EnDat Sample Program

Table 4.27 lists the major static type variables. Const type variables are not used.

Table 4.27 Static Variables Used in the EnDat Sample Program

Type	Variable Name	Description	Function to be used
bool	endat_flag	Transmission completion flag (true: transmission completed, false: transmission is in progress)	endat_pos endat_poscon endat_elctimer endat_stop endat_temp endat_callback endat_rdst_callback
bool	endat_elc_flg	ELC mode operating flag (true: operating in ELC mode, false: not operating in ELC mode)	endat_pos endat_poscon endat_elctimer endat_stop
r_endat_result_t	*p_endat_result	Address containing data acquisition results	endat_pos endat_temp endat_callback
r_endat_protocol_err_t	*p_endat_err	Address containing error information	endat_pos endat_temp endat_callback
r_endat_req_err_t	poscon_err[ENDAT_POS_NUM]	Errors in continuously acquired positional values An array with 10 elements is used as a ring buffer to store the results of the latest 10 acquisitions.	endat_poscon endat_elctimer endat_stop endat_poscon_callback
uint64_t	poscon[ENDAT_POS_NUM]	Continuously acquired positional values An array with 10 elements is used as a ring buffer to store the results of the latest 10 acquisitions.	endat_poscon endat_elctimer endat_stop endat_poscon_callback
uint8_t	poscon_valid	Number of valid elements in poscon, poscon_err array Indicates the number of valid elements of positional values stored in the array.	endat_poscon endat_elctimer endat_stop endat_poscon_callback
uint8_t	poscon_num	Update position indices for poscon and poscon_err arrays The following are the indexes to be updated by the acquired position values.	endat_poscon endat_elctimer endat_stop endat_poscon_callback
bool	poscon_empty	Space information in poscon and poscon_err arrays (true: has space, false: has no space)	endat_poscon endat_elctimer endat_poscon_callback
int32_t	endat_cur_id	Used EnDat I/F driver ID	enc_main endat_cmd_control endat_pos endat_pocson endat_elctimer endat_stop endat_temp

4.15.7 Constants of EnDat Sample Program

Table 4.28 lists the major constants used in the sample program.

Table 4.28 Major Constants Used in the EnDat Sample Program

Constants	Value	Content
ENDAT_ENC_TSAT_WAIT	1300u	Standby time after power-on (1.3 s)
ENDAT_ENC_100US_WAIT	100u	Waiting time after activating TCLK pin output (100 us)
ENDAT_ENC_INIT_RESET_WAIT	60u	Time to wait after encoder reset process (60 ms)
ENDAT_ENC_INIT_MEM_WAIT	743u	Waiting time for detection of timeout errors in the process of selecting memory area in encoder initialization (743 us)
ENDAT_ENC_INIT_PRAM_WAIT	13u	Waiting time for detection of timeout errors in the process of sending and receiving parameters in encoder initialization. (13 ms)
ENDAT_ENC_INIT_CABLE_WAIT	588u	Waiting time for detection of timeout errors in the process of measuring cable propagation delay in encoder initialization. (588 us)
ENDAT_WDG_MAX	127u	Maximum watchdog timer setting value
ENDAT_POS_NUM	10u	Number of elements of the array for storing continuously received position values
ENDAT_TEMP_SCA_FAC	0.1	Number of elements of the array for storing continuously received position values
ENDAT_TEMP_ABS_ZERO	273.2	Constant for temperature data unit conversion

4.15.8 Flowchart of Main Processing

(1) Flowchart of enc_main

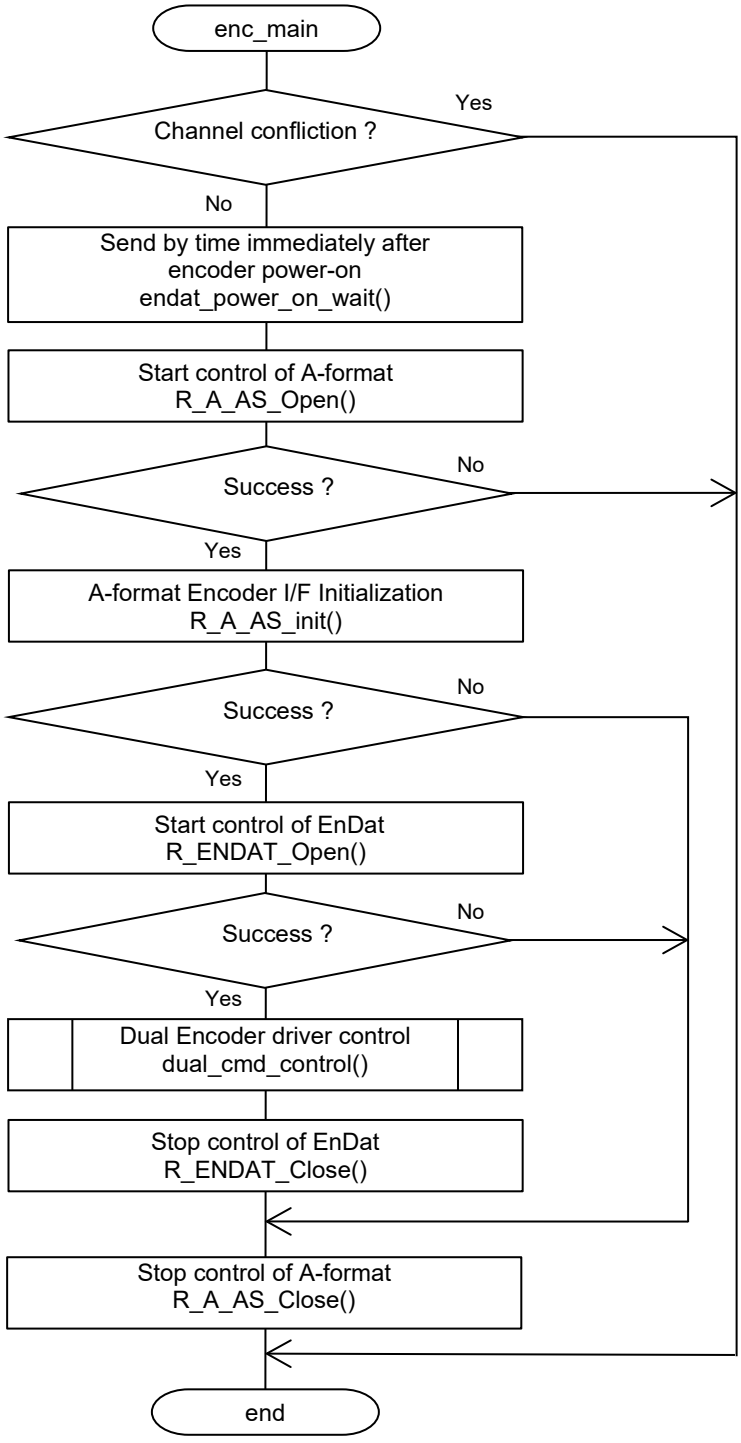


Figure 4.3 Flowchart of enc_main Function

(2) Flowchart of dual_cmd_control

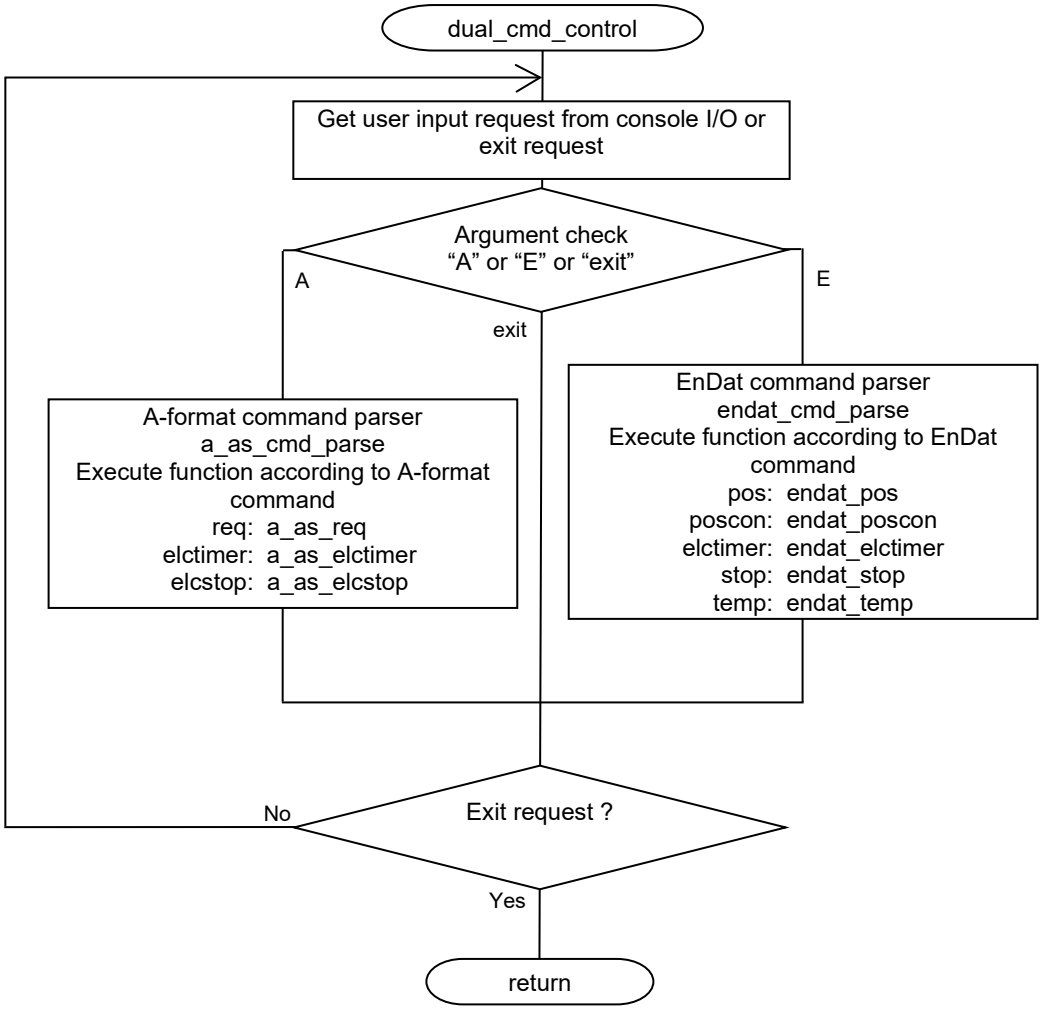


Figure 4.4 Flowchart of dual_cmd_control Function

(3) Flowchart of a_as_req

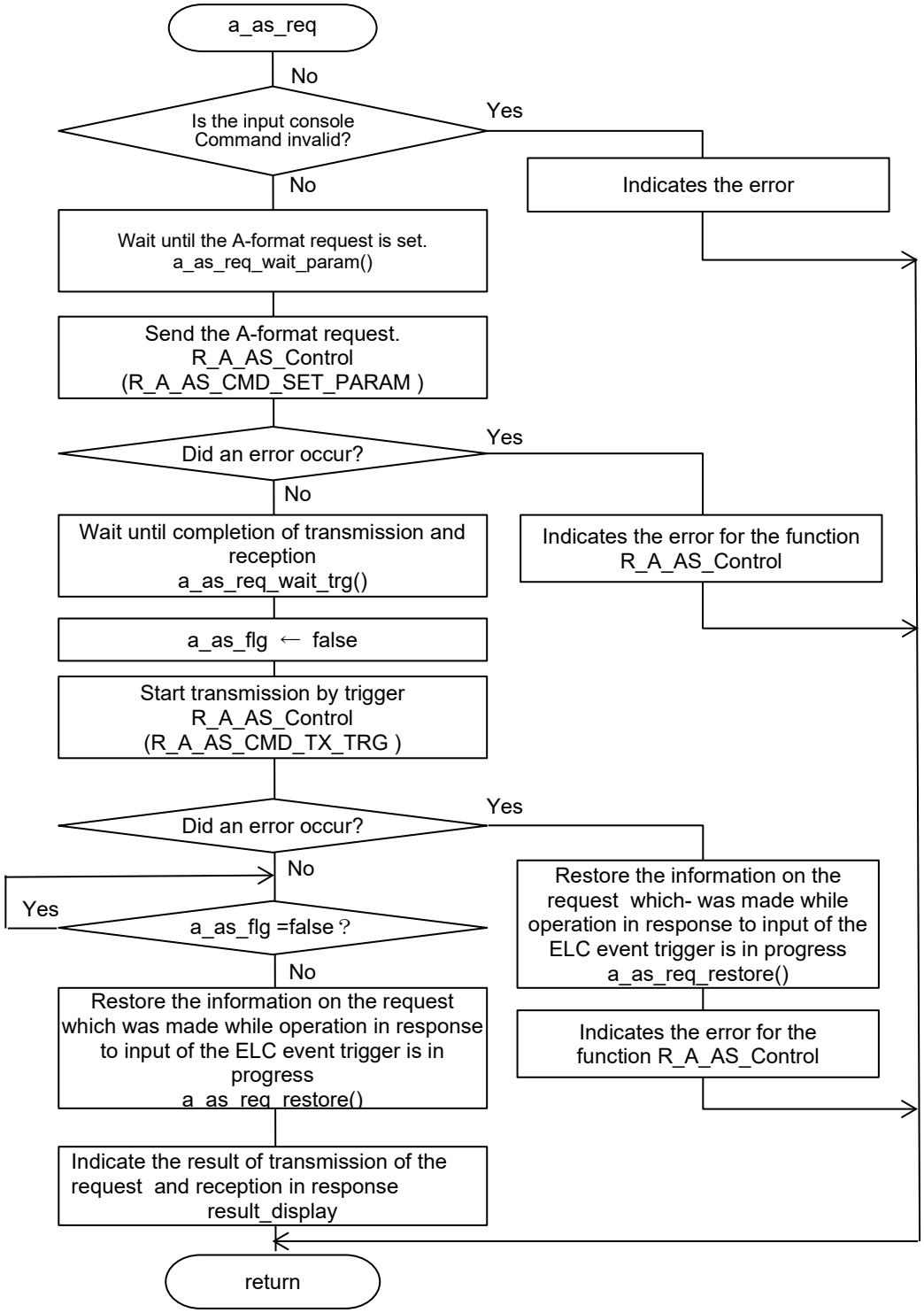


Figure 4.5 Flowchart of a_as_req Function

(4) Flowchart of a_as_elctimer

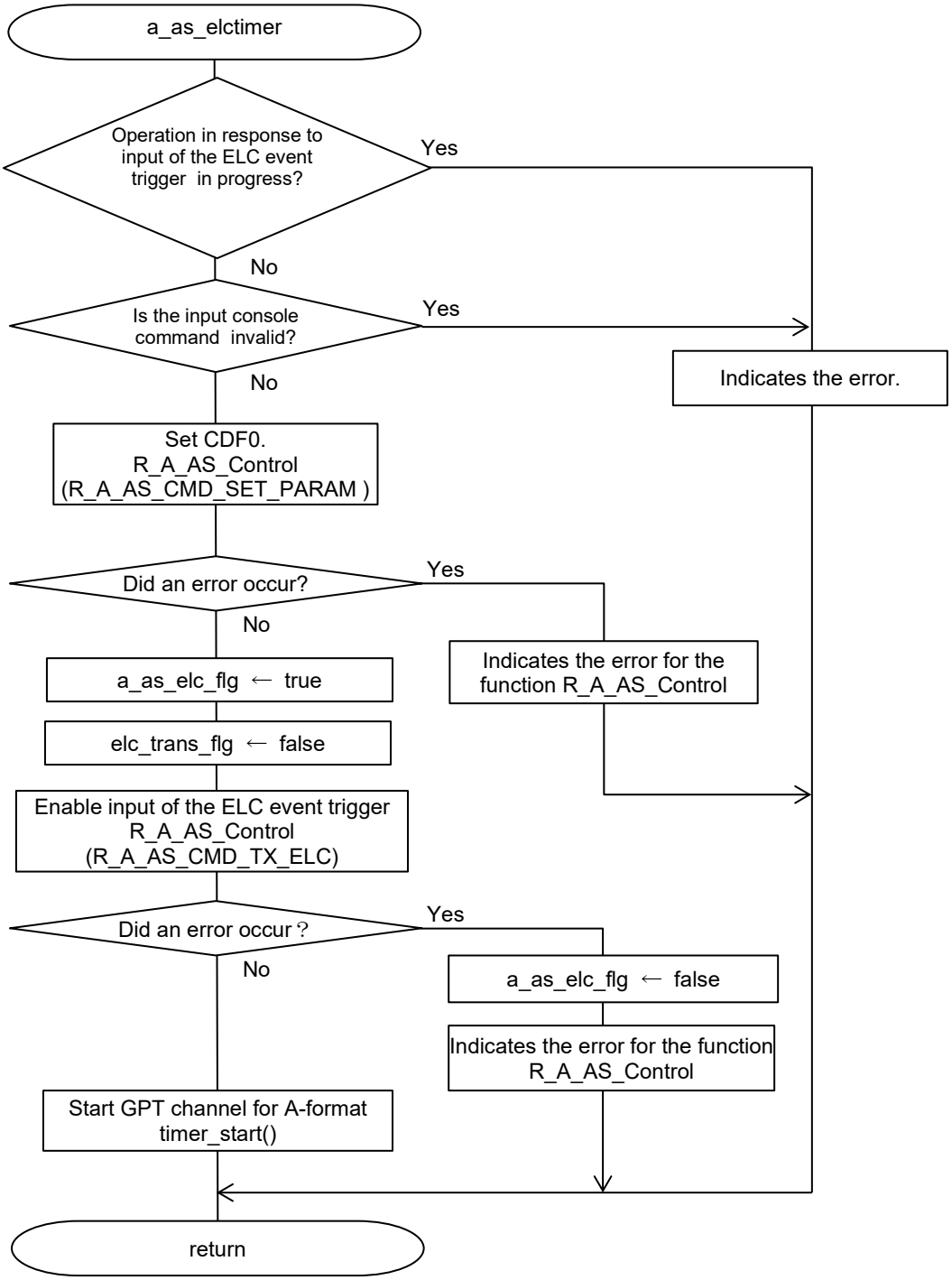


Figure 4.6 Flowchart of a_as_elctimer Function

(5) Flowchart of a_as_elcstop

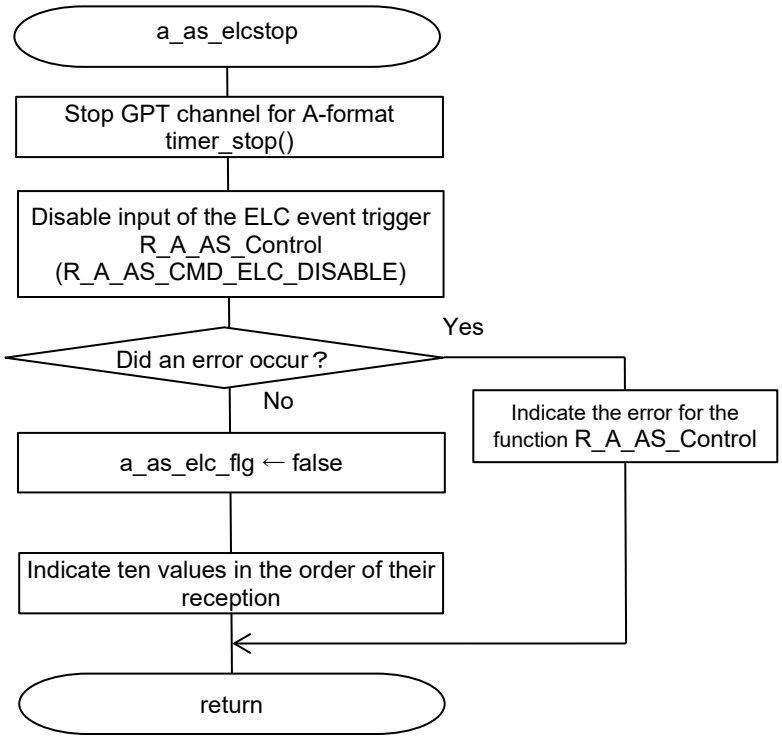


Figure 4.7 Flowchart of a_as_elcstop Function

(6) Flowchart of a_as_txerr_callback

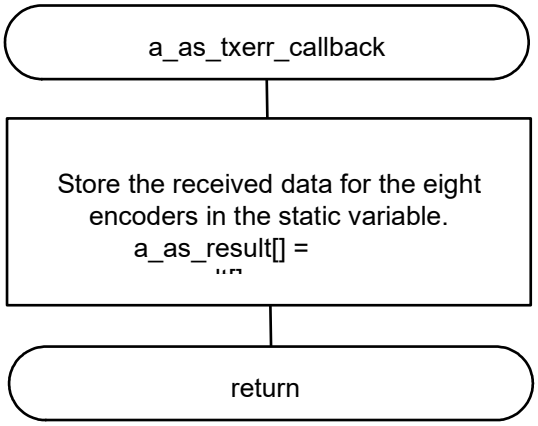


Figure 4.8 Flowchart of a_as_txerr_callback Function

(7) Flowchart of a_as_rxset_callback

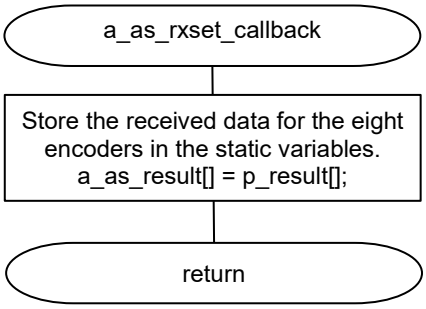


Figure 4.9 Flowchart of a_as_rxset_callback Function

(8) Flowchart of a_as_rxend_callback

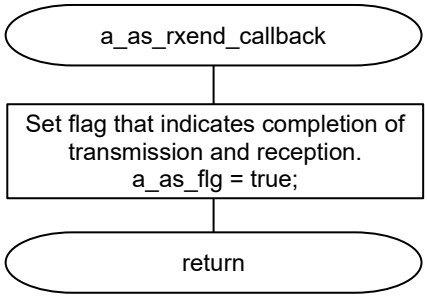


Figure 4.10 Flowchart of a_as_rxend_callback Function

(9) Flowchart of a_as_elctimer_callback

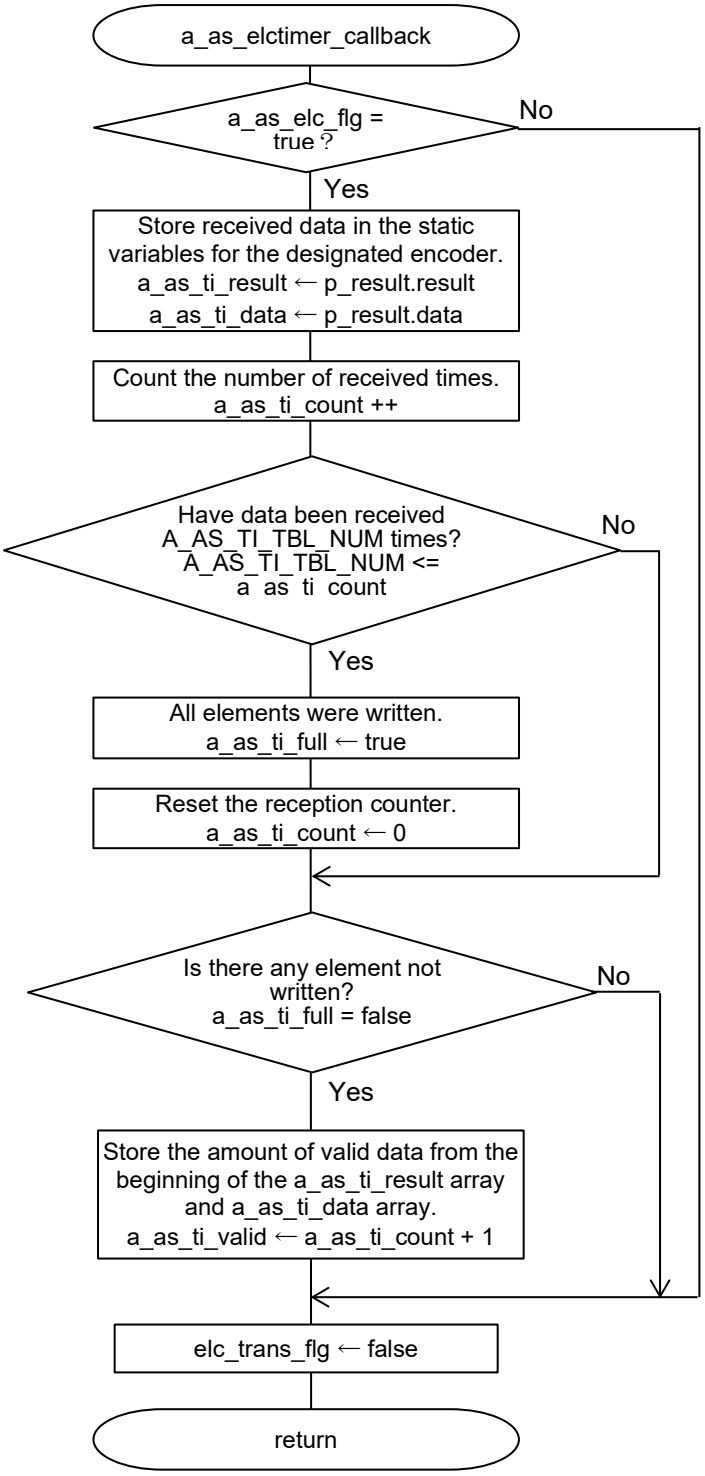


Figure 4.11 Flowchart of a_as_elctimer_callback Function

(10) Flowchart of endat_pos

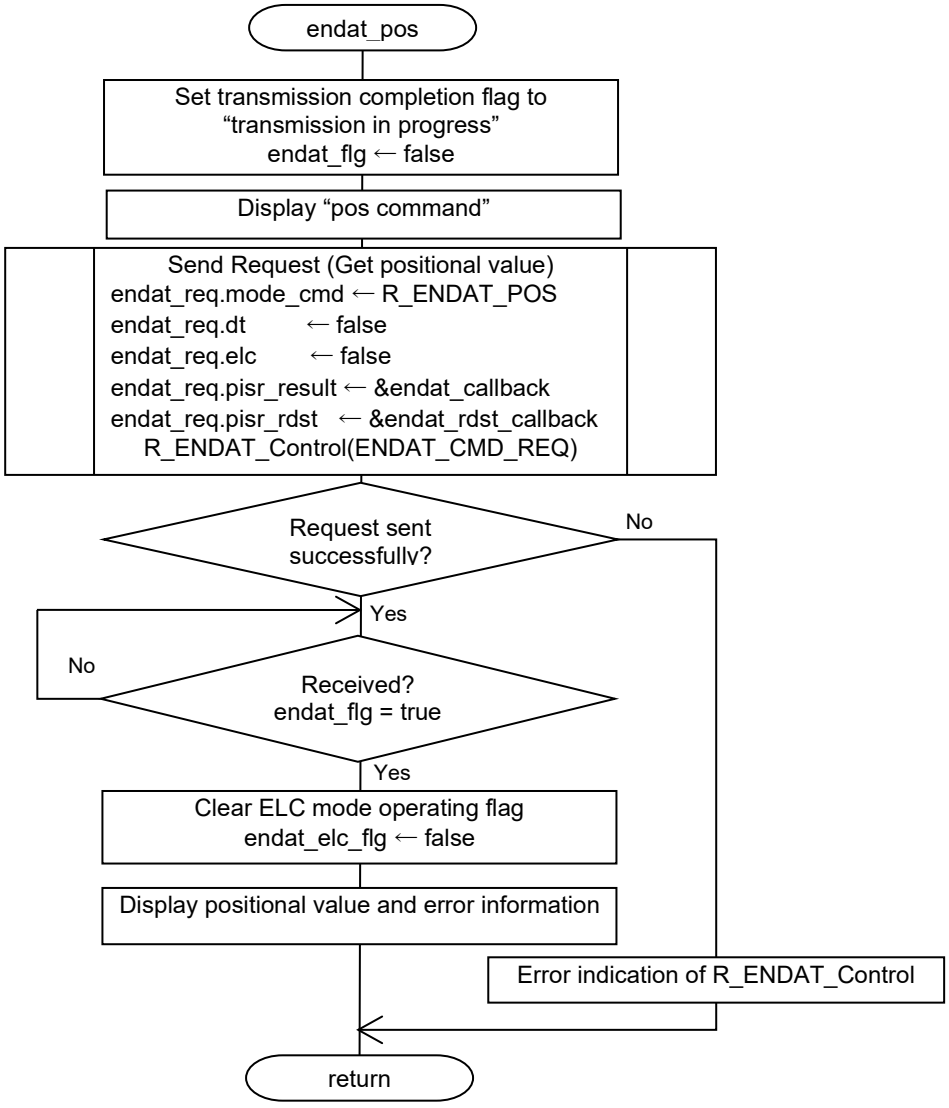


Figure 4.12 Flowchart endat_pos Function

(11) Flowchart of endat_poscon

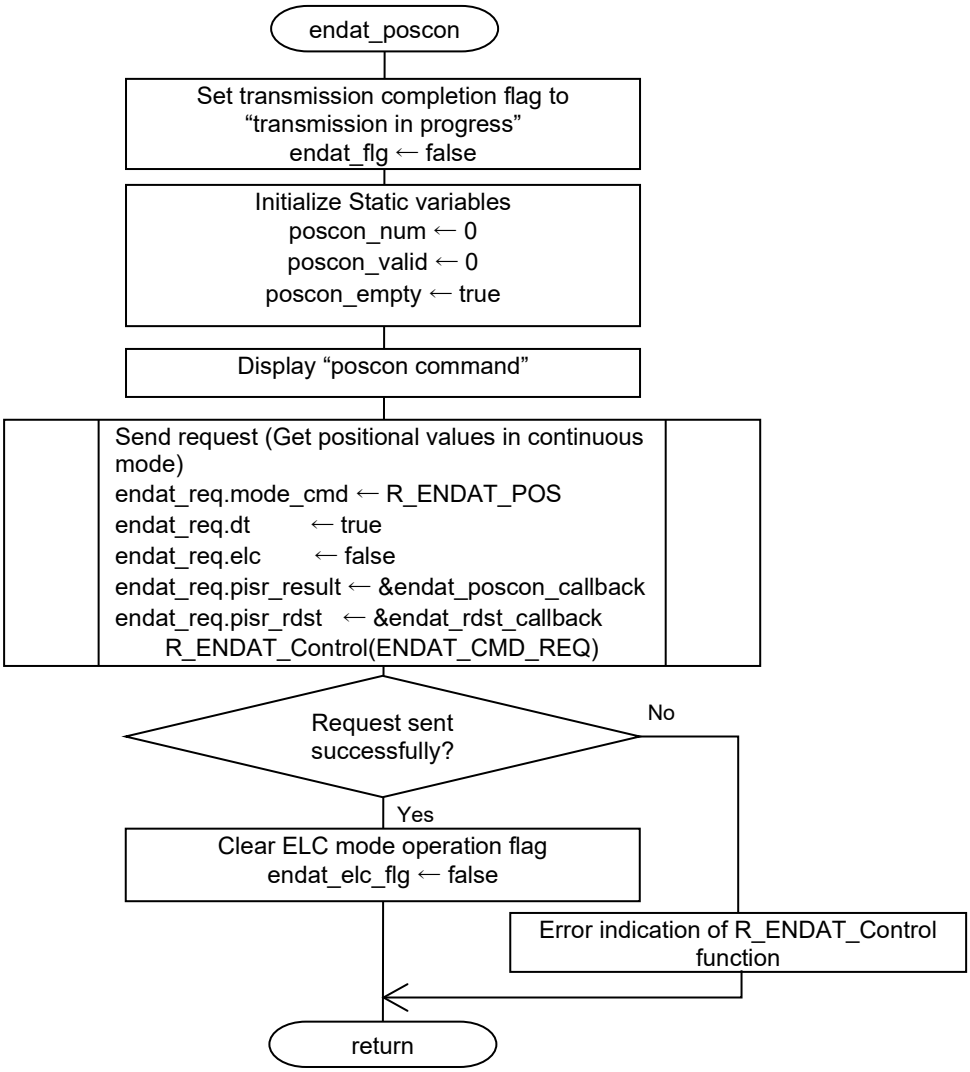


Figure 4.13 Flowchart of endat_poscon Function

(12) Flowchart of endat_elctimer

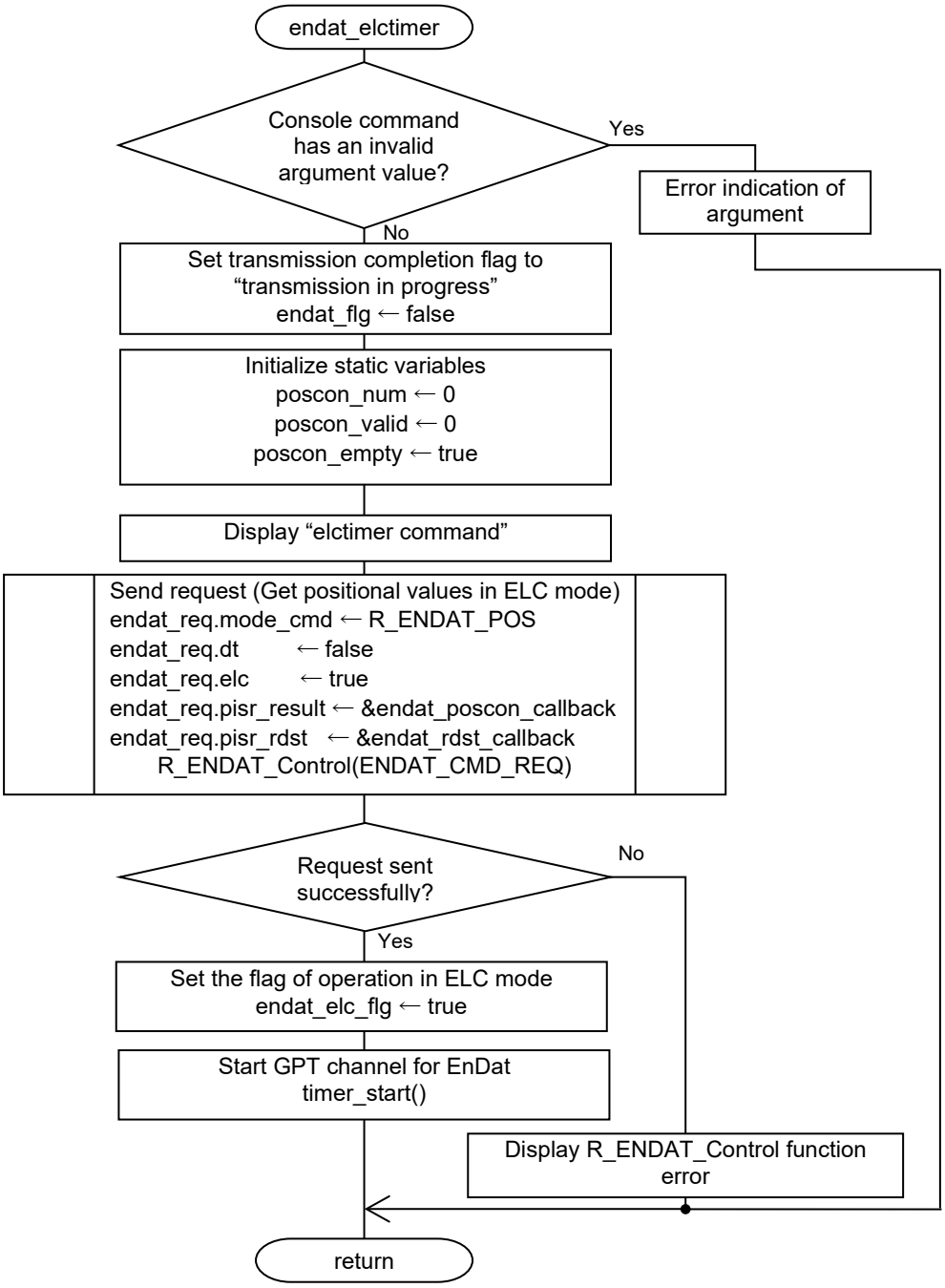


Figure 4.14 Flowchart of endat_elctimer Function

(13) Flowchart of endat_stop

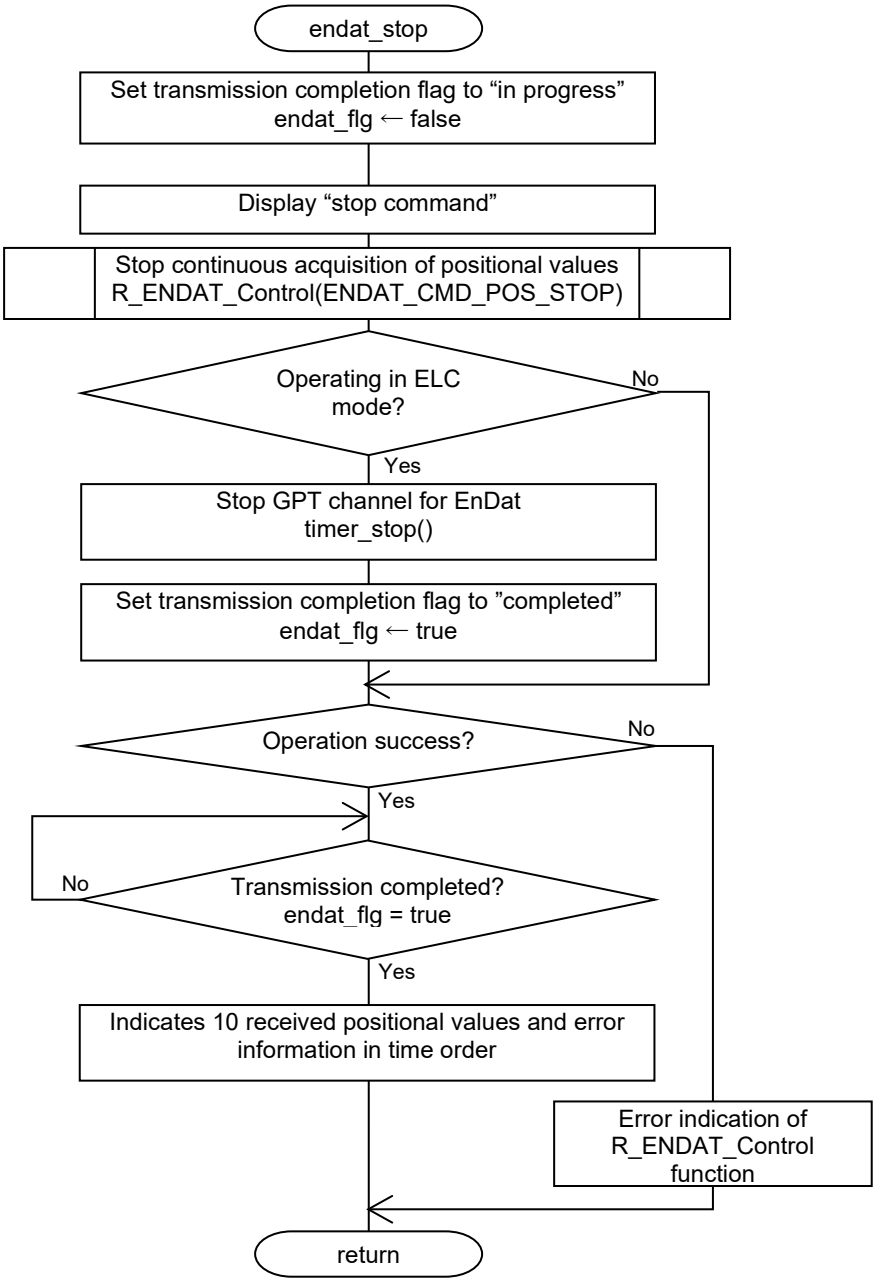


Figure 4.15 Flowchart of endat_stop Function

(14) Flowchart of endat_temp

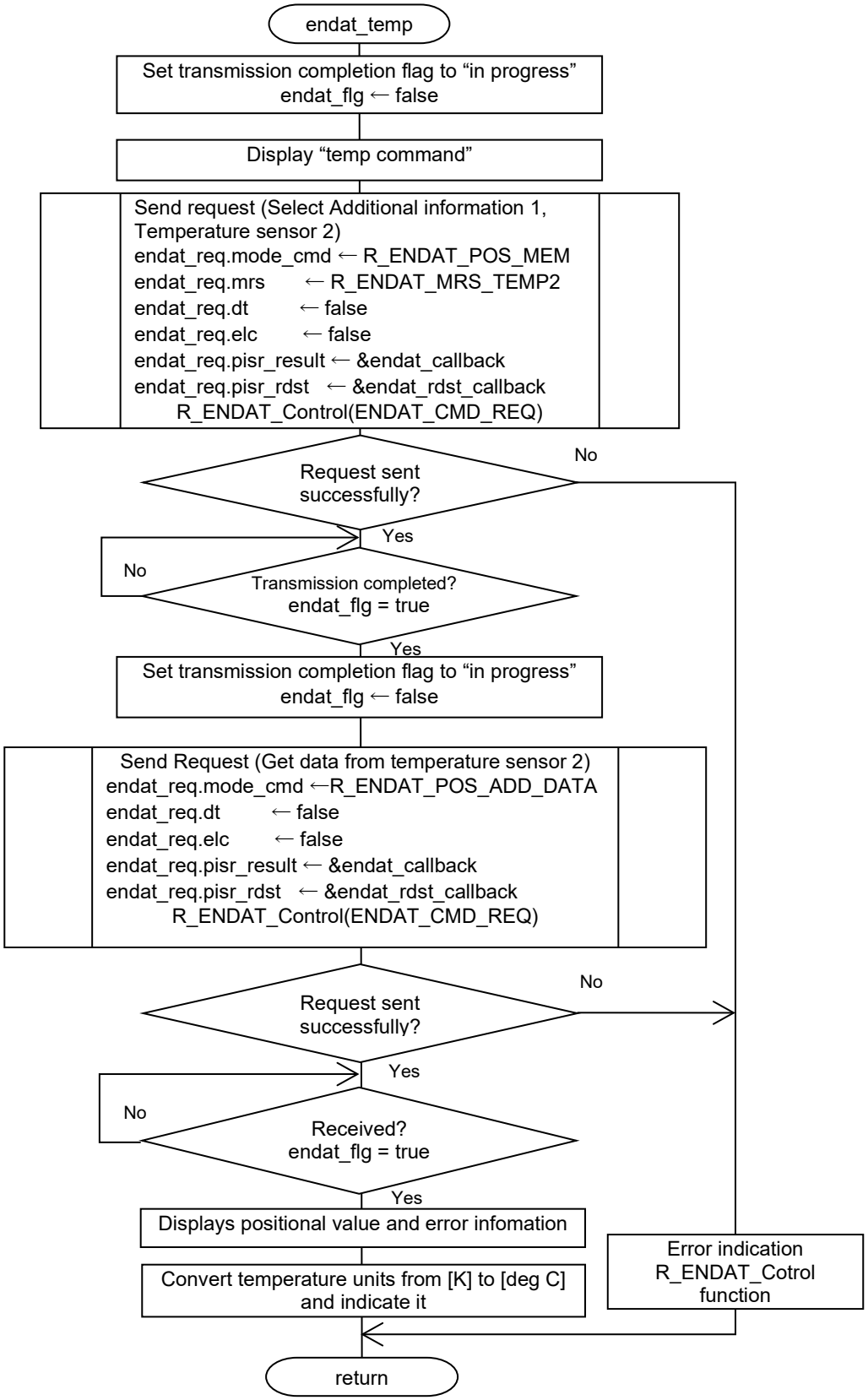


Figure 4.16 Flowchart of endat_temp Function

(15) Flowchart of endat_callback

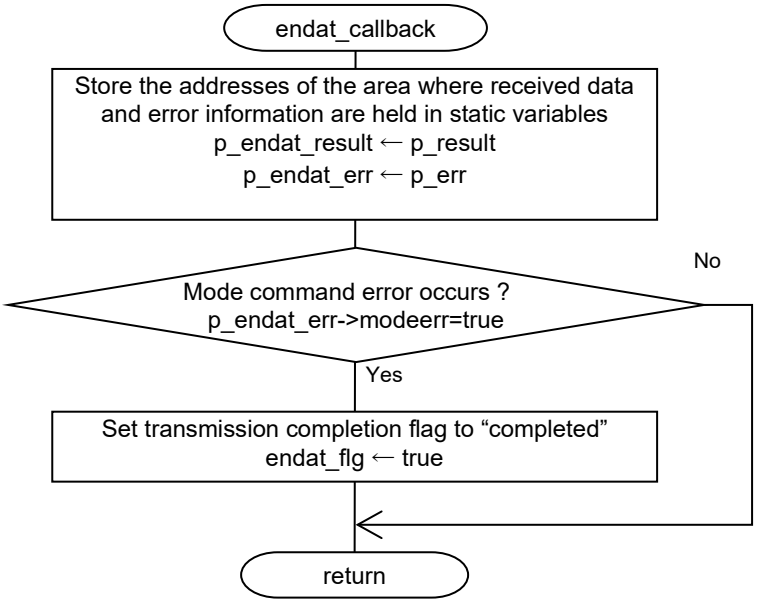


Figure 4.17 Flowchart endat_callback Function

(16) Flowchart of endat_poscon_callback

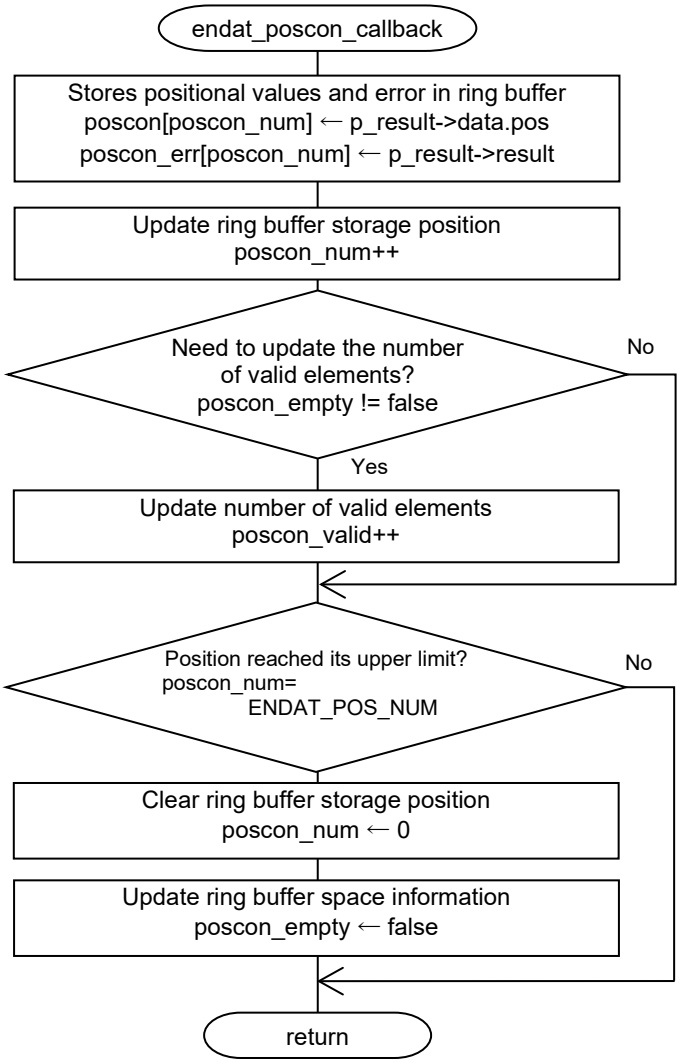


Figure 4.18 Flowchart endat_poscon_callback Function

(17) Flowchart of endat_rdst_callback

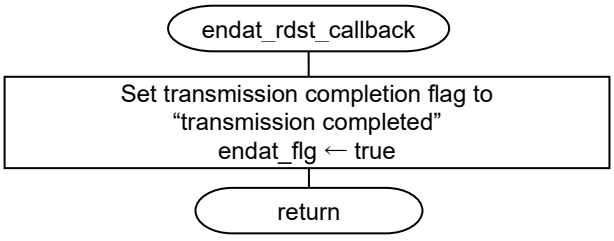


Figure 4.19 Flowchart of endat_rdst_callback Function

4.15.9 Dual Encoder Operation Sequence

(1) Dual Encoder Startup Sequence

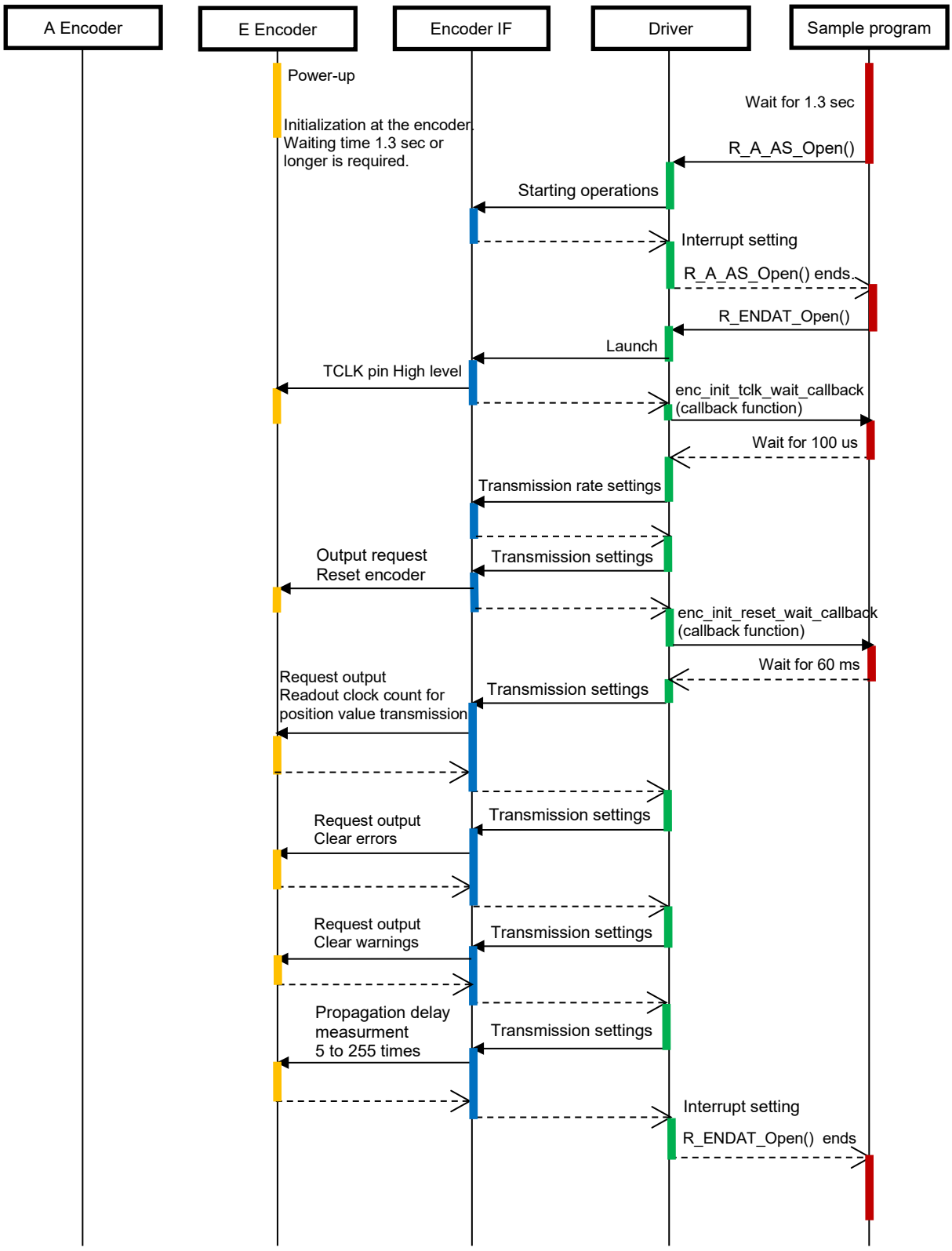


Figure 4.20 Dual Encoder Startup Sequence Diagram

(2) A-format Request Transmission and Data Reception Sequence

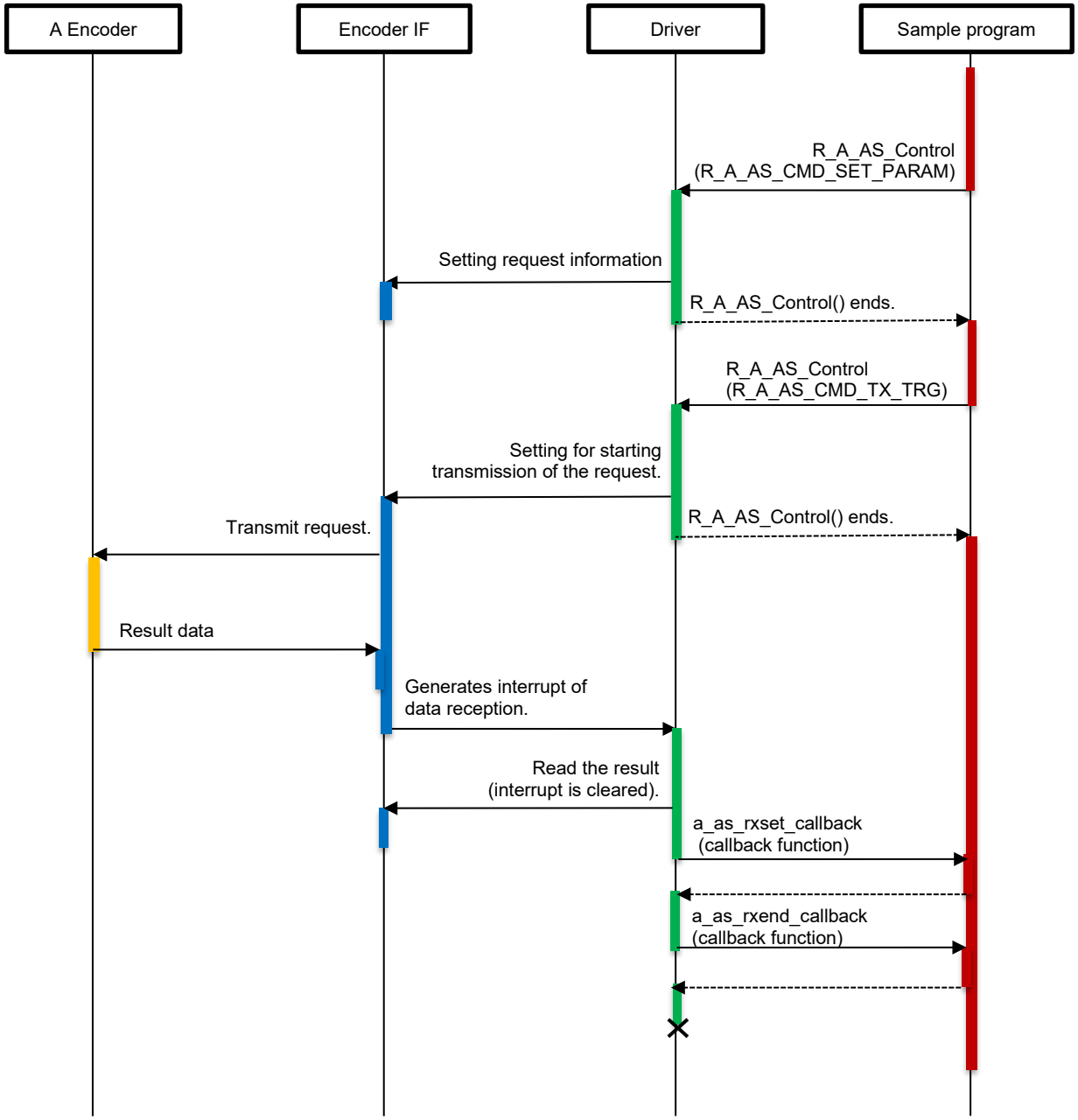


Figure 4.21 A-format Request Transmission and Data Reception Sequence Diagram

(3) EnDat Request Transmission and Data Reception Sequence

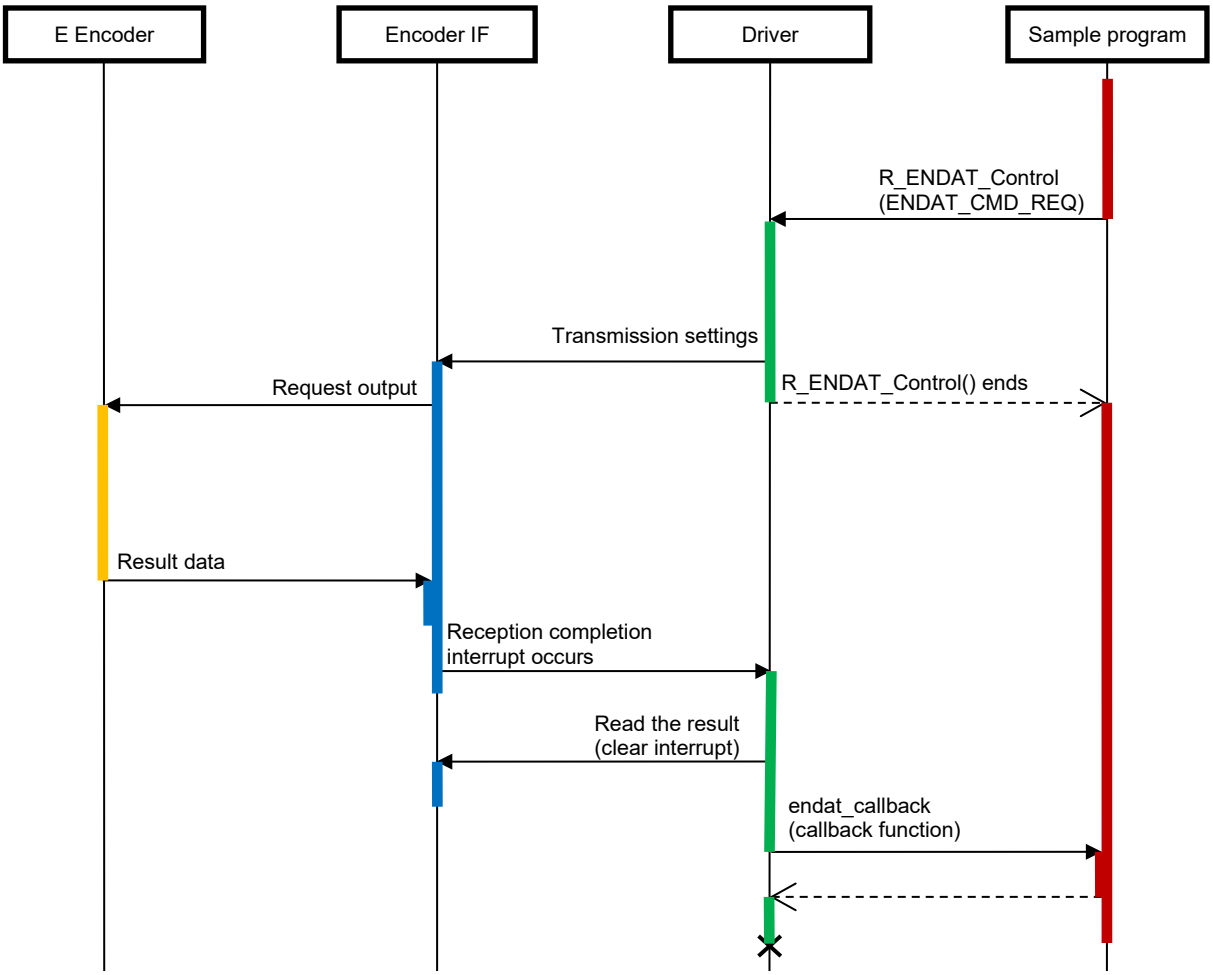


Figure 4.22 EnDat Request Transmission and Data Reception Sequence Diagram

(4) A-format ELC Event Trigger Operation Sequence

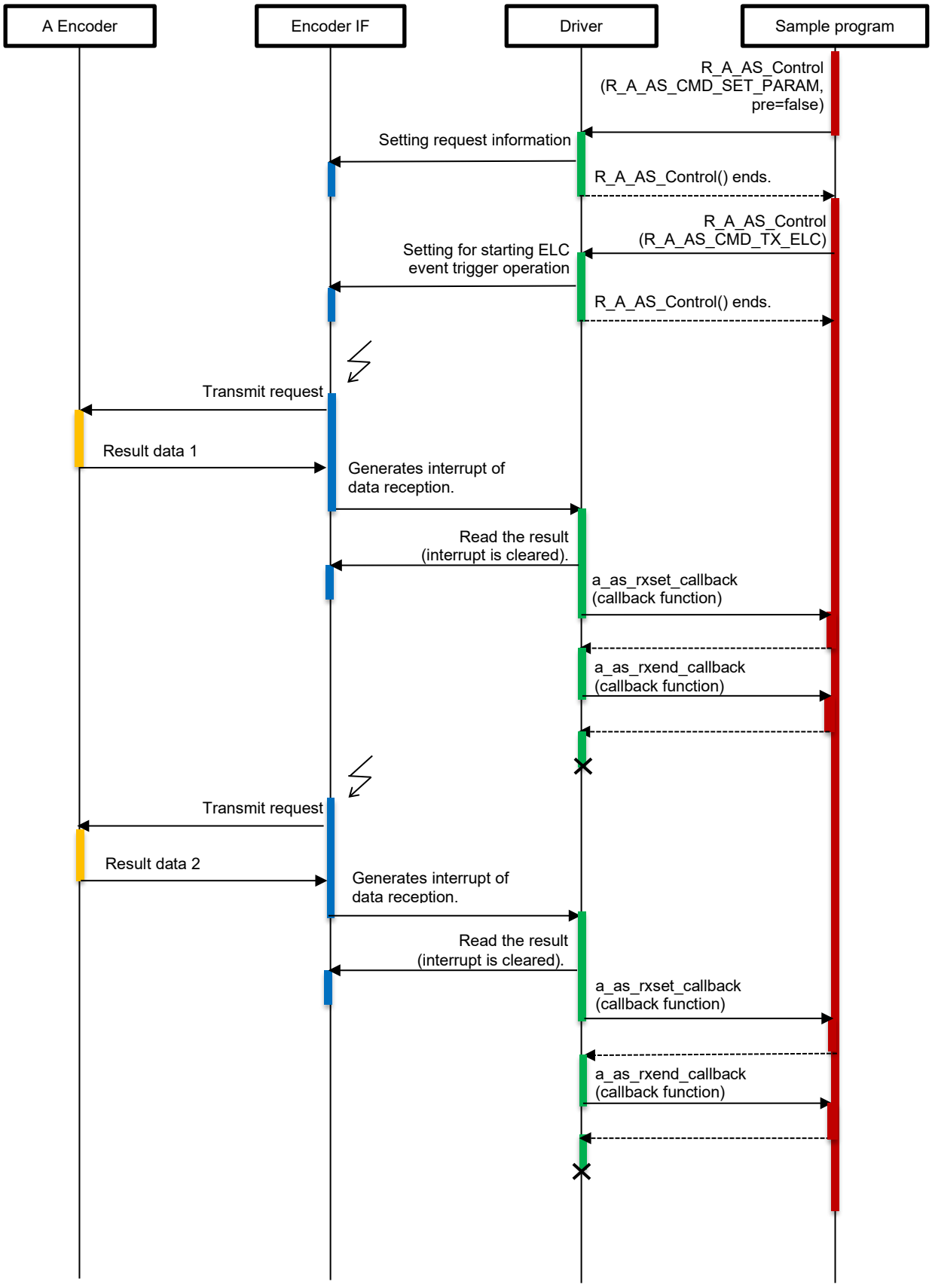


Figure 4.23 A-format ELC Event Trigger Operation Sequence Diagram (1/2)

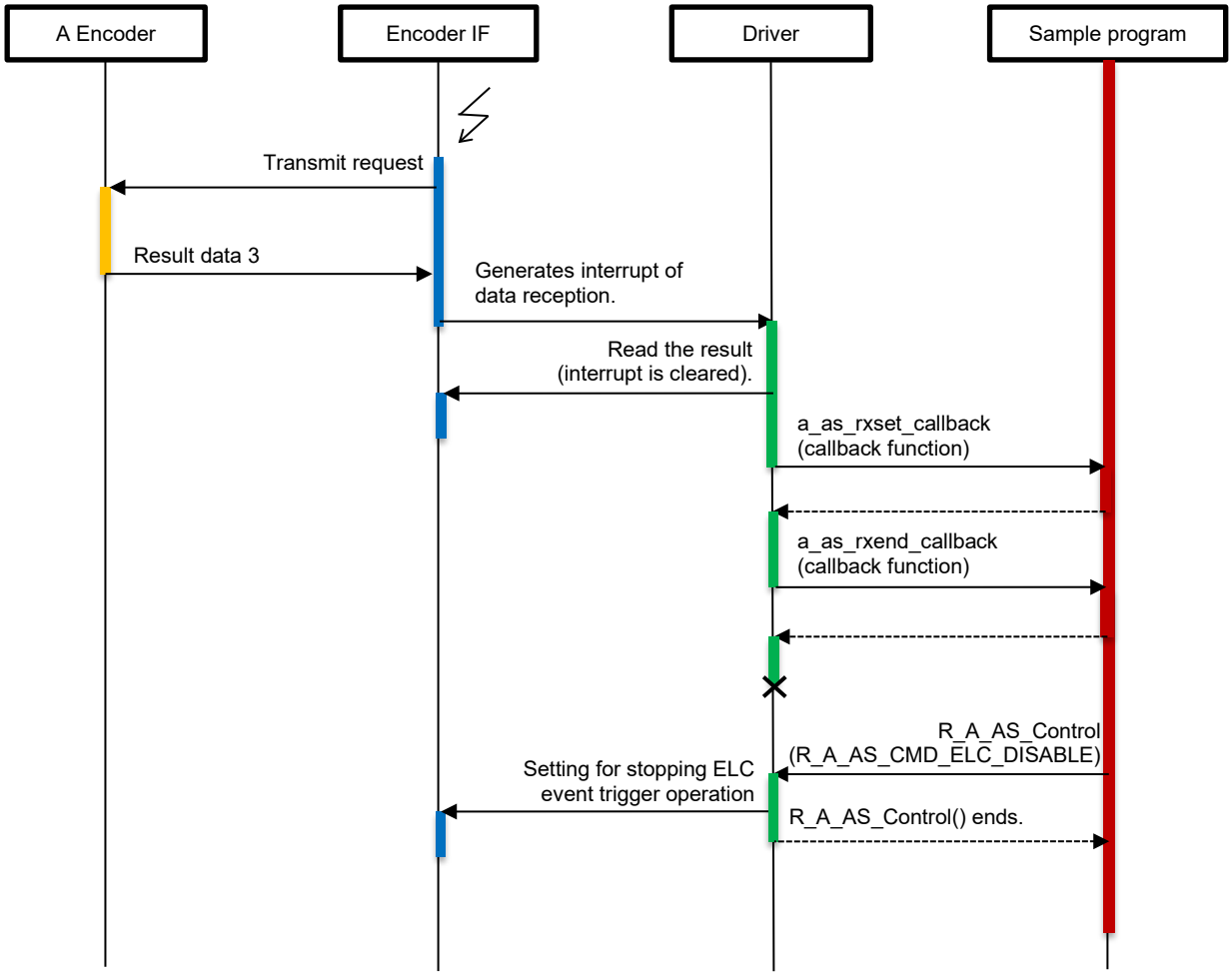


Figure 4.24 A-format ELC Event Trigger Operation Sequence Diagram (2/2)

(5) EnDat Request Transmission (Continuous Mode) and Data Reception Sequence

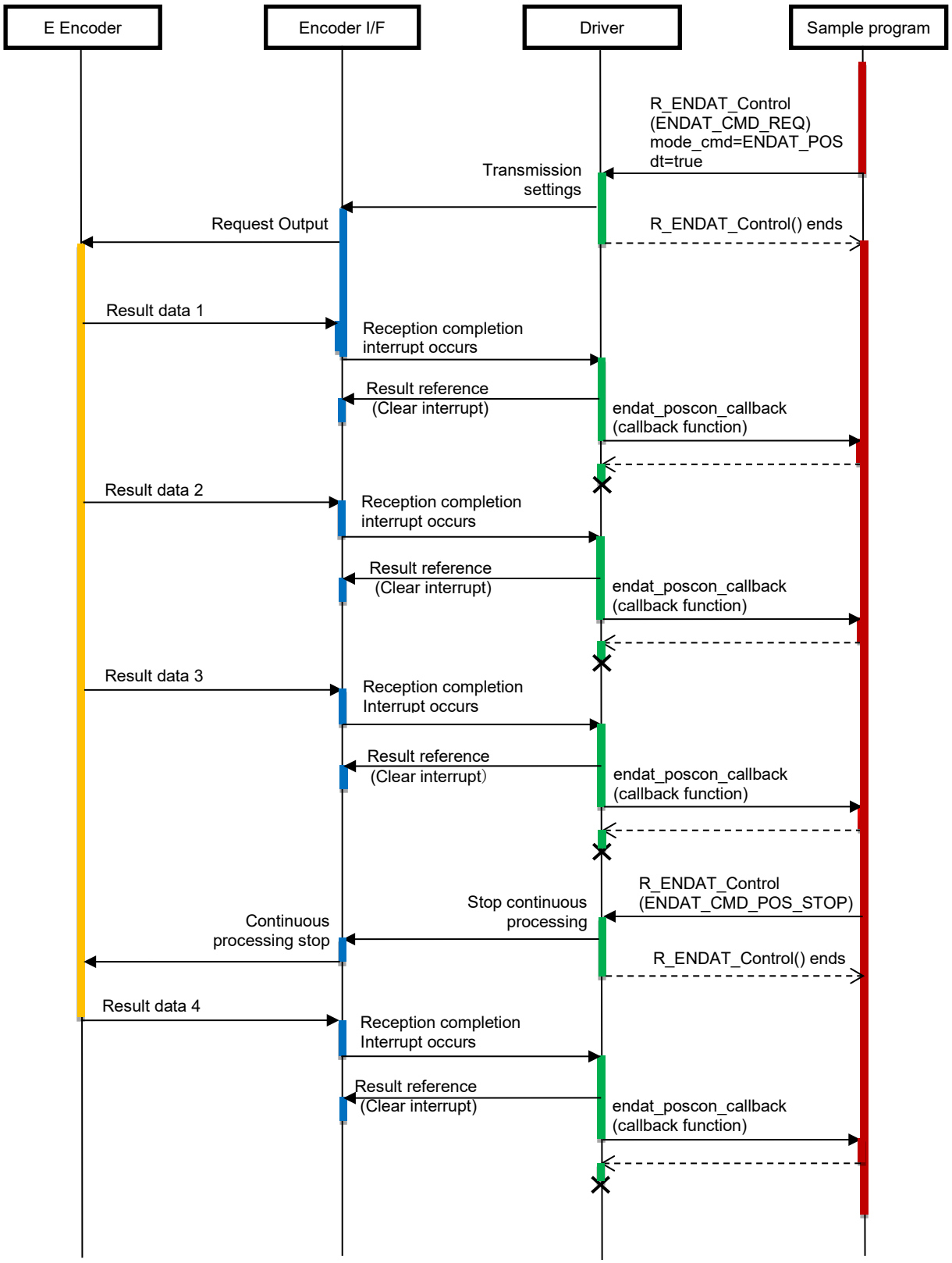


Figure 4.25 EnDat Request Transmission (Continuous Mode) and Data Reception Sequence Diagram

(6) EnDat Request Transmission (ELC Mode) and Data Reception Sequence

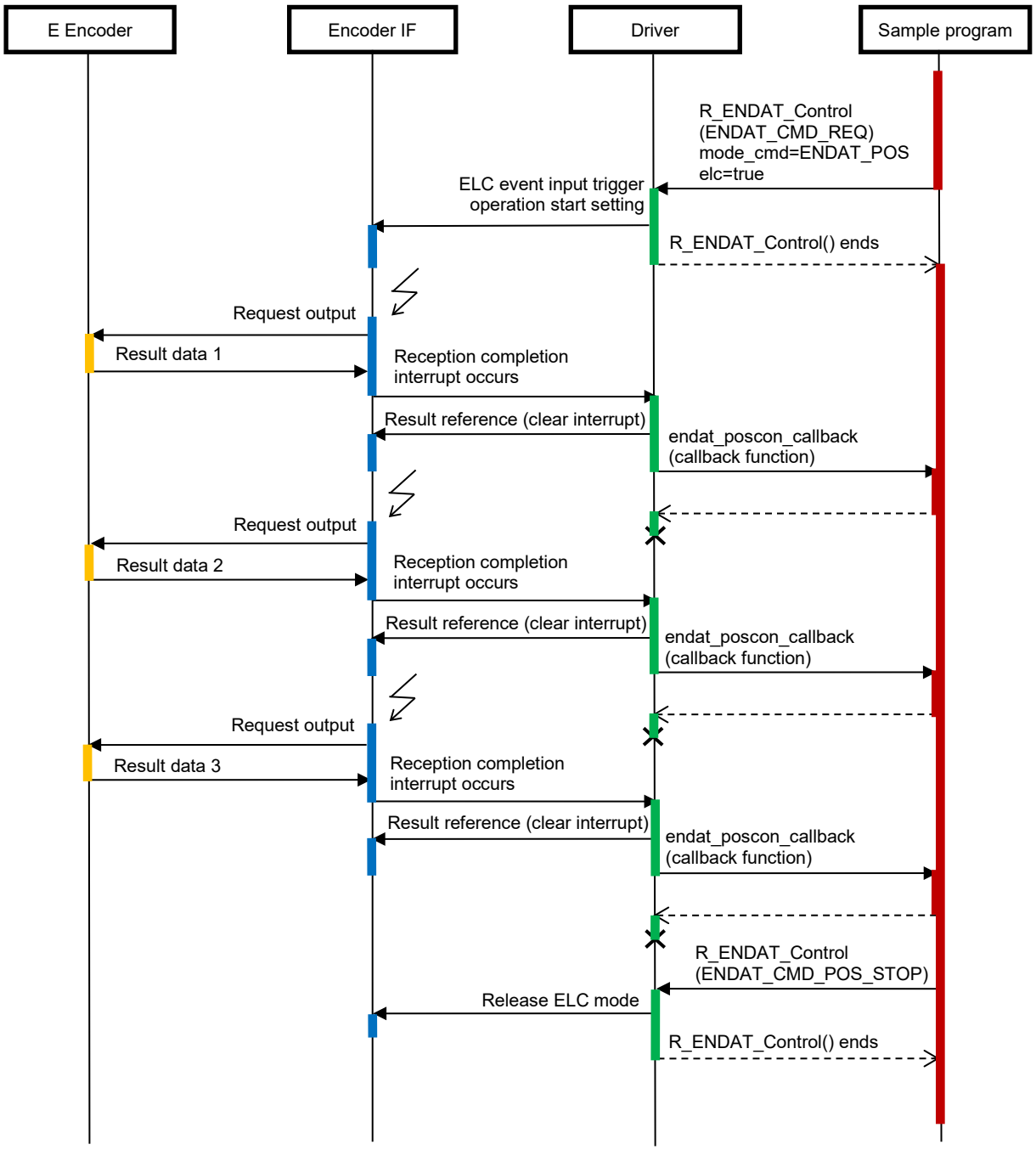


Figure 4.26 EnDat Request Transmission (ELC Mode) and Data Reception Sequence Diagram

(7) Dual Encoder Stop Sequence

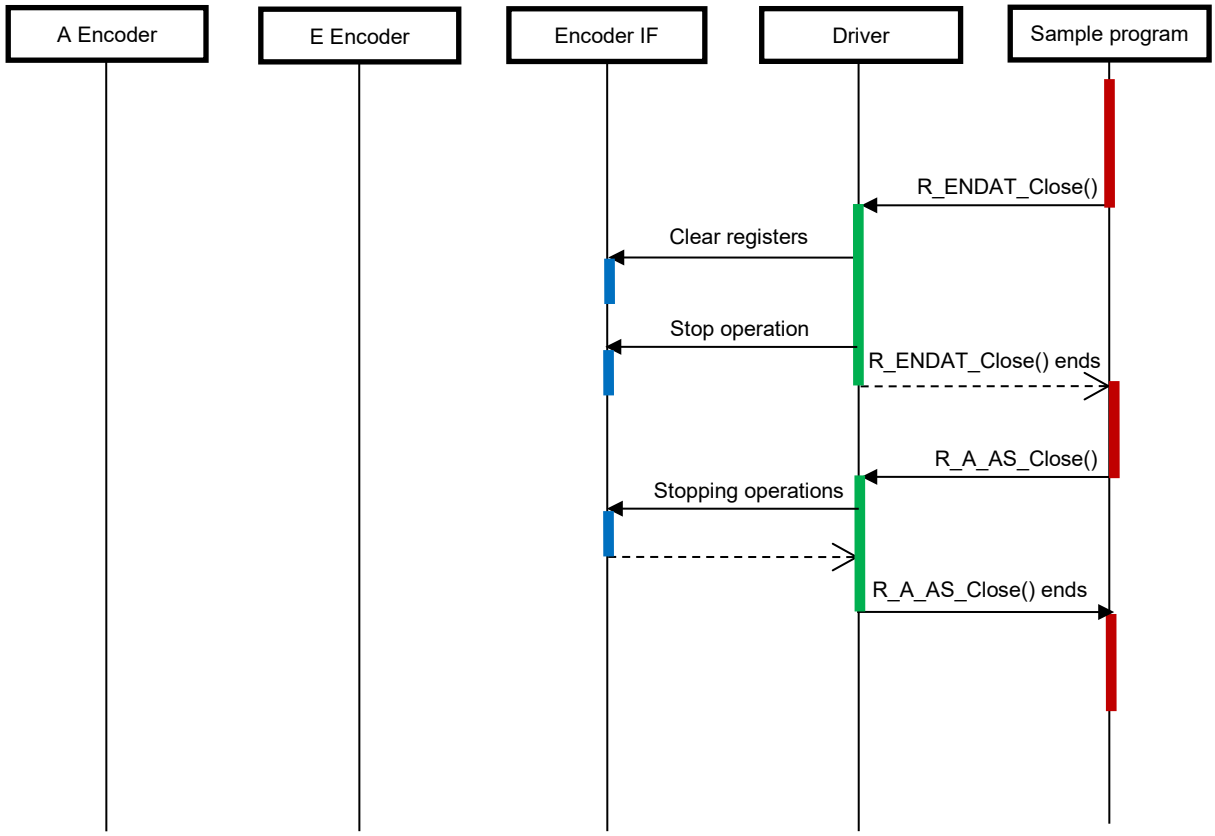


Figure 4.27 Dual Encoder Stop Sequence Diagram

4.15.10 Console Commands

This sample program supports an encoder (MAR-M50A) compliant with the A-format specification and an encoder (EQN1035) compliant with the EnDat 2.2 specification. The commands that can be input from the console are as follows. Commands are prefixed with the identification code “A” or “E” to distinguish the target encoder of the command.

Table 4.29 A-format Console Commands

Command	Content
A req ea cmd param1 param2	Sends the command frame input in the cmd to the encoder. ea: Encoder section number (decimal notation) cmd: Command frame param1 and param2: The values to be input depends on the cmd value. See “Table 4.32, A-format req Commands and Corresponding Parameters”.
A elctimer ea val	Sends the command frame CDF0 to the designated encoder at 2.5 Mbps by the ELC event trigger. ea: Encoder section number (decimal notation) val: Timing of the trigger in microseconds. The maximum value allowed is 6990. Operation in response to input of the ELC event trigger is stopped by executing the console command "elcstop".
A elcstop	Stops the operation in response to input of the ELC event trigger.

Table 4.30 EnDat Console Commands

Command	Content
E pos	Get positional value only once.
E poscon	The positional values are acquired continuously. To stop continuous acquisition, enter the "stop" command.
E elctimer val	The positional value is continuously acquired in a timer cycle as an ELC event input trigger operation. The timer cycle is specified in units of us (maximum 6990us). To stop continuous acquisition, enter the "stop" command.
E stop	Stops continuous acquisition of positional values.
E temp	Obtains temperature measurements along with positional values from the encoder.

Table 4.31 Common Console Commands

command	content
exit	Exit the program.

Table 4.32 A-format req Commands and Corresponding Parameters

cmd	param1	param2
CDF0 to CDF12	None	None
CDF13	An address in EEPROM (hexadecimal notation) Specify a value between 0x00 to 0xFF.	None
	Usage example (reading the data from address 0 of the encoder with section number 2) req 2 CDF13 00	
CDF14	An address in EEPROM (in hexadecimal) Specify a value between 0x00 to 0xEF.	The data to be written to EEPROM (in hexadecimal) Specify a value between 0x0000 to 0xFFFF.
	Usage example (writing 0x1234 to address 0 of the encoder with section number 2) req 2 CDF14 00 1234	
CDF15 to 17	None	None
CDF18, CDF19	ID code (in hexadecimal) Specify a value between 0x00 0000 to 0xFF FFFF.	None
	Usage example (writing ID code 0x12 3456 to the encoder with section number 2) req 2 CDF18 123456	
CDF21, CDF27, CDF29	None	None

Note: Though input of CDF11, CDF17, and CDF19 are possible, they cannot be used because the sample program is for operation with a bus connection.
Multiple transmission commands (CDF4 to 7, CDF22, CDF28, CDF30) and CDF20 command are not supported.

(1) Result of Running

After running, it will display the command prompt following the version. Enter the command after “Dual >”.

```
Dual encoder sample program start
R_A_AS_GetVersion = 4.0


R_ENDAT_GetVersion = 4.0


Dual>
```

(2) Example of Command Execution

It is an example of executing console command that sends command frame CDF0 to a connecting encoder ENC1. Encoder address, status and angular information are displayed as the response from the encoder.

```
Dual>A req 1 CDF0
A req command
A ------------------------------
A ENC1
A R_A_AS_REQ_SUCCESS
A EA : 0
A ES : 2
A CC : 0
A ABS 40bit [39:32] : 0x00000001
A ABS 40bit  [31:0] : 0x00B29A75
```

It is an example of executing E pos command. Results of sending and receiving requests, received positional value and additional data are displayed as the response from the encoder.

```
Dual>E pos
E pos command
E  result     : ENDAT_SUCCESS
E  pos_upper  : 0x00000000
E  pos_lower  : 0x00778D1B
E  add_datum1 : 0x00000000
E  add_datum2 : 0x00000000
```

4.15.11 Procedure of Channel Changing

The RZ/T2H has 16 channels for encoder interfaces from channel 0 to 15. In the Dual Encoder sample program, A-format is initially assigned to channel 0 and EnDat to channel 1. If you change the channel assignments, change the macro definitions in the source code (dual_main.c) and each encoder driver (r_a_as_rzt2.c, r_endat_rzt2.c), as well as the interrupt handler and event link in the FSP Configurator.

(1) Settings of Initial Channel

The default macro settings are listed below.

```
dual_main.c ;
   #define A_AS_CH (0)        /* Set the channel for A-format */
   #define ENDAT_CH (1)       /* Set the channel for EnDat */
r_a_as_rzt2.c ;
   #define VECTOR_NUMBER_AFMTx_INT0 VECTOR_NUMBER_ENCIF00_INT0
                              /* Use the ENCIF00_INT0 vector for A-format */
R_endat_rzt2.c :
   #define VECTOR_NUMBER_ENDATx_INT0 (VECTOR_NUMBER_ENCIF01_INT0)
                              /* Use the ENCIF01_INT0 vector for EnDat */
```

The pins used and their functions are initially assigned as shown in Table 4.33.

Table 4.33 Used Pins and Their Functions

Channel	Pin Name	I/O Port	Input/ Output	Voltage Domain	Description
AFMT0	ENCIFOE00 (D/R)	P14_3	Output	VDD33	Data output enable
	ENCIFDO00 (REQ)	P14_4	Output	VDD33	Data output
	ENCIFDI00 (SDAT)	P14_5	Input	VDD33	Data input
ENDAT_CH1	ENCIFCK1 (TCLK1)	P33_2	Output	VDD1833_3	Clock output
	ENCIFOE1 (DE1)	P33_3	Output	VDD1833_3	Data output enable
	ENCIFDO1 (DATA_DV1)	P33_4	Output	VDD1833_3	Data output
	ENCIFDI1 (DATA_RC1)	P33_5	Input	VDD1833_3	Data input

(2) Settings of Example 1 of Changing Channel

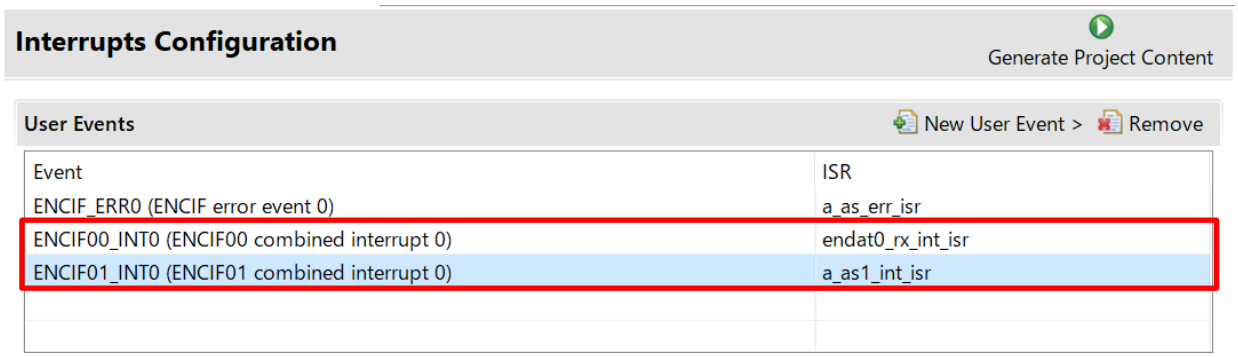
If you change the assignments of A-format to channel 1 and EnDat to channel 0, change the macros definitions in each file as follows.

```
dual_main.c ;
   #define A_AS_CH (1)        /* Change the channel of A-format to 1 */
   #define ENDAT_CH (0)       /* Change the channel of EnDat to 0 */
r_a_as_rzt2.c :
    #define VECTOR_NUMBER_AFMTx_INT0 VECTOR_NUMBER_ENCIF01_INT0
                              /* Use the ENCIF01_INT0 vector for A-format */
r_endat_rzt2.c :
   #define VECTOR_NUMBER_ENDATx_INT0 (VECTOR_NUMBER_ENCIF00_INT0)
                              /* Use the ENCIF00_INT0 vector for EnDat */
```

Furthermore, change the interrupt handler (ISR) corresponding to the ENCIF00_INT0 event and ENCIF01_INT0 event from the FSP Configurator.

Table 4.34 Changes in Interrupt Handler

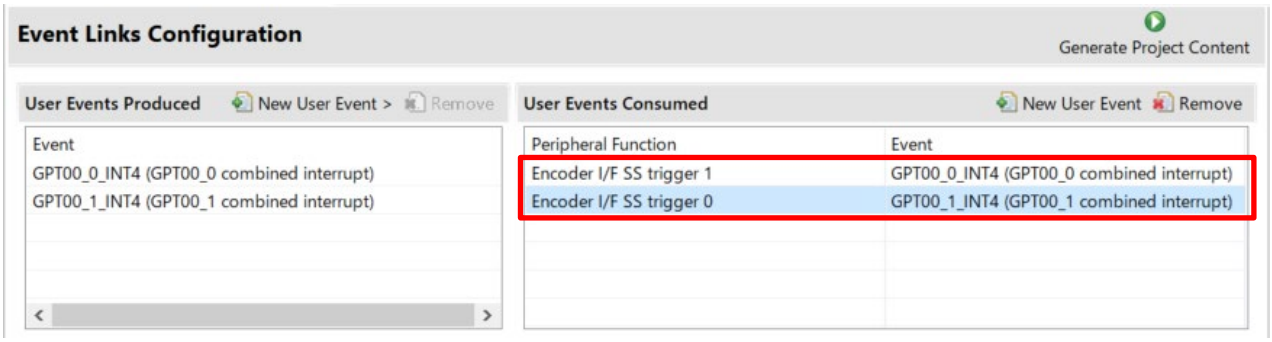
Event	Initial ISR	ISR after changing channel
ENCIF00_INT0 (ENCIF00 combined Interrupt 0)	a_as0_int_isr	endat0_rx_int_isr
ENCIF01_INT0 (ENCIF01 combined Interrupt 0)	endat1_rx_int_isr	a_as1_int_isr



A-format and EnDat have operating modes that receive periodic events output by GPT as ELC events. The assignment of ELC events is also done in the Event Links tab of the FSP Configurator. A-format corresponds to GPT00_0_INT4, and EnDat corresponds to GPT00_1_INT4.

Table 4.35 Changes in Event Links

Event	Initial Peripheral Function	Peripheral Function after changing channel
GPT00_0_INT4 (ENCIF00_0 combined Interrupt)	Encoder I/F SS trigger 0	Encoder I/F SS trigger 1
GPT01_1_INT4 (ENCIF00_1 combined Interrupt)	Encoder I/F SS trigger 1	Encoder I/F SS trigger 0



The pins used and their functions are assigned as shown in Table 4.36.

Table 4.36 Used Pins and Their Functions (Example 1 of Changing Channel)

Channel	Pin Name	I/O Port	Input/ Output	Voltage Domain	Description
AFMT1	ENCIFOE01 (D/R)	P33_3	Output	VDD1833_3	Data output enable
	ENCIFDO01 (REQ)	P33_4	Output	VDD1833_3	Data output
	ENCIFDI01 (SDAT)	P33_5	Input	VDD1833_3	Data input
ENDAT_CH0	ENCIFCK0 (TCLK0)	P14_2	Output	VDD33	Clock output
	ENCIFOE0 (DE0)	P14_3	Output	VDD33	Data output enable
	ENCIFDO0 (DATA_DV0)	P14_4	Output	VDD33	Data output
	ENCIFDI0 (DATA_RC0)	P14_5	Input	VDD33	Data input

(3) Settings of Example 2 of Changing Channel

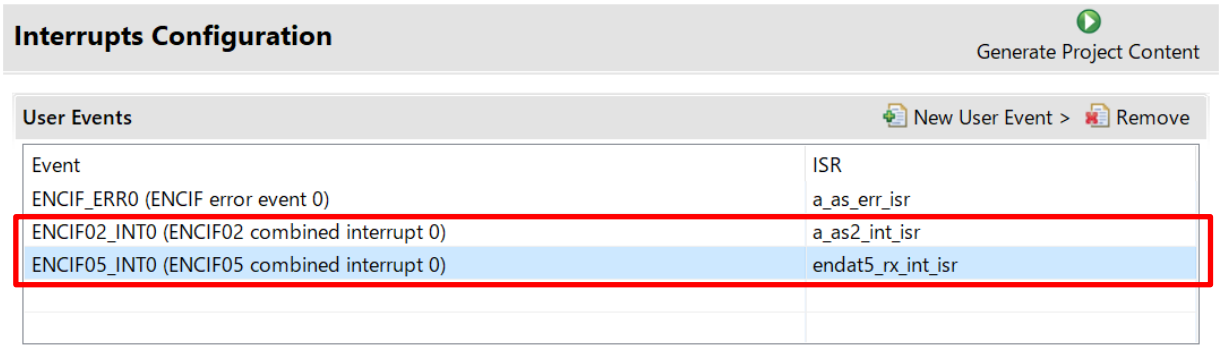
If you change the assignments of A-format to Channel 2 and EnDat to Channel 5, please change the macros definitions in each file as follows.

```
dual_main.c ;
   #define A_AS_CH (2)        /* Change the channel of A-format to 2 */
   #define ENDAT_CH (5)       /* Change the channel of EnDat to 5 */
r_a_as_rzt2.c ;
   #define VECTOR_NUMBER_AFMTx_INT0 VECTOR_NUMBER_ENCIF02_INT0
                              /* Use the ENCIF02_INT0 vector for A-format */
r_endat_rzt2.c :
   #define VECTOR_NUMBER_ENDATx_INT0 (VECTOR_NUMBER_ENCIF05_INT0)
                              /* Use the ENCIF05_INT0 vector for EnDat */
```

Furthermore, delete the interrupt handler (ISR) corresponding to the ENCIF00_INT0 event and ENCIF01_INT0 event from the FSP Configurator, and register the interrupt handlers (ISR) corresponding to the ENCIF02_INT0 event and the ENCIF05_INT0 event from the FSP Configurator.

Table 4.37 Changes in Interrupt Handler

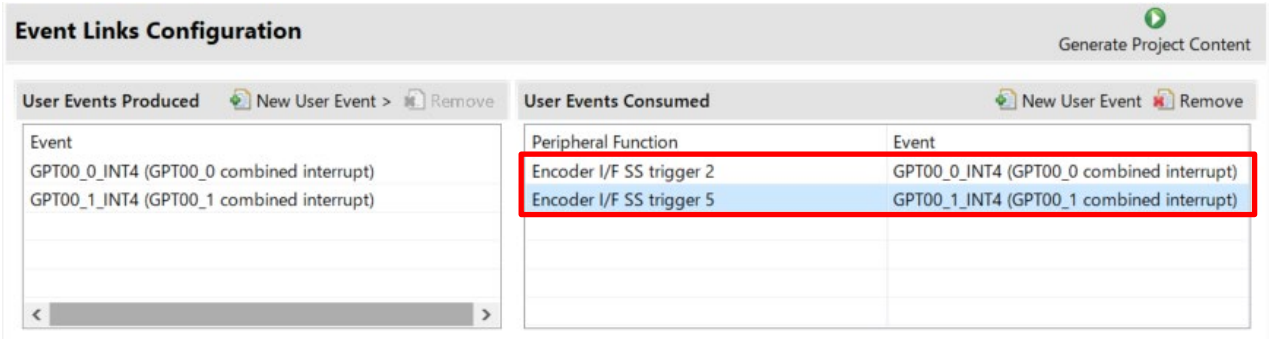
Event	Initial ISR	ISR after changing channel
ENCIF00_INT0 (ENCIF00 combined Interrupt 0)	a_as0_int_isr	(delete)
ENCIF01_INT0 (ENCIF01 combined Interrupt 0)	endat1_rx_int_isr	(delete)
ENCIF02_INT0 (ENCIF02 combined Interrupt 0)	-	a_as2_int_isr
ENCIF05_INT0 (ENCIF05 combined Interrupt 0)	-	endat5_rx_int_isr



Change to the assignment of ELC events in the Event Links tab of the FSP Configurator.

Table 4.38 Changes in Event Links

Event	Initial Peripheral Function	Peripheral Function after changing channel
GPT00_0_INT4 (ENCIF00_0 combined Interrupt)	Encoder I/F SS trigger 0	Encoder I/F SS trigger 2
GPT00_1_INT4 (ENCIF00_1 combined Interrupt)	Encoder I/F SS trigger 1	Encoder I/F SS trigger 5



The pins used and their functions are assigned as shown in Table 4.39. In this sample program, the I/O ports corresponding to the 16 channels of the encoder interface have already been selected. There is no need to change the I/O port settings in the Pins tab of the FSP Configurator.

Table 4.39 Used Pins and Their Functions (Example 2 of Changing Channel) *

Channel	Pin Name	I/O Port	Input/ Output	Voltage Domain	Description
AFMT2	ENCIFOE02 (D/R)	P03_4	Output	VDD33	Data output enable
	ENCIFDO02 (REQ)	P03_5	Output	VDD33	Data output
	ENCIFDI02 (SDAT)	P03_6	Input	VDD33	Data input
ENDAT_CH5	ENCIFCK5 (TCLK5)	P12_4	Output	VDD1833_6	Clock output
	ENCIFOE5 (DE5)	P12_5	Output	VDD1833_6	Data output enable
	ENCIFDO5 (DATA_DV5)	P12_6	Output	VDD1833_6	Data output
	ENCIFDI5 (DATA_RC5)	P12_7	Input	VDD1833_6	Data input

Note: For the pins used and their functions when assigning other channels, refer to the application note for the RZ/T2H Group Encoder I/F EnDat sample program for EnDat, and the RZ/T2H Group Encoder I/F A-format sample program for A-format.

5. Sample Code

The sample code is available from the Renesas Electronics website.

Revision History

Rev.	Date	Description	
		Page	Summary
2.00	Feb.28.25	-	First Edition issued
3.00	Oct 31.25	11 to 19, 24 to 30 11 to 34 45	Change description of headers for functions. Revise to unify description for functions. Revise description of structure r_a_as_status_t.
4.00	Apr 24.26	6 11 to 30, 46, 55 to 62 16 to 19, 27 to 30	Change the frequency of the Cortex-A55 Core0 to 1200MHz. Change the prefix of pointer variables to “p_”. Revised the header column of “Specifications of User-defined Function”.

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   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can 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 must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. 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. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. 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, for example, 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.).
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