
RZ/N2H Group

EnDat Sample Program

Summary

This application note explains a sample program for acquiring and indicating information from an EnDat 2.2 compliant encoder by using the Encoder Interface of the RZ/N2H.

The major features of the program are listed below.

- Supports the mode command and the MRS codes used in EnDat 2.2.
- Obtain angle information, etc. from an encoder (EQN1035 from HEIDENHAIN) compliant with EnDat 2.2 specifications.

Target Device

RZ/N2H

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
EnDat 2.2 Interface (ENDAT)	Communication with the EnDat 2.2 compliant encoder (Incremental signal is not supported)
Interrupt Controller (ICU)	ENDAT interrupt control
General PWM Timer (GPT) unit 0 channel 0	Generation of event cycles to be input to ELC
Event Link Controller (ELC)	Link events output by GPT unit 0 channel 0 to ENDAT
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.

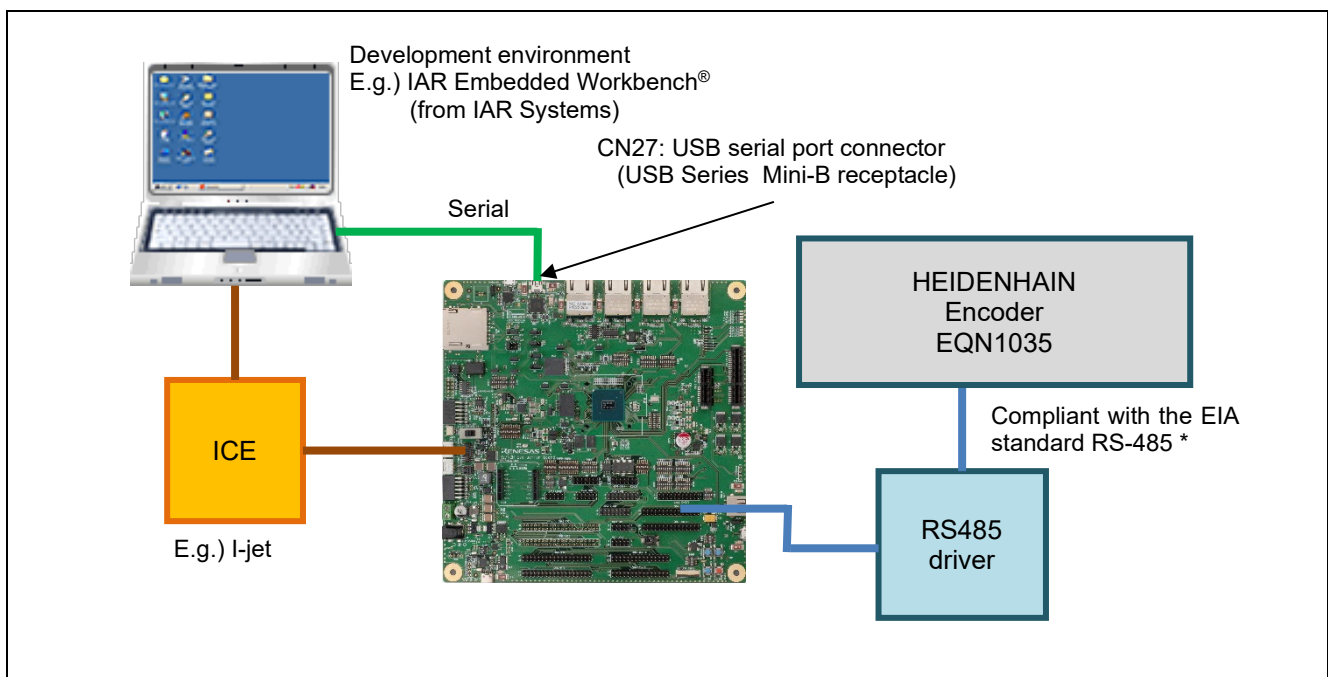


Figure 1.1 Operating Environment

Note: For cable lengths that can be sent and received, please refer to the "EnDat Specification", which can be obtained by contacting HEIDENHAIN.

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/N2H 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/N2H Evaluation Board (RTK9RZN2Hxxxxxxx)	
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.
2. Refer to the RZ/N2H Group Encoder I/F EnDat 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/N2H Group User’s Manual: Hardware”.

3.1 Pins

Table 3.1 lists the pins used and their functions. Channels ENDAT_CH8, ENDAT_CH12, and ENDAT_CH15 out of ENDAT_CH0 to ENDAT_CH15 have no assigned I/O ports. The remaining 13 channels are available to use.

Table 3.1 Pins Used and Their Functions

Channel	Pin Name	I/O Port	Input/Output	Voltage Domain	Description
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
ENDAT_CH1	ENCIFCK1 (TCLK1)	P02_0	Output	VDD1833_5	Clock output
	ENCIFOE1 (DE1)	P02_1	Output	VDD1833_5	Data output enable
	ENCIFDO1 (DATA_DV1)	P26_7	Output	VDD33	Data output
	ENCIFDI1 (DATA_RC1)	P27_0	Input	VDD33	Data input
ENDAT_CH2	ENCIFCK2 (TCLK2)	P03_3	Output	VDD33	Clock output
	ENCIFOE2 (DE2)	P03_4	Output	VDD33	Data output enable
	ENCIFDO2 (DATA_DV2)	P03_1	Output	VDD33	Data output
	ENCIFDI2 (DATA_RC2)	P03_2	Input	VDD33	Data input
ENDAT_CH3	ENCIFCK3 (TCLK3)	P13_0	Output	VDD1833_6	Clock output
	ENCIFOE3 (DE3)	P13_1	Output	VDD1833_6	Data output enable
	ENCIFDO3 (DATA_DV3)	P13_2	Output	VDD1833_6	Data output
	ENCIFDI3 (DATA_RC3)	P13_3	Input	VDD1833_6	Data input
ENDAT_CH4	ENCIFCK4 (TCLK4)	P10_2	Output	VDD33	Clock output
	ENCIFOE4 (DE4)	P10_3	Output	VDD33	Data output enable
	ENCIFDO4 (DATA_DV4)	P10_4	Output	VDD33	Data output
	ENCIFDI4 (DATA_RC4)	P10_5	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
ENDAT_CH6	ENCIFCK6 (TCLK6)	P33_6	Output	VDD1833_3	Clock output
	ENCIFOE6 (DE6)	P33_7	Output	VDD1833_3	Data output enable
	ENCIFDO6 (DATA_DV6)	P34_0	Output	VDD1833_3	Data output
	ENCIFDI6 (DATA_RC6)	P34_1	Input	VDD1833_3	Data input
ENDAT_CH7	ENCIFCK7 (TCLK7)	P34_2	Output	VDD1833_3	Clock output
	ENCIFOE7 (DE7)	P34_3	Output	VDD1833_3	Data output enable
	ENCIFDO7 (DATA_DV7)	P34_4	Output	VDD1833_3	Data output
	ENCIFDI7 (DATA_RC7)	P34_5	Input	VDD1833_3	Data input
ENDAT_CH8	ENCIFCK8 (TCLK8)	-	-	-	N.A.
	ENCIFOE8 (DE8)	-	-	-	N.A.
	ENCIFDO8 (DATA_DV8)	-	-	-	N.A.
	ENCIFDI8 (DATA_RC8)	-	-	-	N.A.

Channel	Pin Name	I/O Port	Input/Output	Voltage Domain	Description
ENDAT_CH9	ENCIFCK9 (TCLK9)	P29_1	Output	VDD1833_2	Clock output
	ENCIFOE9 (DE9)	P29_2	Output	VDD1833_2	Data output enable
	ENCIFDO9 (DATA_DV9)	P29_3	Output	VDD1833_2	Data output
	ENCIFDI9 (DATA_RC9)	P29_4	Input	VDD1833_2	Data input
ENDAT_CH10	ENCIFCK10 (TCLK10)	P29_5	Output	VDD1833_2	Clock output
	ENCIFOE10 (DE10)	P29_6	Output	VDD1833_2	Data output enable
	ENCIFDO10 (DATA_DV10)	P29_7	Output	VDD1833_2	Data output
	ENCIFDI10 (DATA_RC10)	P30_0	Input	VDD1833_2	Data input
ENDAT_CH11	ENCIFCK11 (TCLK11)	P30_1	Output	VDD1833_2	Clock output
	ENCIFOE11 (DE11)	P30_2	Output	VDD1833_2	Data output enable
	ENCIFDO11 (DATA_DV11)	P30_3	Output	VDD1833_2	Data output
	ENCIFDI11 (DATA_RC11)	P30_4	Input	VDD1833_2	Data input
ENDAT_CH12	ENCIFCK12 (TCLK12)	-	-	-	N.A.
	ENCIFOE12 (DE12)	-	-	-	N.A.
	ENCIFDO12 (DATA_DV12)	-	-	-	N.A.
	ENCIFDI12 (DATA_RC12)	-	-	-	N.A.
ENDAT_CH13	ENCIFCK13 (TCLK13)	P13_4	Output	VDD1833_6	Clock output
	ENCIFOE13 (DE13)	P13_5	Output	VDD1833_6	Data output enable
	ENCIFDO13 (DATA_DV13)	P13_6	Output	VDD1833_6	Data output
	ENCIFDI13 (DATA_RC13)	P13_7	Input	VDD1833_6	Data input
ENDAT_CH14	ENCIFCK14 (TCLK14)	P18_4	Output	VDD33	Clock output
	ENCIFOE14 (DE14)	P18_5	Output	VDD33	Data output enable
	ENCIFDO14 (DATA_DV14)	P18_6	Output	VDD33	Data output
	ENCIFDI14 (DATA_RC14)	P18_7	Input	VDD33	Data input
ENDAT_CH15	ENCIFCK15 (TCLK15)	-	-	-	N.A.
	ENCIFOE15 (DE15)	-	-	-	N.A.
	ENCIFDO15 (DATA_DV15)	-	-	-	N.A.
	ENCIFDI15 (DATA_RC15)	-	-	-	N.A.

4. Software

4.1 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 commands
 - B) MRS codes
 - 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.

4.2 File Structures

For the file structure, refer to the release note for the RZ/N2H Group Encoder I/F EnDat sample program.

4.3 Functions

Table 4.1 lists the functions to be used.

Table 4.1 List of Functions

Category	Function Name	Page Number
Endat driver API functions	R_ENDAT_Open	10
	R_ENDAT_Close	11
	R_ENDAT_GetVersion	11
	R_ENDAT_Control	12
User-defined functions	enc_init_tclk_wait_callback	14
	enc_init_reset_wait_callback	15
	enc_init_mem_wait_callback	15
	enc_init_pram_wait_callback	15
	enc_init_cable_wait_callback	16
	endat_callback	16
	endat_poscon_callback	17
Interrupt-handlers	endat0_rx_int_isr	18
	endat1_rx_int_isr	18
	endat2_rx_int_isr	18
	endat3_rx_int_isr	18
	endat4_rx_int_isr	19
	endat5_rx_int_isr	19
	endat6_rx_int_isr	19
	endat7_rx_int_isr	19
	endat9_rx_int_isr	20
	endat10_rx_int_isr	20
	endat11_rx_int_isr	20
	endat13_rx_int_isr	20
	endat14_rx_int_isr	21

4.4 Specifications of API Functions

4.4.1 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	<p>EnDat Driver initializes following initial settings.</p> <ol style="list-style-type: none"> 1. Initialization of the encoder (Encoder with a battery unit is not supported.) 2. Settings of propagation delay compensation <p>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.</p>
Arguments	<p>id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.)</p> <p>R_ENDAT0_ID : Specifies channel 0.</p> <p>R_ENDAT1_ID : Specifies channel 1.</p> <p>⋮</p> <p>R_ENDAT15_ID : Specifies channel 15.</p> <p>Others : Setting is not allowed.</p> <p>p_info : Specifies the encoder information. Specify the address of the structure r_endat_info_t, which contains encoder information.</p>
Return value	<p>ENDAT_SUCCESS : Normal termination</p> <p>ENDAT_ERR_INVALID_ARG : Abnormal termination (The id or p_info member of the r_endat_info_t structure is not available or not specified.)</p> <p>ENDAT_ERR_ACCESS : Abnormal termination (The driver is already open.)</p> <p>ENDAT_ERR_DRV : Abnormal termination (Encoder initialization failed.)</p>
Note	<p>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).</p> <p>The channel 8, the channel 12, and the channel 15 are not available in this sample program.</p>

4.4.2 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 argument id is not available or not specified.) ENDAT_ERR_ACCESS : Abnormal termination (A request is being sent.)
Note	The channel 8, the channel 12, and the channel 15 are not available in this sample program.

4.4.3 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 the minor parts of the version number are stored in the sixteen MSBs and the sixteen LSBs, respectively. Ex.) For ver.1.2, the value returned is 0x00010002

4.4.4 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 "4.4.5 List of Control Commands" for the operation of the control commands.
Arguments	<p>id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.)</p> <p>R_ENDAT0_ID : Specifies channel 0.</p> <p>R_ENDAT1_ID : Specifies channel 1.</p> <p>: :</p> <p>R_ENDAT15_ID : Specifies channel 15.</p> <p>Others : Setting is not allowed.</p> <p>cmd : Command</p> <p>For details, see section "4.10.3(2), r_endat_cmd_t".</p> <p>p_buf : Arguments for each cmd</p>
Return value	<p>ENDAT_SUCCESS : Normal termination</p> <p>ENDAT_ERR_INVALID_ARG : Abnormal termination (id or cmd is not available or not specified.)</p>
Note	<p>For other return values, see "4.4.5 List of Control Commands".</p> <p>Be sure to execute R_ENDAT_Open before executing this function.</p> <p>The channel 8, the channel 12, and the channel 15 are not available in this sample program.</p>

4.4.5 List of 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	<p>Sends requests to the EnDat encoder.</p> <p>The endat_callback function is called once for each request sent.</p> <p>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.</p> <p>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.</p>
Arguments	<p>id : Specifies the ID to be used. (It is defined in r_endat_rzt2_dat.h.)</p> <p>R_ENDAT0_ID : Specifies channel 0.</p> <p>R_ENDAT1_ID : Specifies channel 1.</p> <p>:</p> <p>R_ENDAT15_ID : Specifies channel 15.</p> <p>Others : Setting is not allowed.</p> <p>cmd : ENDAT_CMD_REQ</p> <p>p_buf : Request information</p> <p>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 "4.10.1(3), r_endat_req_t".</p>
Return value	<p>R_ENDAT_SUCCESS : Normal termination</p> <p>R_ENDAT_ERR_INVALID_ARG : Abnormal termination (id or cmd is not available or not specified, p_buf is NULL or the structure r_endat_req_t member of the p_buf is not specified.)</p> <p>R_ENDAT_ERR_BUSY : Abnormal termination (The transfer is in progress or STATR register RDY4STRB bit is 0.)</p> <p>R_ENDAT_ERR_ACCESS : Abnormal termination (The channel has not been started.)</p>
Note	The channel 8, the channel 12, and the channel 15 are not available in this sample program.

(2) ENDAT_CMD_POS_STOP

ENDAT_CMD_POS_STOP	
Synopsis	Stop continuous acquisition 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.
Return value	cmd : ENDAT_CMD_POS_STOP p_buf : Not used (Specify NULL.) R_ENDAT_SUCCESS : Normal termination R_ENDAT_ERR_INVALID_ARG : Abnormal termination (id or cmd is not available or not specified.) R_ENDAT_ERR_ACCESS : Abnormal termination (Continuous mode or ELC mode request has not been sent.)
Note	The channel 8, the channel 12, and the channel 15 are not available in this sample program.

4.5 Specifications of User-Defined Functions**4.5.1 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

4.5.2 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

4.5.3 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	<p>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.</p> <p>Note: This value assumes that (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))\times(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.</p>
Arguments	None
Return value	None

4.5.4 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	<p>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.</p> <p>Note: This value assumes that memory access time (12 ms) + (Start(1 clock cycle) + Address(8 clock cycles) + Parameters(16 clock cycles) + CRC(5 clock cycles))\times(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.</p>
Arguments	None
Return value	None

4.5.5 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	<p>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.</p> <p>Note: This value assumes that $t_{cal}(5 \text{ us}) + (\text{Start}(1 \text{ clock cycle}) + \text{Error}(1 \text{ clock cycle}) + \text{maximum number of bits of main received data (48 bits)} + \text{number of CRC bits (5 bits)}) \times (1/100 \text{ kHz}) + t_m(30 \text{ us}) + t_R(0.5 \text{ us}) + t_D(1.7 \text{ us}) = 587.2 \text{ us}$.</p> <p>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.</p>
Arguments	None
Return value	None

4.5.6 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	<p>This callback function is registered with the R_ENDAT_Control(ENDAT_CMD_REQ) function.</p> <p>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.</p>
Argument	<p>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> <p>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.</p>
Return value	None

4.5.7 endat_poscon_callback

endat_poscon_callback	
Synopsis	Data reception result notification function for sending requests (Continuous mode, ELC mode)
Header	-
Declaration	<code>void endat_poscon_callback(r_endat_result_t * p_result, endat_protocol_err_t *p_err);</code>
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><code>p_result</code> : Result of sending/receiving Pointer to the structure <code>r_endat_result_t</code> that stores the result of sending/receiving data. The data reception result is valid until the next request is sent/received.</p> <p><code>p_err</code> : Error information Pointer to the structure <code>r_endat_protocol_err_t</code> that stores the results of sending and receiving. The data reception result is valid until the next request is sent/received.</p>
Return value	None

4.5.8 endat_rdst_callback

endat_rdst_callback	
Synopsis	Callback function to notify that the next data communication is ready to start
Header	-
Declaration	<code>void endat_rdst_callback(void);</code>
Description	This callback function is registered with the R_ENDAT_Control(ENDAT_CMD_REQ) function. It is called after the <code>endat_callback</code> 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 <code>endat_poscon_callback</code> 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

4.6 Interrupt Handler

4.6.1 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

4.6.2 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 interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.3 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

4.6.4 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

4.6.5 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.6 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.7 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.8 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.9 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.10 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.11 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.12 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. <ul style="list-style-type: none"> 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
Arguments	None
Return value	None

4.6.13 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

4.7 Interrupts

Table 4.2 lists the interrupts for the EnDat driver.

Table 4.2 Interrupts for the EnDat Driver

Interrupt	ID *1		Outline
	CR52 ver.	CA55 ver.	
EnDat channel 0	388	716	Interrupts are generated by the following interrupt factors *2 1. ERR1, IERR2 interrupts 2. WTDG interrupt 3. EMPFR1-3 interrupts
EnDat channel 1	389	720	
EnDat channel 2	390	724	
EnDat channel 3	391	728	
EnDat channel 4	392	732	
EnDat channel 5	393	736	
EnDat channel 6	394	740	
EnDat channel 7	395	744	
EnDat channel 8	-	-	
EnDat channel 9	396	752	
EnDat channel 10	397	756	
EnDat channel 11	398	760	
EnDat channel 12	-	-	
EnDat channel 13	399	768	
EnDat channel 14	400	772	
EnDat channel 15	-	-	

- 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.
2. The channel 8, the channel 12, and the channel 15 are not available in this sample program. The interrupt requests EnDat channel 8, EnDat channel 12 and EnDat channel 15 are not generated.

4.8 Constants and Error Codes

The major constants and error codes are listed below. Table 4.3 lists user-defined constants for the EnDat driver (r_endat_rzt2_config.h), Table 4.4 lists EnDat 2.2 mode commands, Table 4.5 lists transmission clock frequencies, Table 4.6 lists watchdog timer time units, Table 4.7 lists low-level period at the start of data transmission, and Table 4.8 lists the MRS codes. The error code is given in section "4.10.3(1), r_endat_err_t".

Table 4.3 User-defined Constants for 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 5 to 255 times.
R_ENDAT_ADD_NUM	0u	Number of additional information to receive

Table 4.4 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 4.5 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 4.6 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 4.7 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 4.8 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.

4.9 Fixed-Width Integer Types

Table 4.9 lists the fixed-width integers for the sample code. These fixed-width integers are defined in the standard libraries.

Table 4.9 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)

4.10 Structures, Unions, and Enumerated Types

4.10.1 Structures

(1) r_endat_info_t

Initialization information of the EnDat control unit

```
typedef struct
{
    uint8_t          ftclk;          Transmission clock frequency setting
                                See "Table 4.5 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/N2H.

    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 4.7 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 p_enc_init_tclk_wait; A pointer to a callback function that generates the wait
                                time after activating TCLK pin output.
                                See "4.5.1 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 "4.5.2 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 "4.5.3 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 "4.5.4 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 "4.5.5 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 4.6 Watchdog Timer Time Units"
    uint8_t          time;    Set the time for the Watchdog Timer
                        See "Table 4.10 Watchdog Timer Table"
} r_endat_watchdog_t

```

Table 4.10 Watchdog Timer Table

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 4.11 Mode Command Combination Table".

```

typedef struct
{
    uint8_t          mode_cmd;    EnDat 2.2 Mode Command
                                See "Table 4.4 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 4.8 MRS Codes".
                                The setting is valid only if the mode command
                                combined with the MRS code in the "Table 4.11 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 4.11 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 4.11 Mode Command Combination Table" is
                                designated as the mode_cmd.
    r_endat_watchdog_t watchdog; Setting time of watchdog timer
                                See "4.10.1(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
                                WTD0G 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 p_isr_result; Pointer to a callback function that conveys the result
                                of the request.
                                See "4.5.6 endat_callback" and "4.5.7
                                endat_poscon_callback" for details.
                                Do not set NULL.
    r_endat_isr_rdst_cb_t p_isr_rdst;  Pointer to a callback function that conveys that the
                                next data communication is ready.
                                See "4.5.8 endat_rdst_callback" for details.
                                Do not set NULL.
} r_endat_req_t

```

Table 4.11 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 "4.10.3(3) r_endat_req_err_t".
    r_endat_data_t      data;             Received data
                                     See "4.10.1(5) r_endat_data_t".
    r_endat_status_t    status;           Encoder Status
                                     See "4.10.1(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.) *1
} r_endat_protocol_err_t

```

Note: 1. This is reserved for driver interface compatibility with RZ/T2M group EnDat encoder driver. This is not used in the driver for RZ/N2H.

4.10.2 Unions

No unions are used.

4.10.3 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_req_err_t
```

4.11 Description of the Sample Program

4.11.1 Operation Outline

This sample program supports the EnDat 2.2 compliant encoder "EQN1035". This sample program performs the following process.

- 1) Send requests input from the console to the EnDat encoder (EQN1035).
- 2) Display the data received from the EnDat encoder (EQN1035).
- 3) Send and receive commands using the ELC event input trigger function of the EnDat Interface. (GPT events are linked as input events.)

(1) System Block Diagram

Figure 4.1 shows a block diagram of the system.

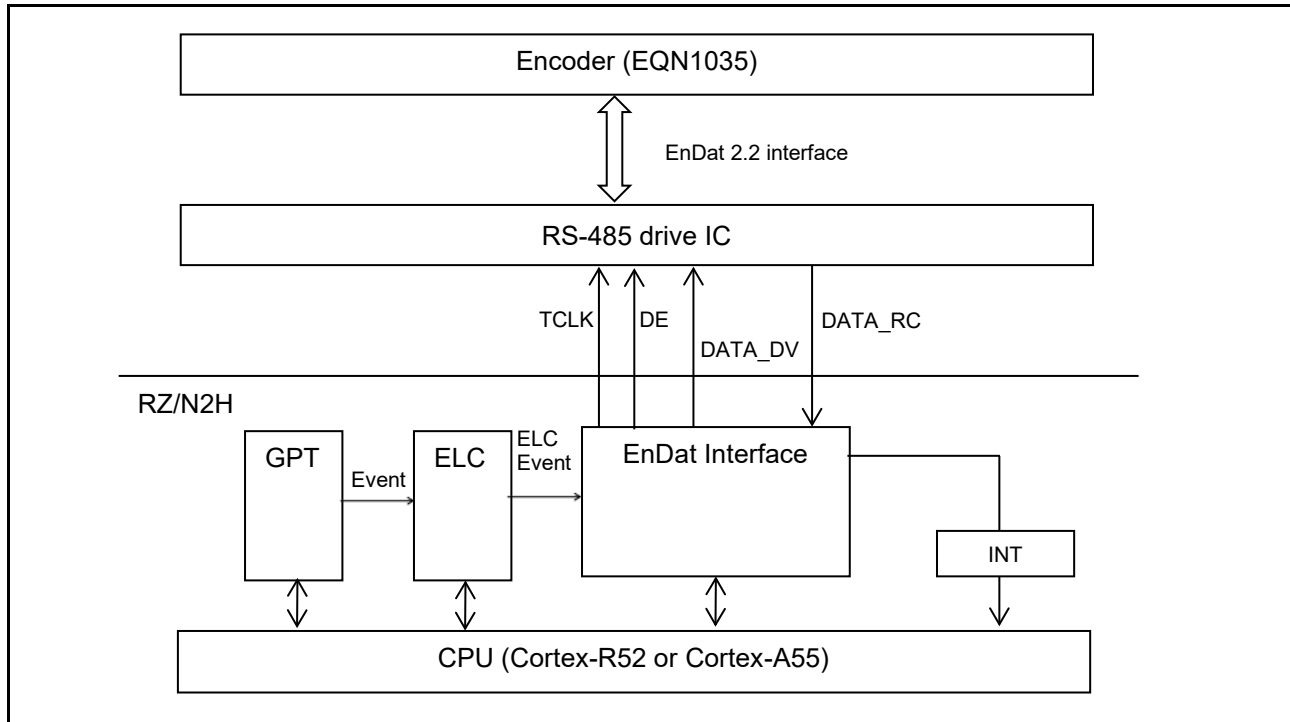


Figure 4.1 System Block Diagram

(2) Software Structure

Figure 4.2 shows the structure of the software.

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

The sample program has an EnDat driver controller section that controls the EnDat driver and sends requests, and a results indication section (callback) that displays the results of data reception.

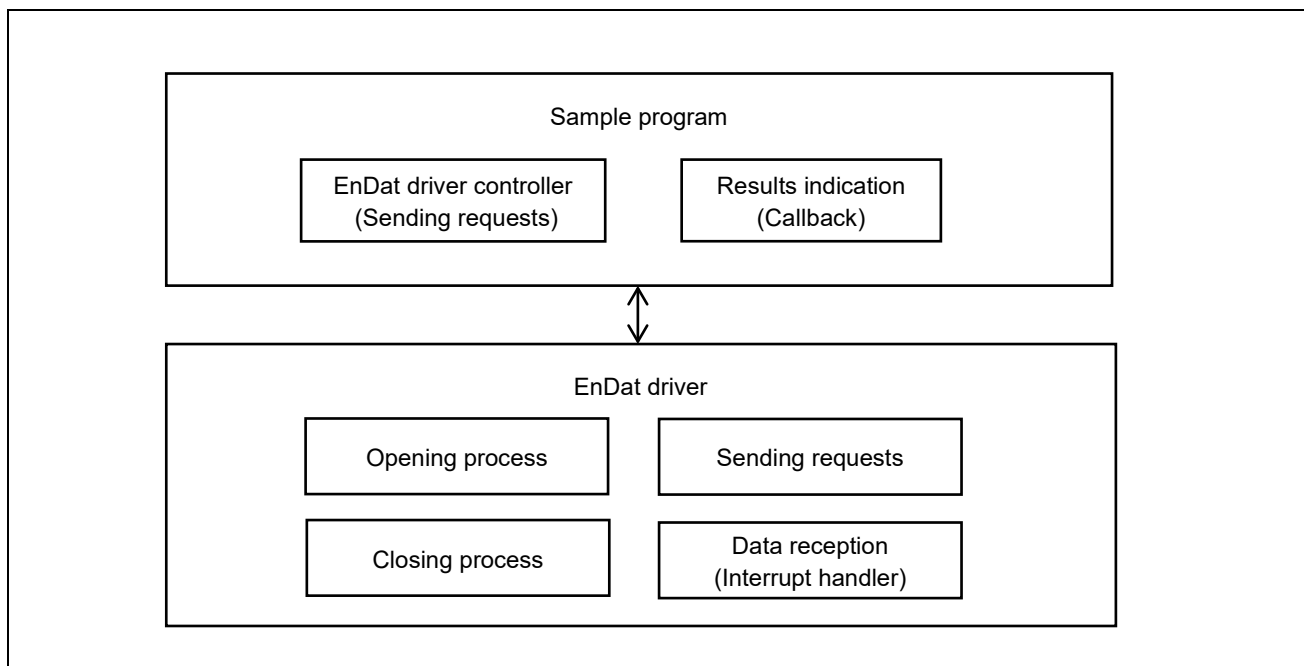


Figure 4.2 Software Structure

4.11.2 Sample Program Functions

Table 4.12 lists the major functions of the sample program.

Table 4.12 Major Functions of the Sample Program

Function Name	Page Number	
	Specification	Flowchart
hal_entry	35	-
enc_main	35	43
endat_cmd_control	35	43
endat_power_on_wait	35	-
enc_init_tclk_wait_callback	36	-
enc_init_reset_wait_callback	36	-
enc_init_mem_wait_callback	36	-
enc_init_pram_wait_callback	36	-
enc_init_cable_wait_callback	37	-
endat_pos	37	44
endat_poscon	37	45
endat_elctimer	37	46
endat_stop	38	47
endat_temp	38	48
endat_callback	38	49
endat_poscon_callback	38	50
endat_rdst_callback	39	50
get_cmd	39	-
cmd_exit	39	-
result_display	39	-
timer_start	40	-
timer_stop	40	-

4.11.3 Specifications of Sample Program Functions

(1) hal_entry

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

(2) enc_main

enc_main	
Synopsis	Main function of the EnDat sample program
Header	-
Declaration	int32_t enc_main(uint8_t ch);
Description	This is the main function of the EnDat sample program. For details, see section "4.11.6(1), Flowchart of enc_main".
Arguments	ch Encoder channel number 0: specify channel 0, 1: specify channel 1, ..., 15: specify channel 15
Return value	0 : Normal termination Others : Abnormal termination (error code of the encoder IF driver)
Note	The channel 8, the channel 12, and the channel 15 are not available in this sample program.

(3) endat_cmd_control

endat_cmd_control	
Synopsis	EnDat driver control function
Header	-
Declaration	static void endat_cmd_control(void);
Description	This function performs the following operations: <ul style="list-style-type: none"> • Start of EnDat encoder control • Console command input processing • Termination of EnDat encoder control
Arguments	None
Return value	None

(4) 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

(5) 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 "4.5.1 enc_init_tclk_wait_callback".
Arguments	None
Return value	None

(6) 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 "4.5.2 enc_init_reset_wait_callback".
Arguments	None
Return value	None

(7) 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 "4.5.3 enc_init_mem_wait_callback".
Arguments	None
Return value	None

(8) 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 "4.5.4 enc_init_pram_wait_callback".
Arguments	None
Return value	None

(9) enc_init_cable_wait_callback

enc_init_cable_wait_callback	
Synopsis	Waiting 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 "4.5.5 enc_init_cable_wait_callback".
Arguments	None
Return value	None

(10) 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

(11) 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.
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

(12) 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

(13) 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

(14) 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

(15) 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

(16) 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

(17) 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 ELC mode. This function sets the acquisition completion flag.
Arguments	None
Return value	None

(18) get_cmd**get_cmd**

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

(19) cmd_exit**cmd_exit**

Synopsis	Function to indicate end of the EnDat sample program
Header	-
Declaration	static void cmd_exit(uint32_t arg_num, char_t *p_arg[]);
Description	This function is executed when the console command exit is entered. It indicates an end of the EnDat sample program in the console.
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

(20) result_display**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 EnDat.
Arguments	p_result : Result of the request transmission p_err : EnDat I/F and encoder error information
Return value	None

(21) timer_start

timer_start

Synopsis	GPT unit 0 channel 0 cycle setting/startup function
Header	-
Declaration	static void timer_start(uint32_t us);
Description	This function sets the timer interval on GPT unit 0 channel 0, and starts the timer.
Arguments	us : Timer interval [us]
Return value	None

(22) timer_stop

timer_stop

Synopsis	GPT unit 0 channel 0 timer stop
Header	-
Declaration	static void timer_stop(void);
Description	This function stops GPT unit 0 channel 0 timer.
Arguments	None
Return value	None

4.11.4 Variables of Sample Program

Table 4.13 lists the major static type variables. Const type variables are not used.

Table 4.13 Major Static Variables

Type	Variable Name	Description	Function to be used
bool	endat_flg	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 arrays 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	cur_id	Used EnDat interface driver ID	enc_main endat_cmd_control endat_pos endat_poscon endat_elctimer endat_stop endat_temp

4.11.5 Constants of Sample Program

Table 4.14 lists the major constants used in the sample program.

Table 4.14 Major Constants

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

4.11.6 Flowchart of Main Processing

(1) Flowchart of enc_main

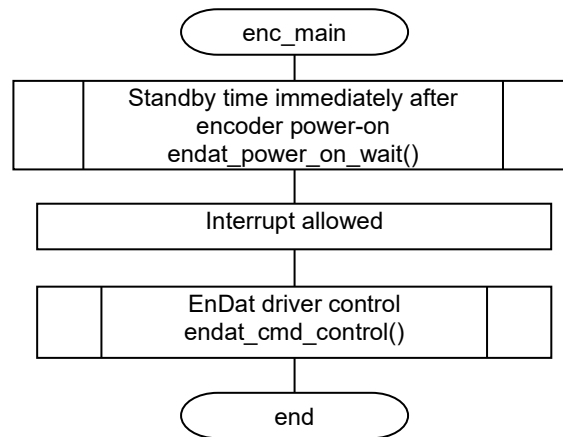


Figure 4.3 Flowchart of enc_main Function

(2) Flowchart of endat_cmd_control

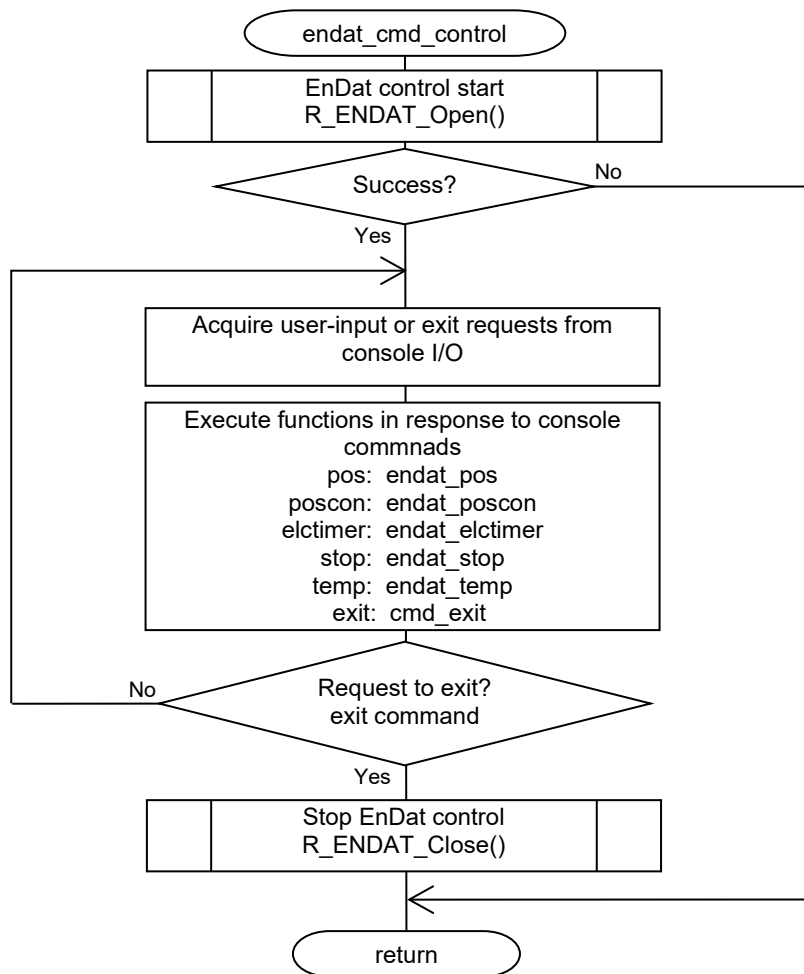


Figure 4.4 Flowchart of endat_cmd_control Function

(3) Flowchart of endat_pos

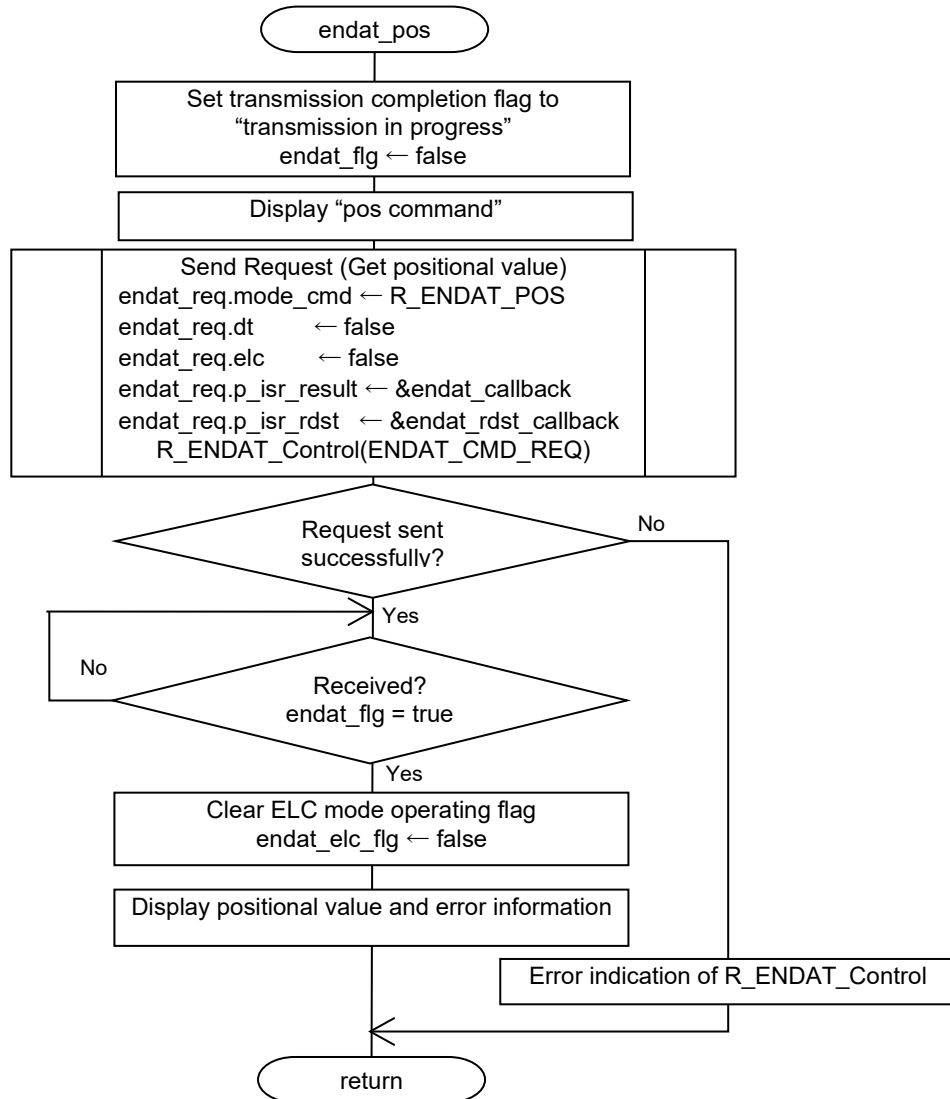


Figure 4.5 Flowchart of endat_pos Function

(4) Flowchart of endat_poscon

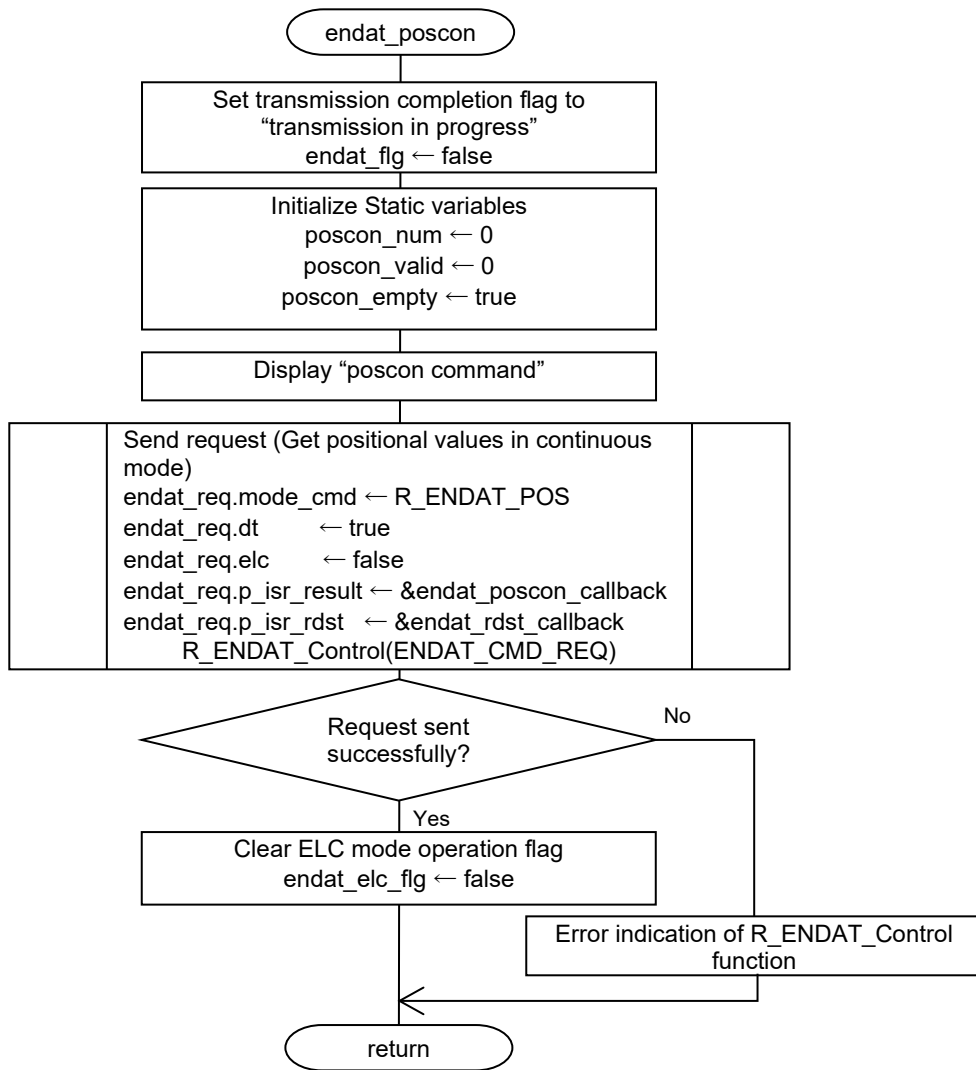


Figure 4.6 Flowchart of endat_poscon Function

(5) Flowchart of endat_elctimer

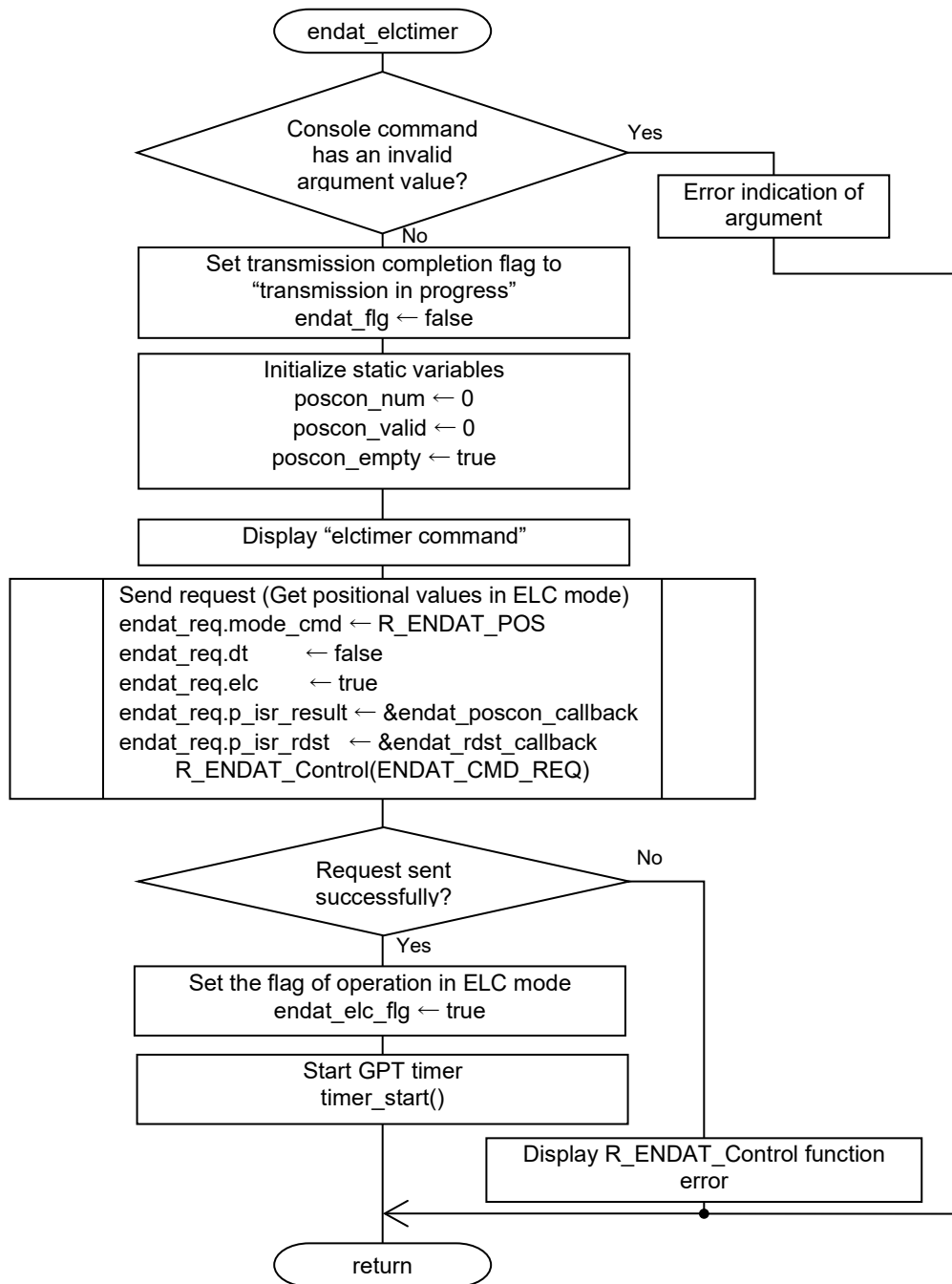


Figure 4.7 Flowchart of endat_elctimer Function

(6) Flowchart of endat_stop

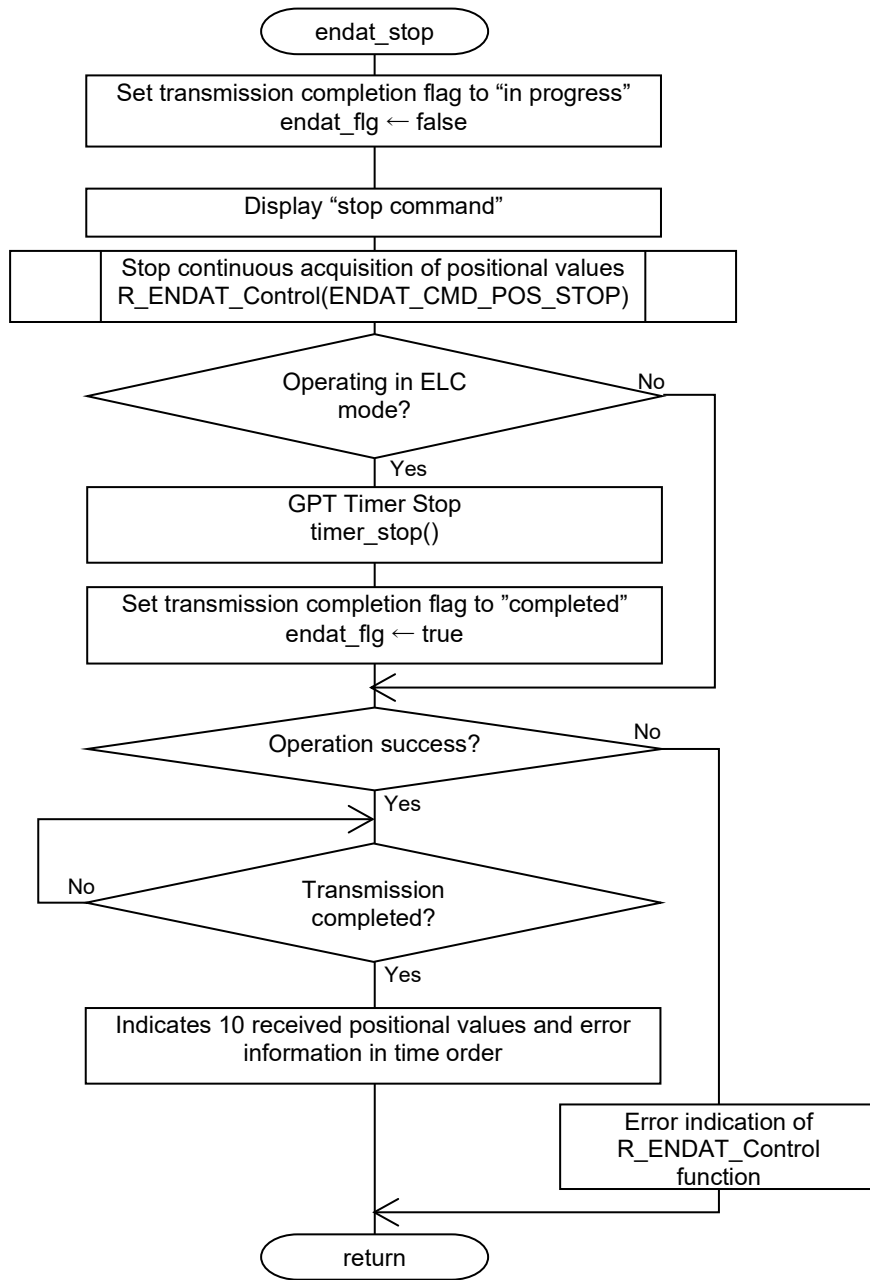


Figure 4.8 Flowchart of endat_stop Function

(7) Flowchart of endat_temp

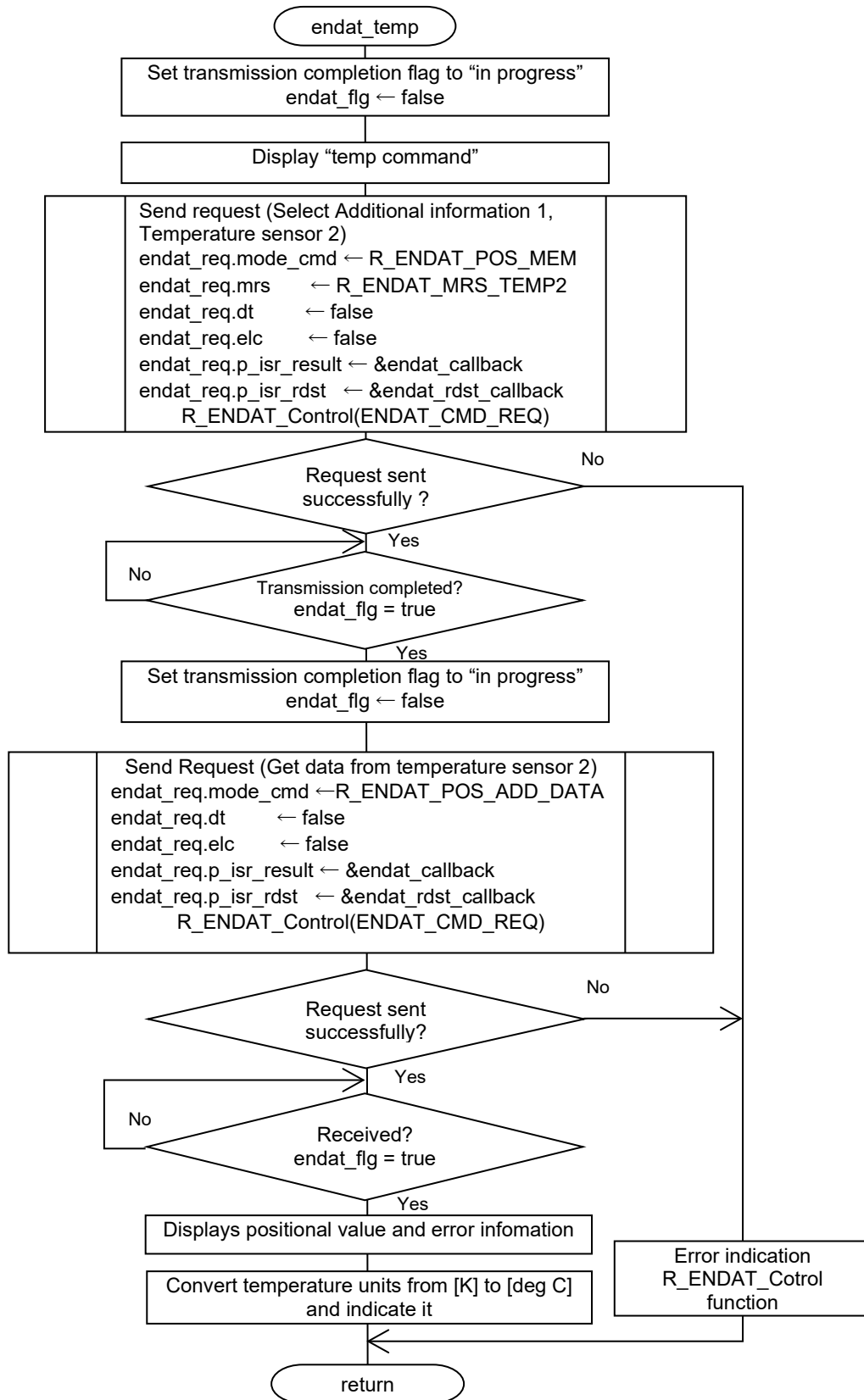


Figure 4.9 Flowchart of endat_temp Function

(8) Flowchart of endat_callback

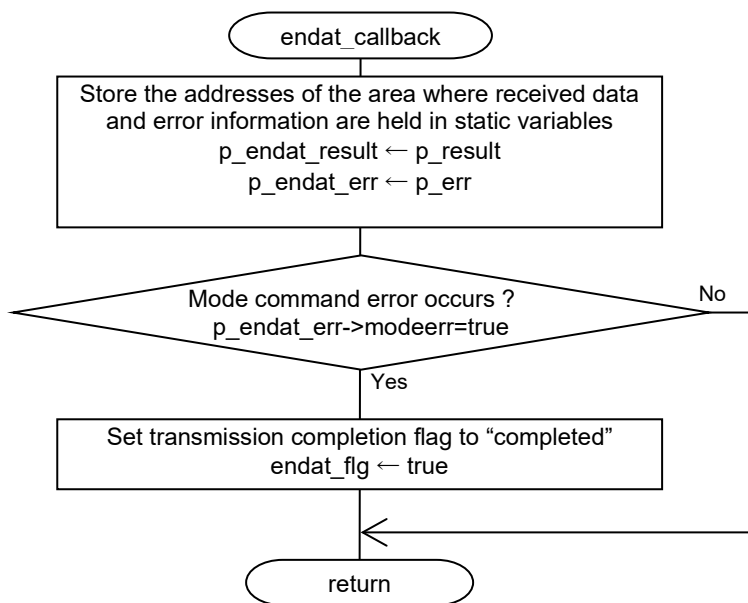


Figure 4.10 Flowchart endat_callback Function

(9) Flowchart of endat_poscon_callback

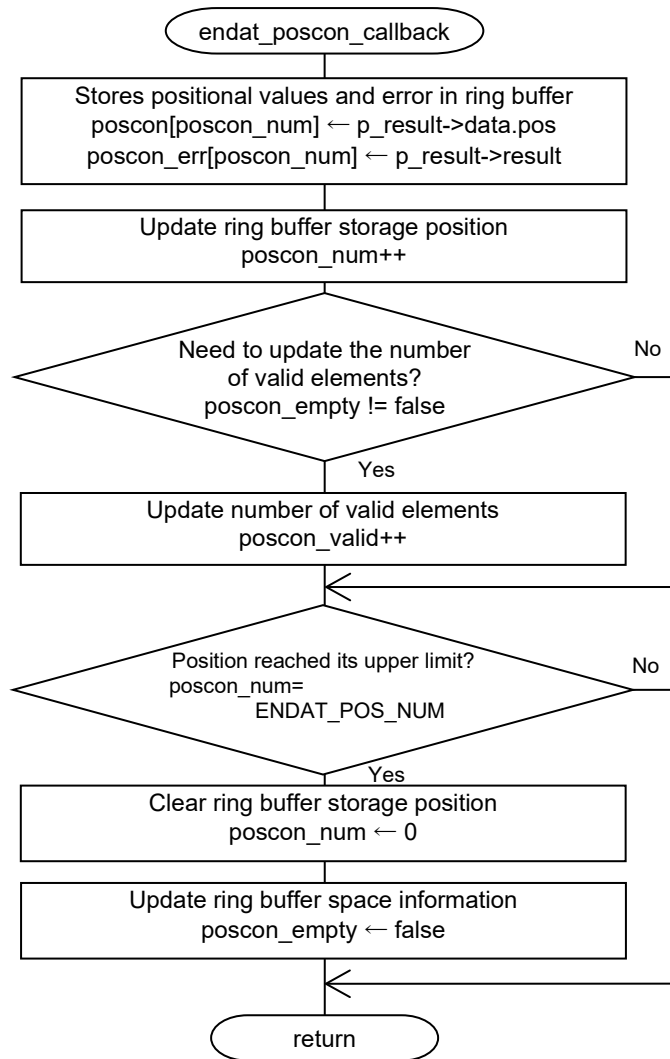


Figure 4.11 Flowchart endat_poscon_callback Function

(10) Flowchart of endat_rdst_callback

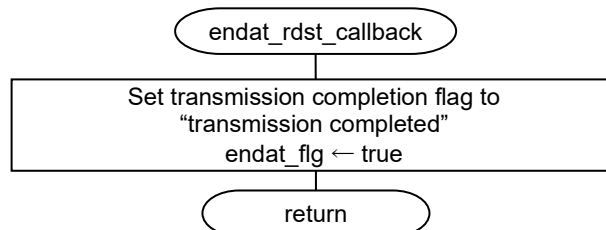


Figure 4.12 Flowchart of endat_rdst_callback Function

4.11.7 Operation Sequence

(1) Start Sequence

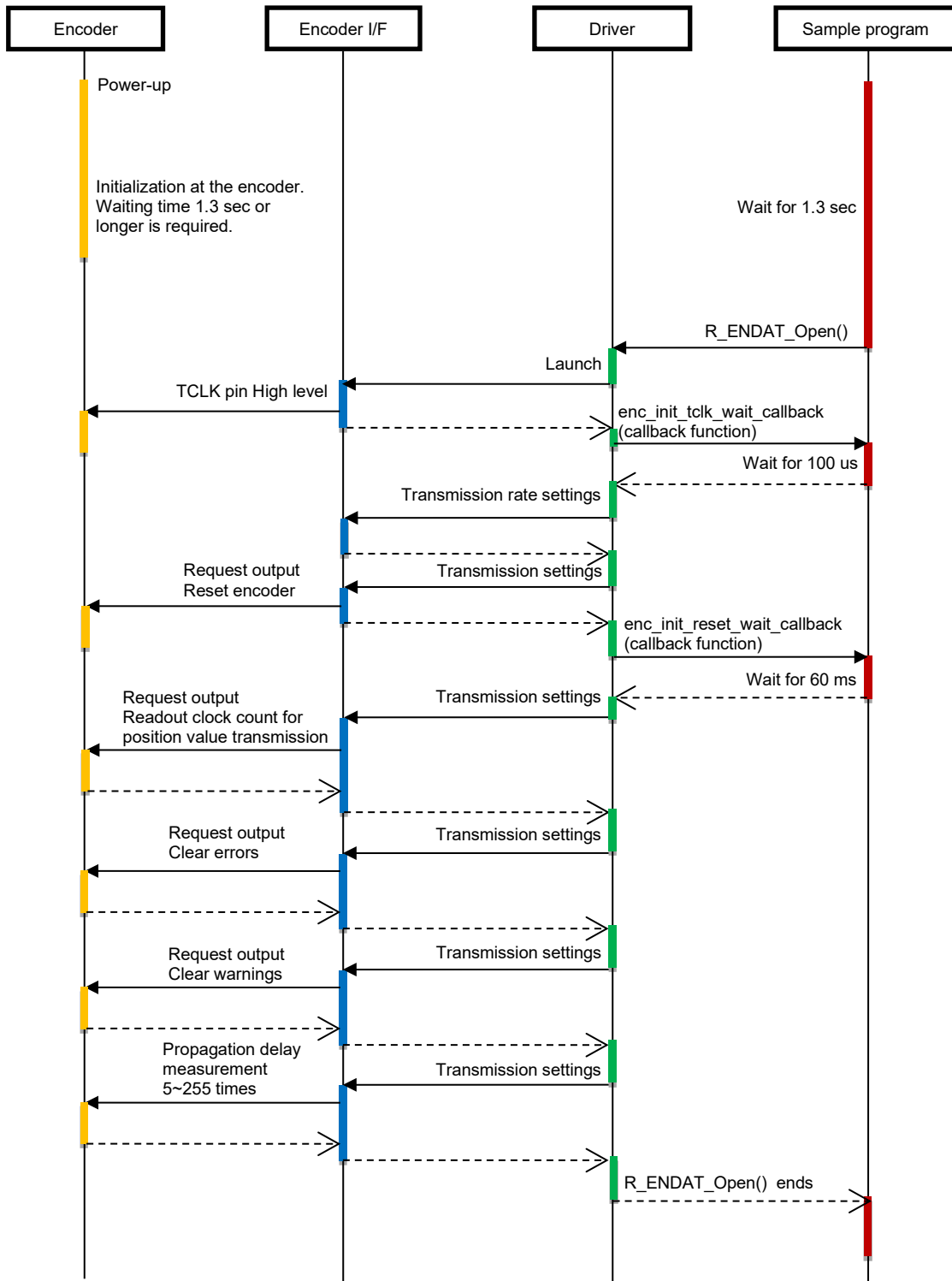


Figure 4.13 Start Sequence Diagram

(2) Request Transmission and Data Reception Sequence

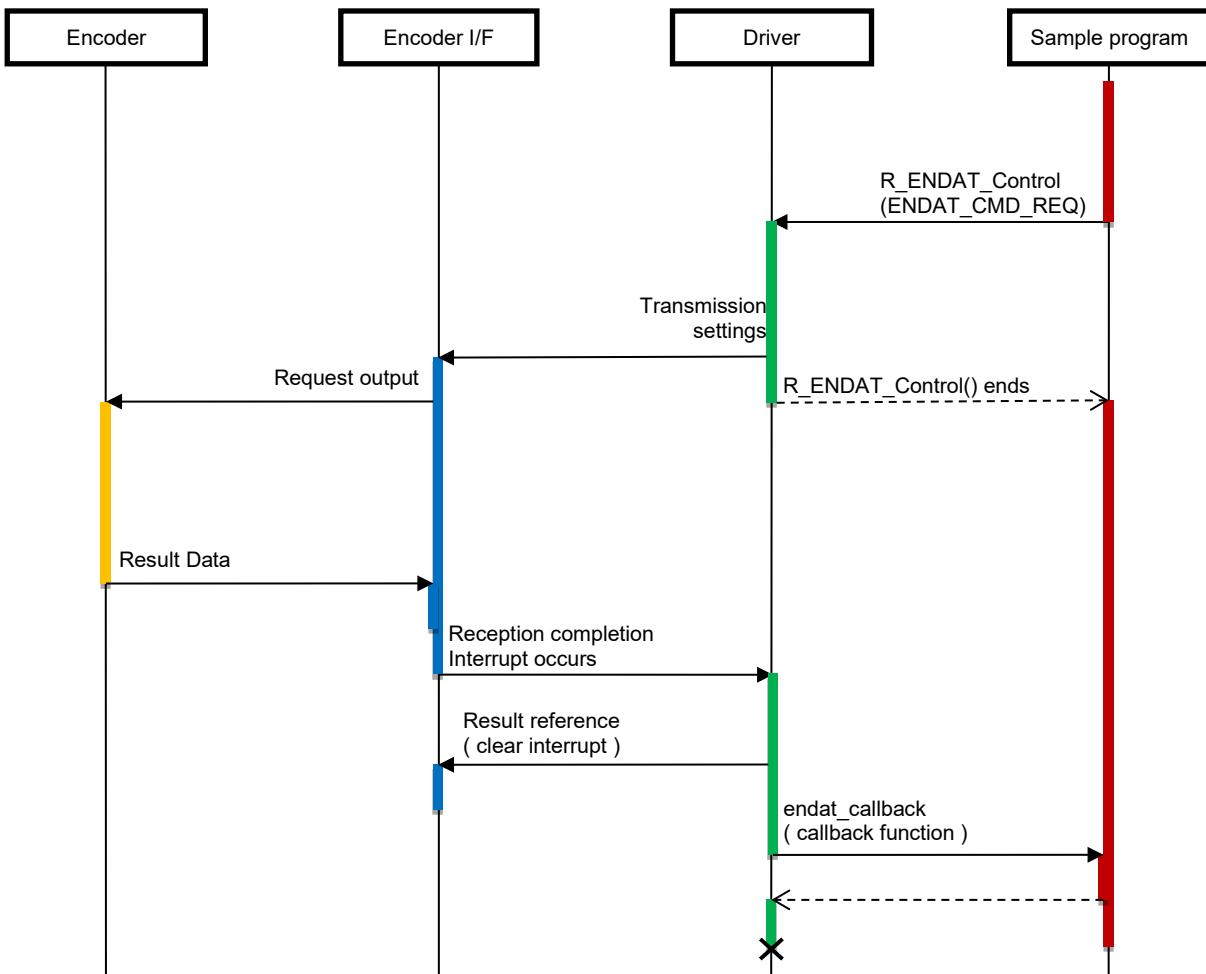


Figure 4.14 Request Transmission and Data Reception Sequence Diagram

(3) Request Transmission (Continuous Mode) and Data Reception Sequence

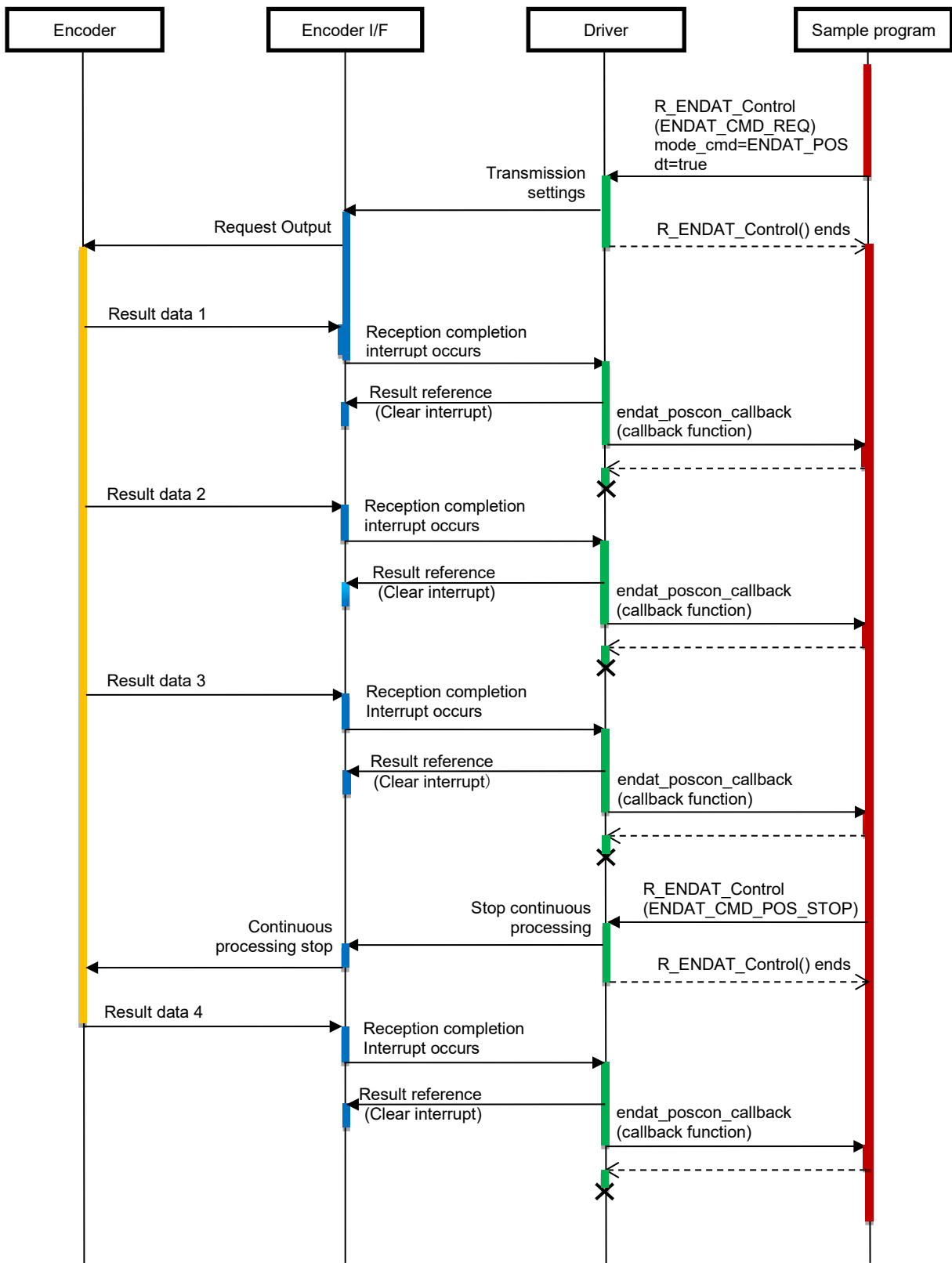


Figure 4.15 Request Transmission (Continuous Mode) and Data Reception Sequence Diagram

(4) Request Transmission (ELC Mode) and Data Reception Sequence

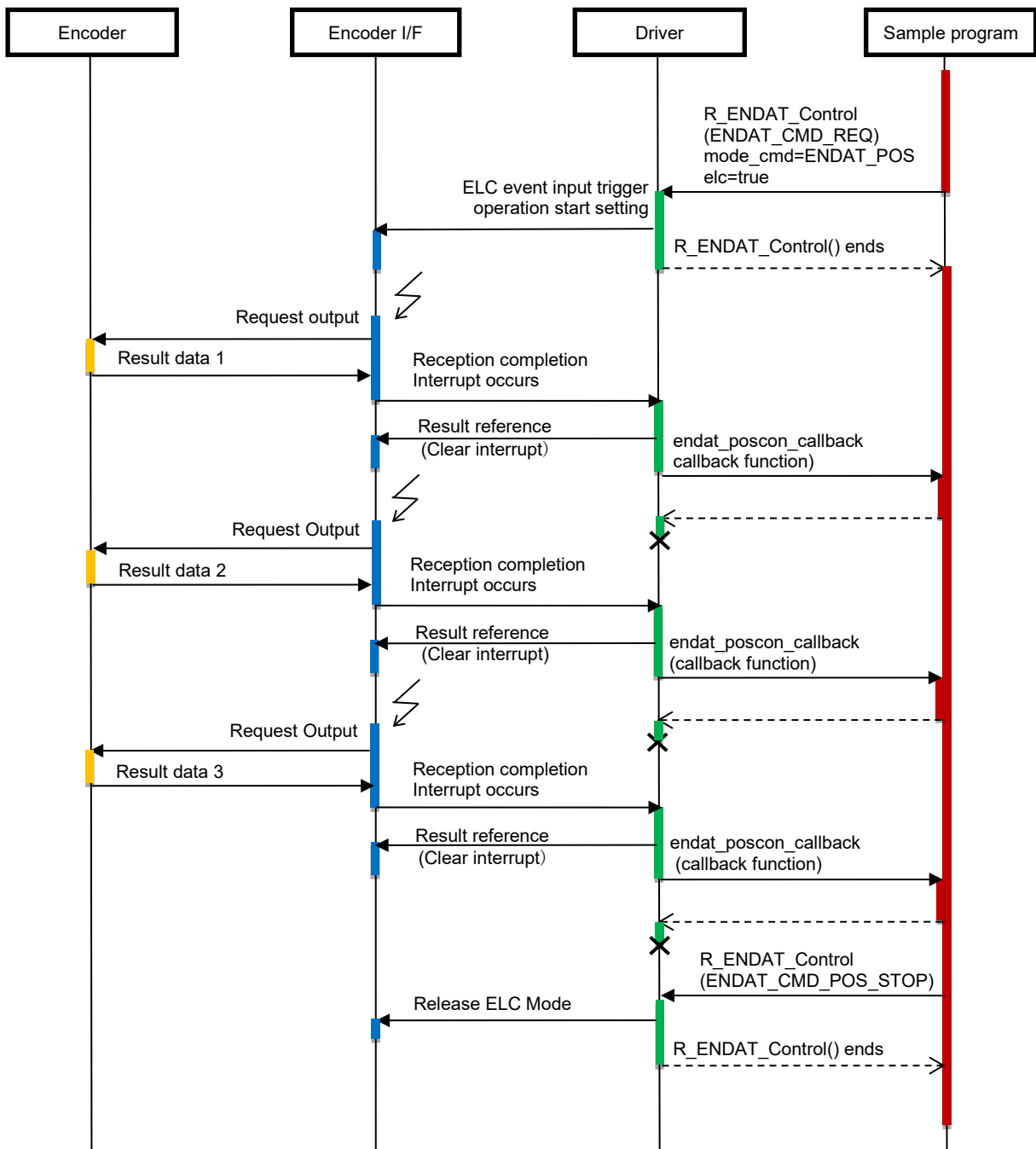


Figure 4.16 Request Transmission (ELC Mode) and Data Reception Sequence Diagram

(5) Stop Sequence

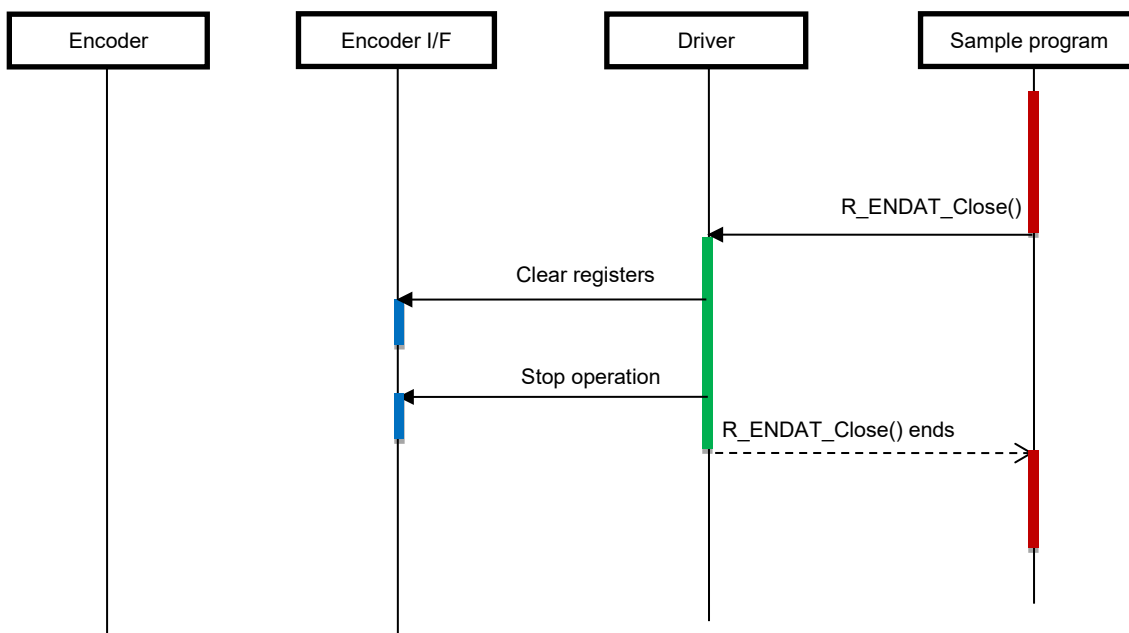


Figure 4.17 Stop Sequence Diagram

4.11.8 Console Commands

This sample program corresponds to the EnDat 2.2 compliant encoder "EQN1035". The command available for input from the console are listed below.

Table 4.15 Console Commands

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

(1) Result of Running

After running, it will display the command prompt. Enter the command after "endat >".

```
EnDat sample program start
endat >
```

(2) Example of Command Execution

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

```
endat >pos
pos command
  result      : ENDAT_SUCCESS
  pos_upper   : 0x00000000
  pos_lower   : 0x0028DB42
  add_datum1  : 0x00000000
  add_datum2  : 0x00000000
```

5. Sample Code

The sample code is available from the Renesas Electronics website.

Revision History

Rev.	Date	Description	
		Page	Summary
2.00	Dec.23.24	-	First edition
3.00	Nov 21.25	1, 4, 5	Change description for trademarks.
4.00	May 08.26	5 10 to 17, 37 to 39 14 to 17	Change frequency of the Cortex-A55 Core0 to 1200MHz. Change prefix of pointer variables to "p_". Revise header column of the specifications of user-defined functions.

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

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.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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