17-bit Encoder Specification Conforming to Format A

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Approval	Verification	Planning
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History

REV	Date	Description	Remarks

1. Application

This specification applies to encoders which are installed in SHA actuators and whose communication specification conforms to format A.

2. Outlines

The encoders specified herein are 33-bit multi-revolution absolute encoders, each consisting of absolute positions with a resolution of 17 bits per revolution achieved by a unique magnetic system, and a 16-bit multi-revolution counter backed up by a battery.

3. Basic specifications

3.1 Resolution

	Single-revolution part (ST)	Multi-revolution part (MT)
Resolution	217 (Addresses 0 to +131071)	216 (65536 revolutions)

３．２ Response speed

(1) Normal operation: 6000r/min

(2) Backup operation: 6000r/min

３．３ Types of operation modes

Three operation modes are available, as shown in the table below, according to the power-supply voltage.

(1) Separate battery wiring

Status	Main power voltage Vcc (TYP)	External battery Input voltage (TYP)	For internal back-up Capacitor voltage (TYP)
Normal operation mode	4.75 to 5.25 V	—	—
Backup operation mode	0V	2.9 to 4.0 V	—
		Less than 2.9 V	2.9V or more
Non-operation mode	0V	Less than 2.9 V	Less than 2.9 V

(2) Common battery wiring

Status	Main power voltage Vcc (TYP)	For internal back-up Capacitor voltage (TYP)
Normal operation mode	4.75 to 5.25 V	—
Backup operation mode	2.9 to 4.0 V	—
	Less than 2.9 V	2.9V or more
Non-operation mode	Less than 2.9 V	Less than 2.9 V

3.3.1 Normal Operation Mode

In this mode, single-revolution data and multi-revolution data can be counted and data can be sent/received.

If the main circuit is turned on in the non-operation mode, it will take up to 5 seconds until the clock oscillation circuit stabilizes and internal initialization process is completed. The BUSY flag is set during this period. Once the clock stabilizes, data can be sent/received.

When switching from the backup mode to normal operation, data can be sent/received after an elapse of at least 5 seconds.

When switching from the backup mode to normal operation mode (when the power is turned on), the rotational speed must be kept to 300 r/min or below. If the rotational speed of the encoder increases to 300 r/min or above after the main power has been turned on, absolute single-revolution position data cannot be confirmed and thus the BUSY flag is set. Once the rotational speed drops and confirmation of absolute positions becomes possible, the BUSY flag is automatically cancelled at point and absolute position data is confirmed. Note, however, that the BUSY flag is automatically cancelled even when the rotational speed is 300 r/min or above, as long as absolute position data is confirmed.

3.3.2 Back-up status

This is the mode where multi-revolution counting operation is possible due to the external battery power supply or internal backup power supply. In this mode, sending/receiving of data is stopped.

Internal operations are discrete in that the power is supplied to each circuit/cut off repeatedly.

3.3.3 Non-operation mode

This is the mode where all encoder operations are stopped. In this mode, the MT error flag is latched in the encoder. The flag will be sent to an external device once the main power is turned on.

3.3.4 Checking of Alarm Status Flag

WHILE THE BUSY FLAG IS SET, INDICATION OF THE ALARM STATUS FLAG IS INDETERMINABLE.

Check/confirm the alarm status flag while the BUSY flag is cancelled.

3.4 Communication Function

3.4.1 Communication Function by Bus Connection

Up to eight encoders can be connected via a bus. Connect each encoder to the bus by setting a unique encoder address. When a specified command signal is sent to the encoder, the encoder converts specified data to serial signals and sends the converted signals.

Two modes are available, as explained below, in which the encoder outputs data.

- Individual transmission mode: In this mode, multiple encoders connected to the bus receive a specified command from the controller and then compare their pre-set encoder address against the command signal, after which only those encoders whose encoder address matches the command signal send data.
- Multiple transmission mode: In this mode, multiple encoders connected to the bus receive a specified command from the controller and then send data continuously according to the different communication start timings which are set based on the pre-set encoder addresses.

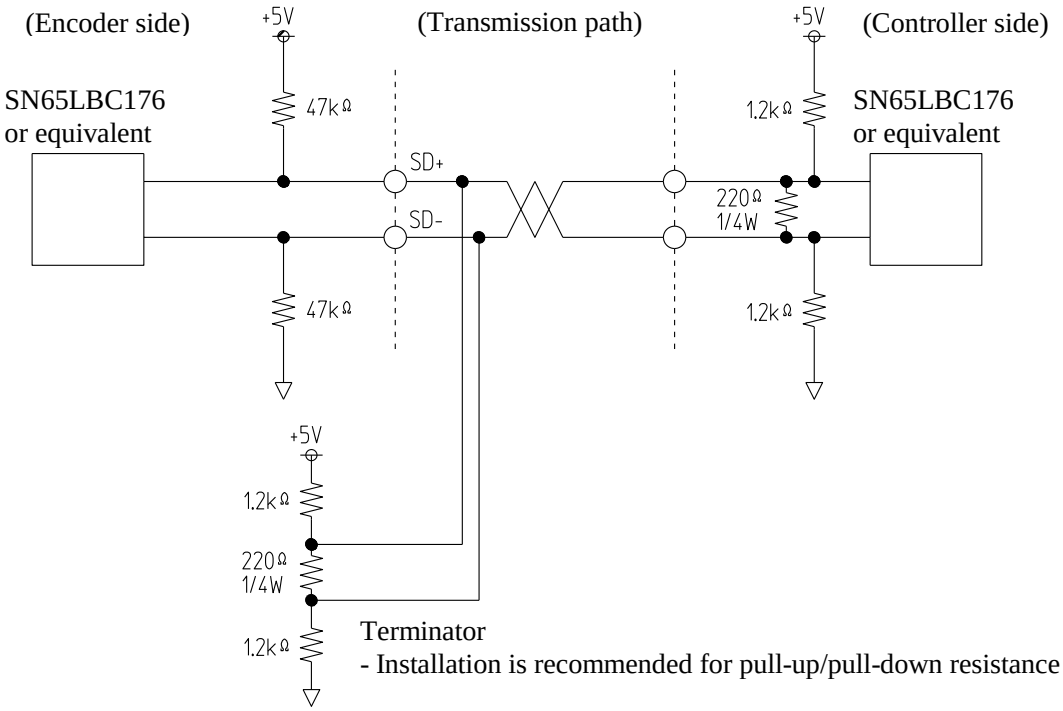
3.4.2 Communication Function by One-on-One Connection

The encoder communicates with the controller one on one. The encoder outputs data in the individual transmission mode. The encoder address of the connected encoder must be specified in the command signal.

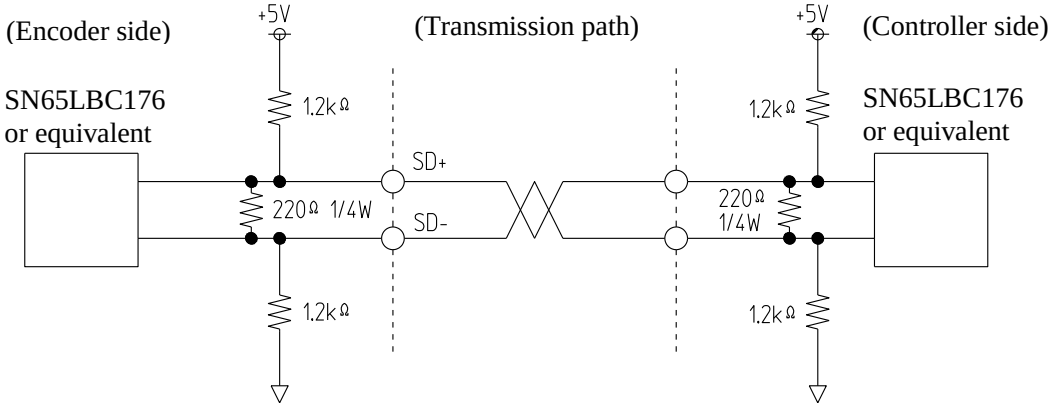
Note1. The hardware specification varies between the communication functions by bus connection and one-on-one connection.

3.4.3 Examples of Send/Receive Circuits

(1) Bus connection



(2) One-on-one connection



Note) The above send/receive circuits as well as constants, wirings, etc., shown in the reference connection patterns may vary depending on the actual environment of use. Make adjustments according to the condition.

Also note that depending on the wiring length, the effect of voltage drop may not be unignorable.

3.5 Communication Speed

The standard communication speed between the encoder rand controller is 2.5 Mbps.

Note) The software specification varies depending on whether the communication speed is 4 Mbps or 2.5 Mbps.

* The communication speed and connection pattern are identified by “10” in the model number shown below.

SHA xx x xxx xx – x xx x xxx – xx x xxx x - xx – xx
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

MA x xx x xxx – xx x xxx x – xx – xx
1 6 7 8 9 10 11 12 13 14 15

10: Communication speed/connection pattern

Indication	Communication speed	Connection pattern
10	2.5 Mbps	One-on-one connection
11	2.5 Mbps	Bus connection
12	4 Mbps	One-on-one connection
13	4 Mbps	Bus connection

4. Electrical Specifications

4.1 Absolute Maximum Ratings

Item	Symbol	Rated value	Unit
Main power voltage	Vcc	-0.3～6.0	V
External battery voltage	Vbat	-0.3～6.0	V

４．２ Electrical characteristics

Item	Conditions	Rated value			Unit
		MIN	TYP	MAX	
Main power voltage Note 1)	Normal operation (Ripple: 1% or below)	4.75	5.0	5.25	V
External battery input voltage	Backup operation	3.25	3.6	4.0	V
Normal operation <- -> Backup operation Note 1)	Normal -> Backup	4.1	4.2	4.3	V
	Backup -> Normal	4.14	4.32	4.5	V
MT error voltage generated Note 2)	Backup operation	2.80	2.90	3.00	V
Battery alarm voltage generated Note 2)	External battery voltage	3.05	3.15	3.25	V
Permitted starting time of data send	Backup -> Normal operation After mode switching:			5	s
The power supply impedance is assumed as 0.	Non-operation -> Normal operation After mode switching:			5	s
Temperature alarm detection	Board temperature	91	95	99	℃
Response speed	Non-operation -> Normal Backup -> Normal			300	r/min
	Normal operation			6000	r/min
	Backup operation			6000	r/min
Current consumption during normal operation Note 3)	When the capacitor has been discharged		155	185	mA
	Normal operation		150	180	mA
Battery current consumption during backup Note 4)	Stopped		50	70	μA
After charging for at least 10 minutes at an ambient temperature of 20° C and Vcc of 5 V	Rotating		320	350	μA

Back-up time Note 5)	After charging for at least 3 hours at Vcc of 5 V	0.5			hour

Note 1) Voltage value at the power terminal on encoder side

Note 2) Voltage of the internal backup capacitor or that of the external battery, whichever is higher.

Note 3) Current consumption when the serial transmission line is open

Note 4) The battery current consumption during backup is calculated based on the slope of the line of measured changes in internal backup power-supply voltage over time.

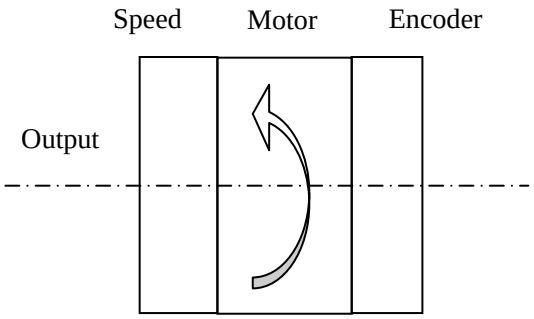
Note 5) Value measured with all axes stopped prior to product shipment

4.3 Electrical Specifications Per Revolution

Item		Specifications	Remarks
Resolution		2^{17} ST[19:3]	Addresses 0 to +131071 ST[02:00]=0 (The last 3bit are zero.)
Maximum rotation speed	Normal operation	6000r/min	
Output code		Binary	
Increasing direction		CCW	Depending on the rotating direction of the motor shaft shown below
Motor shaft accuracy		±0.1°	

4．4 Electrical Specifications over Multiple Revolutions

Item		Specifications	Remarks
Resolution		1 count/rotation	
Maximum multi-revolution counter value		2^{16} MT[15:0]	65,536 rotations
Maximum rotation speed	Normal operation	6000 r/min	
	Backup operation	6000 r/min	
Output code		Binary	
Increasing direction		CCW	Depending on the rotating direction of the motor shaft shown below



CCW as viewed from the output shaft

Refer to the actuator specification for the rotating direction of the output shaft.

Note) ST[19:3], MT[15:0], etc., indicate bit ranges [upper bits: lower bits] .

4.5 Backup Part

4.5.1 Internal Backup Power Supply (Electrical Double-layer Capacitor)

(1) Definition of backup time

Backup time when no battery is connected. To be specific, the backup time refers to the time after which multi-revolution data can no longer be retained (the encoder switches to the non-operation mode), measured by supplying 5 VDC to Vcc for at least 3 hours so that the encoder can operate and then opening the Vcc terminal.

(2) Capacitor charge circuit

The capacitor is charged from the main power supply (5 VDC) and external battery via a diode/resistor.

(3) Capacitor life

The life of the built-in capacitor changes according to the ambient temperature. Be careful not to expose the encoder to an ambience of high temperature.

Also note that the life of the built-in capacitor also varies depending on the conditions of use.

４．５．２ External backup power supply (external battery)

(1) Battery whose operation is guaranteed: Lithium battery ER6V (3.6 V) by Toshiba

Capacity: 2000 mAh.

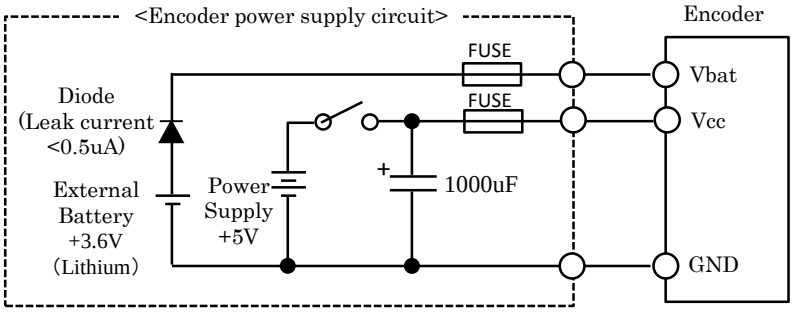
We recommend that you set up a battery protection diode with 0.5uA leak current or less to prevent charging to the battery. For reference, the encoder has a leak current characteristic of about 2μA at 25ºC and 35μA at 60ºC.

(2) Recommended power-supply circuit (reference)

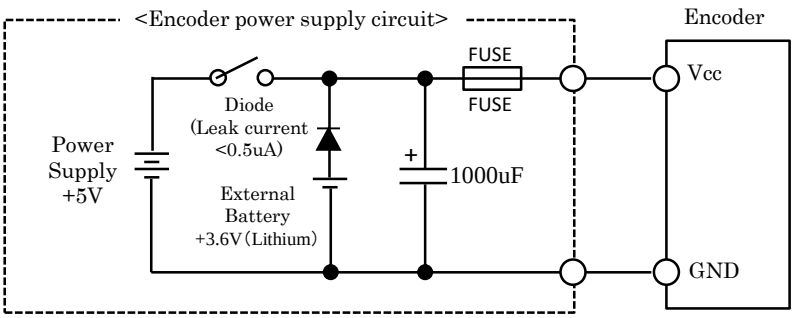
As a failsafe measure in the event of a voltage delay (VD) from the lithium battery, it is recommended to provide an electrolytic capacitor of approx. 1000 μm in the Vcc (5-V) line on encoder power-supply circuit side.(See the figure below.)

* About VD --- A phenomenon where the voltage drops temporarily when a larger-than-normal current is supplied, due to an impact of film generated on the surface of the negative electrode after the battery has not been used for many hours or has been used at very small current.

・Separate battery wiring



・Common battery wiring



4.5.3 Switching between Backup Power Supplies

The power is supplied from the main power supply (5 VDC), external backup power supply or internal backup power supply, whichever provides the highest voltage. Note, however, that the switching will not complete unless the voltage difference is equal to or greater than the forward voltage of the diode in the switching circuit.

5. I/O Signal

(1) Separate battery wiring

Connector pin layout

Constituted by twisted

Pin number	Signal name	Function
1	Vcc	Main power supply +5 V
2	GND	Signal ground (for Vcc)
3	SD+	Serial data signal
4	SD-	Serial data signal
5	Vbat	Battery power supply
6	GND	Signal ground (for Vbat)

Note) Use a twisted paired cable for the output cable.

(Twist a pair of wires for signal SD+ and SD-, Vcc and GND, and Vbat and GND, respectively.)

(2) Common battery wiring

Connector pin layout

Constituted by twisted

Pin number	Signal name	Function
1	Vcc	Common wiring of the main power supply of +5 V and battery of +3.6 V
2	GND	Signal ground
3	SD+	Serial data signal
4	SD-	Serial data signal

Note) Use a twisted paired cable for the output cable.

(Twist a pair of wires for signal SD+ and SD-, and Vcc and GND, respectively.)

6 Functional Explanation of Status Flags

Name	Explanation	How to cancel
BUSY FLAG (BUSY)	Function: A flag that confirms absolute single-revolution values. Once the magnetic sensor positions are confirmed, the flag is reset to "0." Detection timing: During normal operation (while the main power is input) Output: Not latched	Automatically reset (When the rotational speed becomes 300 r/min)
PS ERROR (PSERR)	Function: The multi-revolution detection block ([1]) in the high-speed operation part is compared against the multi-revolution detection block ([2]) in the auxiliary calculation part, and an alarm is generated if [1]≠ [2]. Detection timing: During normal operation Output: Latched	Reconnection of main power
ST ERROR (STERR)	Function: The single-revolution detection block ([1]) in the high-speed operation part is compared against the single-revolution detection block ([3]) in a separate circuit, and an alarm is generated if the discrepancy is equal to or greater than the specified mechanical angle A (refer to Note 1). Or, [1] is compared against the single-revolution block ([2]) in the auxiliary calculation part, and an alarm is generated if the discrepancy is equal to or greater than the specified mechanical angle B (refer to Note 1). Note1) The specified angle varies depending on the motor model. The motor model is identified by "6" and "7" in the model number*. Detection timing: During normal operation Output: Latched	Reconnection of main power
Overspeed Alarms (OVSPD)	Function: An alarm is generated if the rotational speed exceeds 6600 r/min during normal operation. During backup operation, an alarm is also generated if the rotational speed exceeds 6600 r/min (typ). Detection timing: During normal operation/backup operation Output: Latched	Command input (CDF8, CDF10) Reconnection of main power
Battery alarm (BATT)	Function: An alarm is generated if the voltage of the internal backup power supply and that of the external battery both drop to 3.15 V (TYP) or below. Detection timing: During backup operation Output: Latched	Command input (CDF8, CDF10)

Motor model		Specified angle A [°]	Specified angle B [°]
"6"	"7"		
B	09	8	12
B	12	6.2	12
B	15	5.1	12
A	21	3.3	7.5

MT ERROR (MTERR)	Function: An alarm is generated if the encoder switches to the non-operation mode and stops functioning as an encoder. To be specific, an alarm is generated if the voltage of the internal backup power supply or that of the external battery, whichever is higher, drops to 2.9 V (TYP) or below. Detection timing: During backup operation Output: Latched	Command input (CDF10)
MEMBUSY FLAG (MEMBUSY)	Function: A flag that indicates that the EEPROM in the encoder is being accessed. Once the access ends, the flag is reset to "0" Detection timing: During normal operation (when data is read or written or encoder address is set) Output: Not latched	Automatically reset (Cancelled after an elapse of time)
MEM ERROR (MEMERR)	Function: An error is generated upon occurrence of an invalid access to the EEPROM in the encoder. Detection timing: During normal operation (when data is read or written or encoder address is set) Output: Latched	Command input (CDF8, CDF10) Reconnection of main power
Temperature sensor alarm (OVTEMP)	Function: "1" is output if the board temperature in the encoder rises to 95° C (TYP) or above. Detection timing: During normal operation Output: Not latched	Automatically reset (Cancelled once the board temperature drops to 93° C (TYP) or below.)
INC ERROR (INCERR)	No detection functions available	—

* SHA xx x xxx xx – x xx x xxx – xx x xxx x - xx - xx
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

*MA x xx x xxx – xx x xxx x – xx – xx
1 6 7 8 9 10 11 12 13 14 15

7. Serial Communication

7.1 Serial Communication Specification

Item		Specification	Remarks
Transmission method		Half-duplex serial communication	CONFORMING TO EIA STANDARD RS-485
Transmission code		NRZ CODING	
Synchronous method		Start-stop	
Baud rate		2.5 Mbps/4 Mbps	
Command Data	Number of transferred frames	1 to 4 frames	
	Frame structure	18 bits/frame	
	Transmission error check	3-bit CRC code	P(X)=X3+X+1
Encoder Data	Number of transferred frames	1 frame	
	Frame structure	2 to 4 fields/frame	
	Field structure	18 bits/field	
	Transmission error check	8-bit CRC code	P(X)=X8+X4+X3+X2+1
	Position data format	Binary data 40 bits ABS [0:39]	When the resolution per revolution is 17 bits ABS[0:16]=ST[0:16] ABS[17:32]=MT[0:15] ABS [33:39] = ”0000000”
			When the resolution per revolution is 20 bits ABS[0:19]=ST[0:19] ABS[20:35]=MT[0:15] ABS [36:39] = ”0000000”

[Outlines]

When specified command signals are sent to the encoder, the encoder outputs various data, resets various status and revolution data, sets the encoder address or perform other specified operations depending on the content of each command.Two modes are available, as explained below, in which the encoder outputs data.

Individual transmission mode

In this mode, multiple encoders connected to the bus receive a specified command from the controller and then compare their pre-set encoder address against the command signal, after which only those encoders whose encoder address matches the command signal send data. This mode can be used with the transmission path connection patterns of one-on-one connection and bus connection.

Multiple transmission mode

In this mode, multiple encoders connected to the bus receive a specified command from the controller and then send data continuously according to the different communication start timings which are set based on the pre-set encoder addresses.

This mode can be used with the transmission path connection pattern of bus connection.

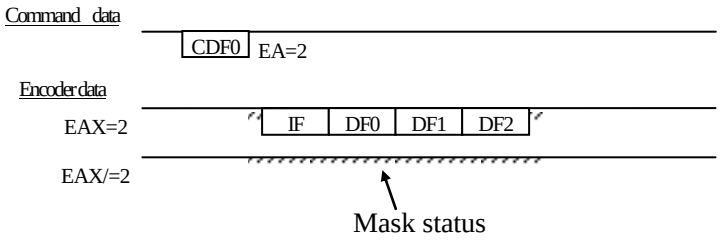
Note) The encoder address (EAX) is set to "0" (ENC1) prior to product shipment.

Note) As explained in 3.4.3, "Examples of Send/Receive Circuits," the communication circuit partially differs between an encoder supporting one-on-one connection and encoder supporting bus connection. Accordingly, an encoder supporting one-on-one connection cannot be used in a configuration based on bus connection (vice versa).

7.2 Frame Format

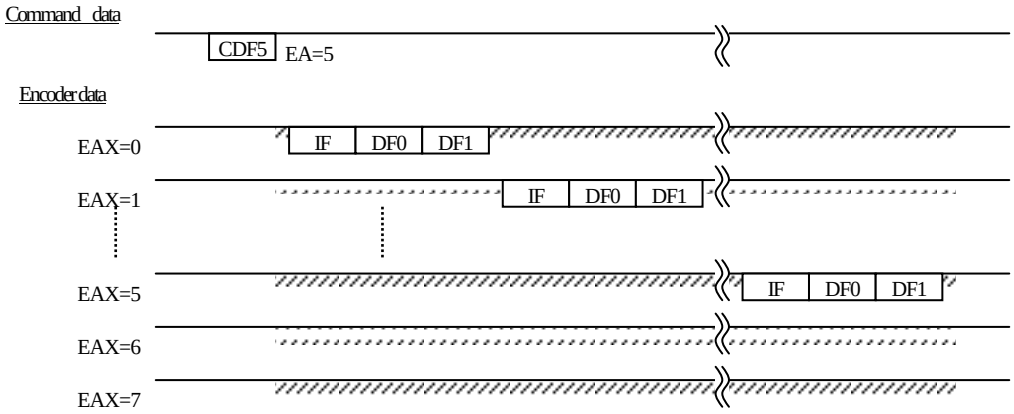
7.2.1 Position Data Request

(1) Individual transmission mode (Application commands: CDF0 to CDF3, CDF21, CDF27, CDF29)



- When any of CDF0 to 3, CDF21, CDF27 and CDF29 is received as command data, the encoder address (EA) specified in the command data is compared against the encoder address (EAX) set for each encoder, and those encoders whose encoder address matches output specified data.
- Other encoders whose address was found not matching are masked and do not accept commands while the matching encoders are outputting data.

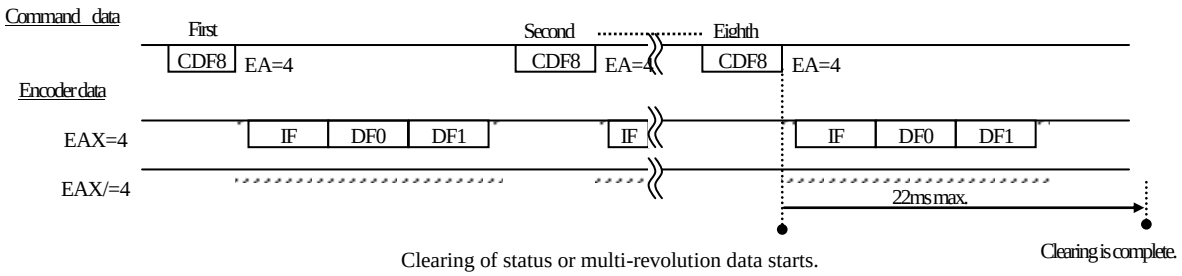
(2) Multiple transmission mode (Application command: CDF4 to CDF7, CDF22, CDF28, CDF30)



- When any of CDF4 to 7, CDF22, CDF28 and CDF30 is received as command data, the encoder address (EA) specified in the command data is compared against the encoder address (EAX) set for each encoder, and those encoders that meet the following condition output specified data continuously in the order from the smallest EAX value at the communication start timings set differently for respective encoders.

  Condition: EAX value ≦ EA value
- Other encoders that do not meet the above condition are masked.

7.2.2 Clear Request (Application command: CDF8, CDF9, CDF10)



- A clear request is issued in the individual transmission mode or axis stopped mode (250 min-1 or below).
- Send one of commands "CDF8 to 10" eight times consecutively to the encoder. The encoder returns status data in response to the command.

  Note) If other command is issued during the sending of eight consecutive commands, or the target command was found invalid due to noise, etc., the clear process is not performed. Send the command eight times consecutively.
- The following statuses or multi-revolution data can be cleared using the commands specified below.

  1) CDF: Status flag (overspeed, MT error, memory access error)

  2) CDF9: Multi-revolution data

  3) CDF10: Status flag + Multi-revolution data
- It takes up to 400 μs after the eighth clear request command is received until the target data is actually cleared. Since the original encoder data is retained during this period, issue a new command request after confirming that the target data has been cleared.

Note) If a clear request is issued while a status error is present and the cause of the status error is not yet resolved, the status error will be cancelled once but it will be detected again thereafter.

Internal encoder operations that take place when a clear request command is received while each status error is present are explained below.

■ Overspeed

- A clear request command is received at @6600 min-1 or below@

  The target data is cleared immediately after the eighth clear request command is received (the ALM[3]: OVSPD bit of encoder data changes to "0" upon receiving of the eighth clear request command).
- A clear request command is received at @6600 min-1 or above@

  The target data is cleared immediately after the eighth clear request command is received (the ALM[3]: OVSPD bit of encoder data changes to "0" upon receiving of the eighth clear request command), but an overspeed will be detected within 60 μs at most.

* Note, however, that if an overspeed of a multi-revolution system was detected/is retained because the rotational speed became 10000 min-1 or above, the target data is cleared within 400 μs at most after receiving of the eighth clear request command.

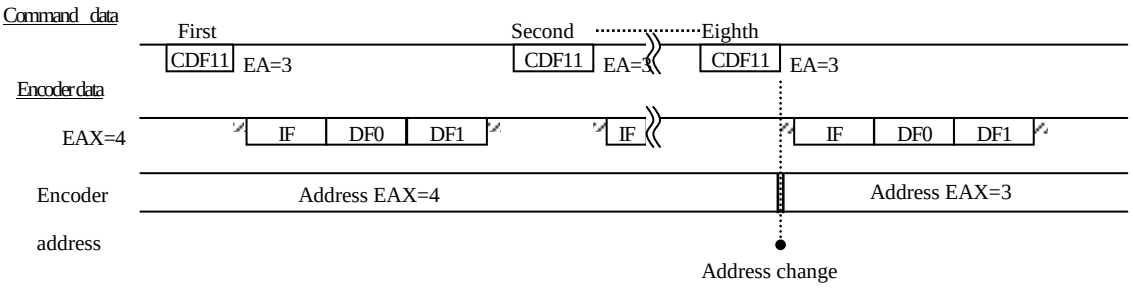
■ MT error

The MT error is reset within 400 μs at most after receiving of the eighth clear request command. Thereafter, the MT error will not occur while the main power is on.

■ Invalid memory access

The memory access error is reset immediately after the eighth clear request command is received. Note, however, that when a memory access error occurs, the encoder may be faulty. If the encoder is faulty, the error will occur again when the memory is accessed the next time.

7.2.3 Encoder Address Setting I(Application command: CDF11)

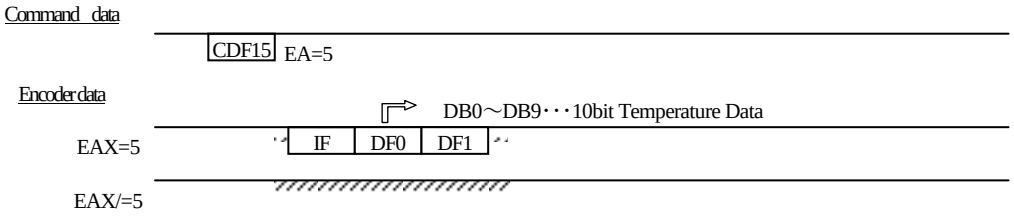


- Connect the controller and encoder one-on-one.
- Enter the specified address in the encoder address field of the command data frame and send the command "CDF11" eight times consecutively to the encoder. The encoder returns status data in response to the command.

Note) The encoder address is set to "EAX = 0" prior to product shipment.

- Once changed, the new encoder address will be retained even after the main power is turned off, regardless of whether an external battery is available or not.
- If serial communication is not established following a specified command, the encoder address is not set correctly. In this case, the encoder address must be set again.
- The MEMBUSY flag is set for up to 30 ms after the eighth command is received until the encoder starts accessing the memory.

7.2.4 Temperature Data Read (Application command: CDF15)



- Temperature data is read in the individual transmission mode.
- When "CDF15" is received as command data, the specified encoder outputs 10-bit information (DB[9:0]) regarding the temperature sensor installed on the encoder board.

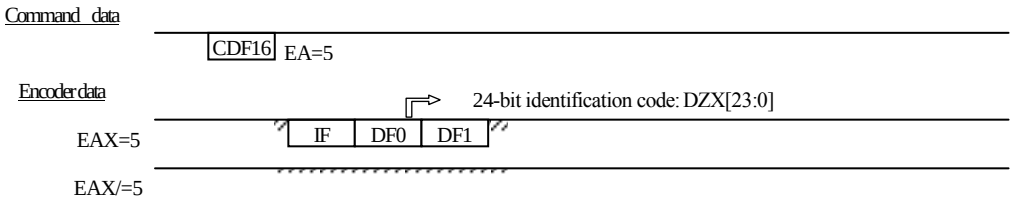
Note 1) Temperature data can also be read using the following commands, in addition to CDF15.

- Send the command CDF29 (individual transmission) or CDF30 (multiple transmission).
  In this case, position data (lower 24 bits of ABS data) is also output together with temperature data.
- Specify the address F9h and send the command CDF13.
  Since EEPROM data is not actually read, MEMBUSY does not generate and temperature data can be read with a single command. Also note that temperature data can be read irrespective of MEMBUSY or MEMERR.

Note 2) Temperature data is refreshed every second inside the encoder, and the temperature data output by the encoder corresponds to the temperature data retained in the encoder at the time the command is received. Note, however, that internal temperature data may not be confirmed yet immediately after the main power is turned on (in which case the output temperature data becomes 0°C). the correct temperature data is output upon an elapse of at least 2.2 seconds after the main power was turned on.

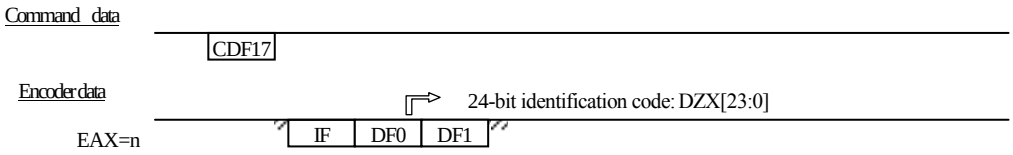
7.2.5 Identification Code Read

(1) Identification Code Read I (Application command: CDF16)



- Identification code read I (CDF16) is performed in the individual transmission mode.
- When "CDF16" is received as command data, the specified encoder outputs the retained identification code (DZX[23:0]).

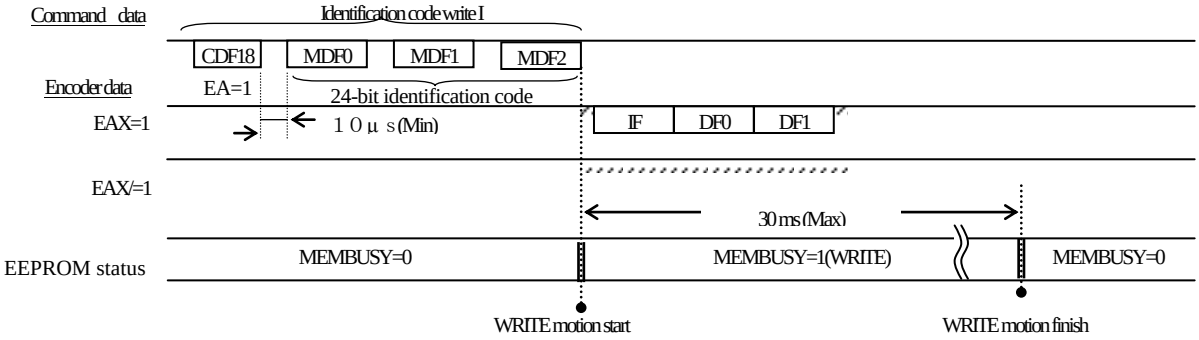
(2) Identification Code Read II (Application command: CDF17)



- Perform identification code read II (CDF17) based on one-on-one connection.
- After receiving "CDF17" as command data, the encoder outputs the retained identification code (DZX[23:0]).

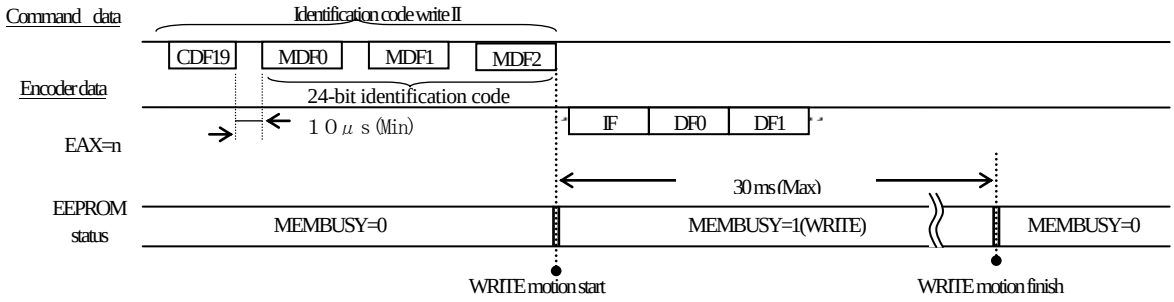
7.2.6 Identification Code Write

(1) Identification Code Write I (Application command: CDF18)



- Identification code write I (CDF18) is performed in the individual transmission mode.
- The identification code write command consists of a total of four frames including one command data frame and three memory data frames. Specify the 24 identification code bits (LSB first) in the three memory data frames.
- The specified encoder returns the retained encoder address and the identification code specified by the command.
- The MEMBUSY flag is set for 30 ms (max) after the write operation is started
- If the data could not be written correctly, the MEMERR flag is latched inside the encoder.
- While the MEMBUSY or MEMERR flag is set, memory access commands are ignored.
  (For the MEMBUSY and MEMERR, refer to 6, "Functional Explanation of Status Flags.")

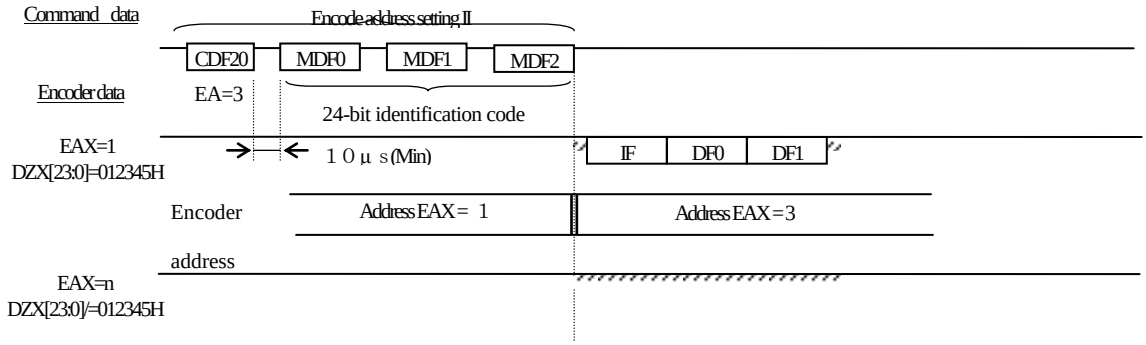
(2) Identification Code Write II (Application command: CDF19)



- Perform identification code read II (CDF19) based on one-on-one connection.
- The identification code write command consists of a total of four frames including one command data frame and three memory data frames. Specify the 24 identification code bits (LSB first) in the three memory data frames.
- After receiving the command, the encoder returns the retained encoder address and the identification code specified by the command.
- The MEMBUSY flag is set for 30 ms (max) after the write operation is started.
- If the data could not be written correctly, the MEMERR flag is latched inside the encoder.
- While the MEMBUSY or MEMERR flag is set, memory access commands are ignored.

(For the MEMBUSY and MEMERR, refer to 6, "Functional Explanation of Status Flags.")

7.2.7 Encoder Address Setting II (Application command: CDF20)



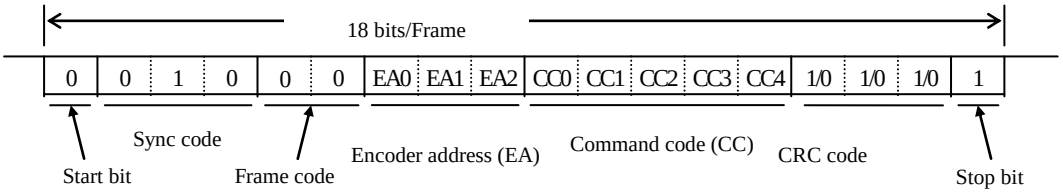
- Perform encoder address setting II in the individual transmission mode.
- You can set the encoder address by specifying a desired encoder identification code.
- The setting command consists of a total of four frames including one command data frame and three memory data frames. Specify the 24 identification code bits (LSB first) in the three memory data frames.
- The encoder matching the identification code specified by the command returns the encoder address specified by the command and the retained identification code.
- The MEMBUSY flag is set for 30 ms (max) after the write operation is started.
- If the data could not be written correctly, the MEMERR flag is latched inside the encoder.
- While the MEMBUSY or MEMERR flag is set, memory access commands are ignored.

(For the MEMBUSY and MEMERR, refer to 6, "Functional Explanation of Status Flags.")

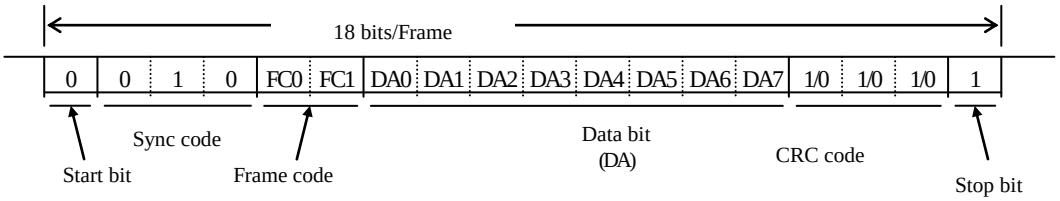
7.3 Command Data Specification

7.3.1 Frame Structure

(1) Command data frame (CDF)



(2) Memory data frame (MDF)



7.3.2 Frame details

(1) Command data frame

Frame name	Frame code		Command code	Category	Remarks
	FC0	FC1	CC [4:0]		
CDF0	0	0	00000	Data request (individual transmission)	Absolute full 40-bit data request
CDF1			00001		Absolute lower 24-bit data request
CDF2			00010		Absolute upper 24-bit data request
CDF3			00011		Encoder status request
CDF4	0	0	00100	Data request (multiple transmission)	Absolute full 40-bit data request
CDF5			00101		Absolute lower 24-bit data request
CDF6			00110		Absolute upper 24-bit data request
CDF7			00111		Encoder status request
CDF8	0	0	01000	Task request (individual transmission)	Status flag clear request
CDF9			01001		Multi-revolution data clear request
CDF10			01010		Status + multi-revolution data clear request
CDF11			01011		Encoder address setting I (one-on-one connection)
CDF15	0	0	01111	Data request (individual transmission)	Temperature data (10-bit) request
CDF16	0	0	10000	Identification code read (individual transmission)	Identification code read I
CDF17			10001		Identification code read II (one-on-one connection)
CDF18	0	0	10010	Identification code write (individual transmission)	Identification code write I
CDF19			10011		Identification code read II (one-on-one connection)
CDF20	0	0	10100	Task request (individual transmission)	Encode address setting II
CDF21	0	0	10101	Data request (individual transmission)	Absolute lower 17-bit data request
CDF22	0	0	10110	Data request (multiple transmission)	Absolute lower 17-bit data request
CDF27	0	0	11011	Data request (individual transmission)	ABS lower 24-bit + status request
CDF28	0	0	11100	Data request (multiple transmission)	ABS lower 24-bit + status request
CDF29	0	0	11101	Data request (individual transmission)	ABS lower 24-bit + temperature data request

CDF30	0	0	11110	Data request (multiple transmission)	ABS lower 24-bit + temperature data request
Other than above	Not defined or cannot be used				

(2) Memory data frame

・ Memory access: CDF13, CDF14

Frame name	Frame code		Assignment to data bits	Remarks
	FC0	FC1		
MDF0	1	0	DA [0:7] = MEMDAT [0:7]	Lower 8 bits of EEPROM data
MDF1	0	1	DA [0:7] = MEMDAT [8:15]	Upper 8 bits of EEPROM data
MDF2	1	1	DA [0:7] = MEMADR [0:7]	8 bits of EEPROM address (Note)

Note) In the case of CDF13 (read), addresses from 00h to FFh are accessible. If the specified address is F9h, however, CDF13 functions as a temperature data read command instead of a memory access command.

Note) In the case of CDF14 (write), addresses from 00h to EFh are accessible. If the specified address is between F0h and FFh, no response is received from the encoder. (These addresses cannot be written because they are reserved by the encoder system.)

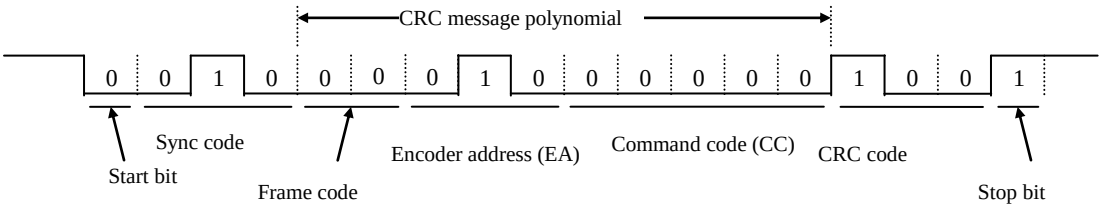
・ Identification code write: CDF18, 19

Frame name	Frame code		Assignment to data bits	Remarks
	FC0	FC1		
MDF0	1	0	DA [0:7] = DZ [0:7]	Identification code bits 0 to 7
MDF1	0	1	DA [0:7] = DZ [8:15]	Identification code bits 8 to 15
MDF2	1	1	DA [0:7] = DZ [16:23]	Identification code bits 16 to 23

(3) CRC code

- CRC code generation polynomial: P(x) = X3 + X + 1
- The CRC calculation range covers all bits except for the start bit, stop bit and sync code.

Example) Command "CDF0"
(full data request for encoder category ENC3 based on bus connection/individual mode)



(4) Encoder address (EA) --- Specified address

[One-on-one connection]

Align the encoder address (EA) with the address (EAX) set for the encoder.
Note, however, that the factory setting is EAX = "000" (ENC1).
The specified encoder address can be changed using the command "CDF11."

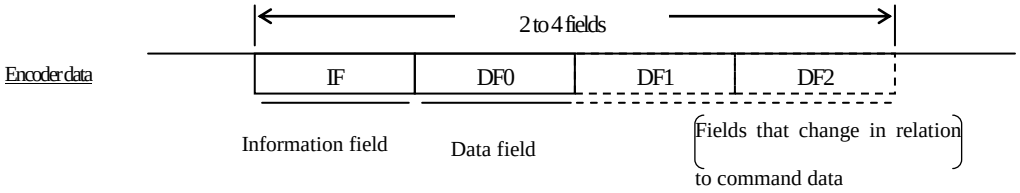
[Bus connection]

- Individual transmission mode --- For the encoder address (EA), specify the address of one of the encoders connected to the bus.
- Multiple transmission mode --- For the encoder address (EA), specify the largest encoder address (EAX) among all encoders connected to the bus (when requesting data from all encoders).

Encoder address (EA)			Encoder category
EA0	EA1	EA2	
0	0	0	ENC1
1	0	0	ENC2
0	1	0	ENC3
1	1	0	ENC4
0	0	1	ENC5
1	0	1	ENC6
0	1	1	ENC7
1	1	1	ENC8

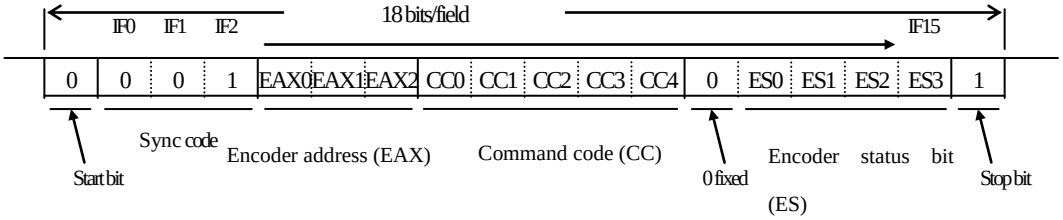
7.4 Encoder Data Specification

7.4.1 Frame Structure

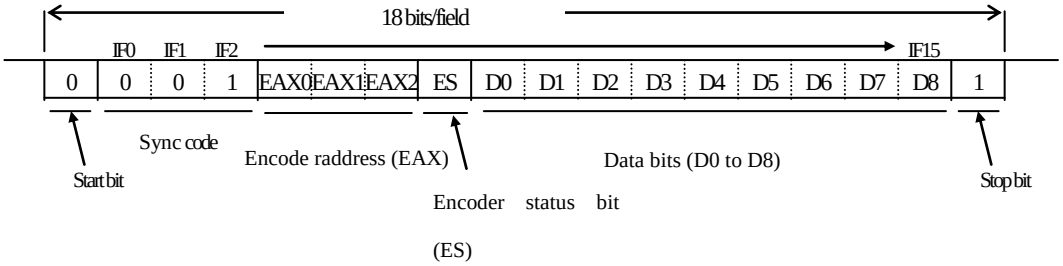


7.4.2 Information Field (IF)

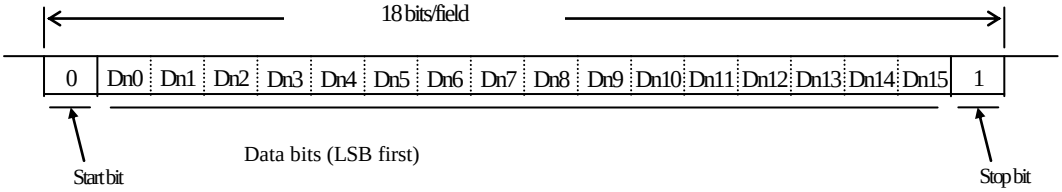
(1) CDF0 to CDF20, CDF27 to CDF30



(2) CDF21, CDF22



7.4.3 Data Field (DFn, n = 0 to 2)



7.4.4 Data Assignment

Command Data	Encoder data/field structure				Data Send time
	IF	DF0	DF1	DF2	
CDF0 CDF4	IF [0:2] = ”001” (Sync code) IF[3:5]=EAX[0:2] (encoder address) IF[6:10]=CC[0:4] : (Command code) IF [11] = ‘0’ IF[12:15]=ES[0:3] : (StatusBit)	D0[0:15]=ABS[0:15]	D1[0:15]=ABS[16:31]	D2[0:7]=ABS[32:39] D2[8:15]=CRC[0:7]	28.8µs (18µs)
CDF1 CDF5		D0[0:15]=ABS[0:15]	D1[0:7]=ABS[16:23] D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF2 CDF6		D0[0:15]=ABS[16:31]	D1[0:7]=ABS[32:39] D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF3 CDF7		D0[0:15]=ALM[0:15]	D1[0:7]=”00000000” D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF8 CDF9 CDF10 CDF11		D0[0:15]=ALM[0:15] Note 1)	D1[0:7]=”00000000” D1[8:15]=CRC[0:7] Note 1)		21.6µs (13.5µs)
CDF15		D0[0:9]=DB[0:9] D0[10:15]=”000000”	D1[0:7]=”00000000” D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF16 CDF17		D0[0:15]=DZX[0:15]	D1[0:7]=DZX[16:23] D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF18 CDF19		D0[0:15]=DZ[0:15]	D1[0:7]=DZ[16:23] D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF20		D0[0:15]=DZX[0:15]	D1[0:7]=DZX[16:23] D1[8:15]=CRC[0:7]		21.6µs (13.5µs)
CDF27 CDF28		D0[0:15]=ABS[0:15]	D1[0:7]=ABS[16:23] D1[8:15]=ALM[0:7]	D2[0:7]=ALM[8:15] D2[8:15]=CRC[0:7]	28.8µs (18µs)
CDF29 CDF30		D0[0:15]=ABS[0:15]	D1[0:7]=ABS[16:23] D1[8:15]=DB[0:7]	D2[0:1]=DB[8:9] D2[2:7]=”000000” D2[8:15]=CRC[0:7]	28.8µs (18µs)
CDF21 CDF22	IF [0:2] = ”001” IF[3:5]=EAX[0:2] IF[6]=ES IF[7:15]=ABS[0:8]	D1[0:7]=ABS[9:16] D1[8:15]=CRC[0:7]			14.4 µs (9 µs)

Note 1) Optionally, the assignments of encoder data for commands CDF8 to CDF12 can be changed to the ABS lower 24-bit output pattern as with CDF1.
Note 2) Commands other than those specified above are not supported by encoders, as a rule. Do not send these commands to encoders.

(1) The IF/sync code is fixed to "001."

(2) IF/encoder address (EAX) --- Address set for the encoder

Encoder address (EAX)			Encoder Category
EAX0	EAX1	EAX2	
0	0	0	ENC1
1	0	0	ENC2
0	1	0	ENC3
1	1	0	ENC4
0	0	1	ENC5
1	0	1	ENC6
0	1	1	ENC7
1	1	1	ENC8

(3) The IF/command code is identical to the command code specified by the command data.
(Refer to the table in 1.3.2 (1).)

(4) IF/encoder status bit

Bit	Status flag	Remarks
ES0	BUSY+ MEMBUSY	Logical sum output
ES1	BATT	
ES2	OVSPD+MEMERR+OVTEMP	Logical sum output
ES3	STERR+PSERR+MTERR	Logical sum output
ES	ES0+ES1+ES2+ES3	Logical sum output (CDF21, 22)

Note) For details on status flags, refer to 6, "Functional Explanation of Status Flags.

(5) DF/ALM [0:15]

・ The table below summarizes status assignments for the status code ALM[0:15].

Bit	ALM[0]	ALM[1]	ALM[2]	ALM[3]	ALM[4]	ALM[5]	ALM[6]	ALM[7]
Status	BATT	MTERR	0 fixed	OVSPD	MEMERR	STERR	PSERR	BUSY

Bit	ALM[8]	ALM[9]	ALM[10]	ALM[11]	ALM[12]	ALM[13]	ALM[14]	ALM[15]
Status	MEMBUSY	OVTEMP	0 fixed	0 fixed	0 fixed	0 fixed	0 fixed	0 fixed

Note) For details on status flags, refer to 6, "Functional Explanation of Status Flags.

(6) DF/CRC [0:7]

・ The last field in the encoder data frame contains the CRC code (8 bits).
・ CRC code generation polynomial: P(x) = X8 + X4 + X3 + X2 + 1
・ The CRC calculation range covers all bits except for the start bit and stop bit in each field.
・ CRC calculation example (when the frame consists of three fields)

IF	DF0	DF1
00111110 00000011	00000000 11101111	11011111 00110101

(7) DF/MEMADR [0:7], MEMDAT [0:15]

- MEMADR [0:7]: 8 bits of EEPROM address (LSB first)
- MEMDAT [0:15]: 16 bits of EEPROM data (LSB first) when reading data
16 bits of user data (LSB first) when writing data

(8) DF/DB [0:9]

10 bits of temperature data: DB[9:0] format

Temperature	Digital Output DB[9:0]
-128 ℃	10 0000 0000
-50 ℃	11 0011 1000
-20 ℃	11 1011 0000
-0.25 ℃	11 1111 1111
0 ℃	00 0000 0000
+0.25 ℃	00 0000 0001
+10 ℃	00 0010 1000
+25 ℃	00 0110 0100
+50 ℃	00 1100 1000
+85 ℃	01 0101 0100
+127 ℃	01 1111 1100

(9) DF/DZ ［0;23］, DZX［0:23］

- DZ [0:23]: 24 bits of command-specified identification code (LSB first)
- DZX [0:23]: 24 bits of encoder-retained identification code (LSB first)

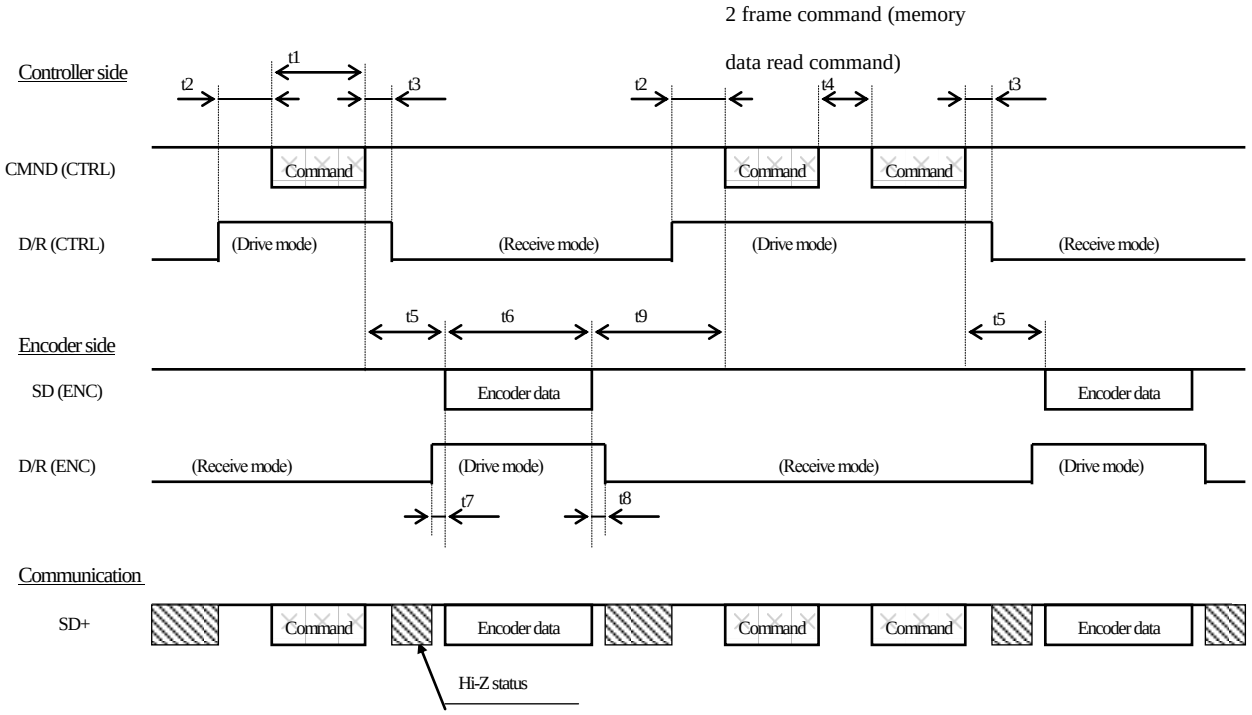
(10) DF/ABS [0:39] 17-bit resolution per revolution

- ABS[0:16] = ST[0:16] --- 17 bits of single-revolution data
- ABS[17:32] = MT[0:15] --- 16 bits of multi-revolution data
- ABS[33:39] = “0000000” --- Fixed to 0

20-bit resolution per revolution

- ABS[0:19] = ST[0:19] --- 20 bits of single-revolution data
- ABS[20:35] = MT[0:15] --- 16 bits of multi-revolution data
- ABS[36:39] = “0000” --- Fixed to 0

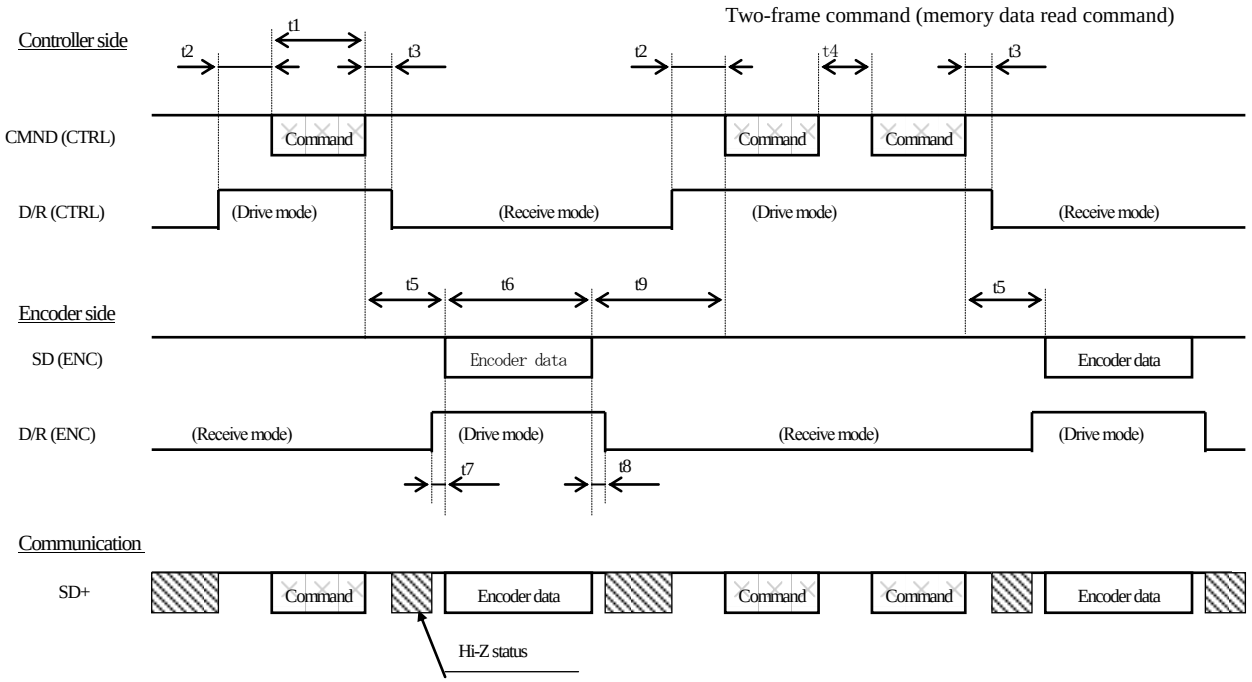
7.5 Send/Receive Timings
7.5.1 Timing Chart
(1) One-on-one connection



Time	Transmission rate		Remarks	Time	Transmission rate		Remarks
	2.5 Mbps	4 Mbps			2.5 Mbps	4 Mbps	
t1	7.2 µs	4.5 µs		t6	28.8 µs	18 µs	Note 1
t2	1 µs (MIN)	0.8 µs (MIN)			21.5 µs	13.5 µs	Note 2
					14.4 µs	9 µs	Note 3
t3	1.5 µs (MAX)	1 µs (MAX)		t7	200 ns	50 ns	
t4	10 µs (MIN)	7 µs (MIN)		t8	200 ns	150 ns	
t5	3 µs	2 µs		t9	5 µs (MIN)	5 µs (MIN)	

Note) The timing specifications conform to 3.4.3, "Examples of Send/Receive Circuits." Take note that transmission path delays and transmission delays in send/receive circuits are assumed as "0."
Note 1) Commands CDF0, CDF27, CDF29 (four-field data)
Note 2) Commands CDF1 to 3, CDF8 to 19 (three-field data)
Note 3) Command CDF21 (two-field data)

(2) Bus connection/individual transmission mode



Time	Transmission rate		Remarks	Time	Transmission rate		Remarks
	2.5 Mbps	4 Mbps			2.5 Mbps	4 Mbps	
t1	7.2 µs	4.5 µs		t6	28.8 µs	18 µs	Note 1
t2	7.5 µs (MIN)	5 µs (MIN)			21.6 µs	13.5 µs	Note 2
					14.4 µs	9 µs	Note 3
t3	1.5 µs (MAX)	1 µs (MAX)		t7	200 ns	50 ns	
t4	10 µs (MIN)	7 µs (MIN)		t8	200 ns	150 ns	
t5	3 µs	2 µs		t9	10 µs (MIN)	7 µs (MIN)	

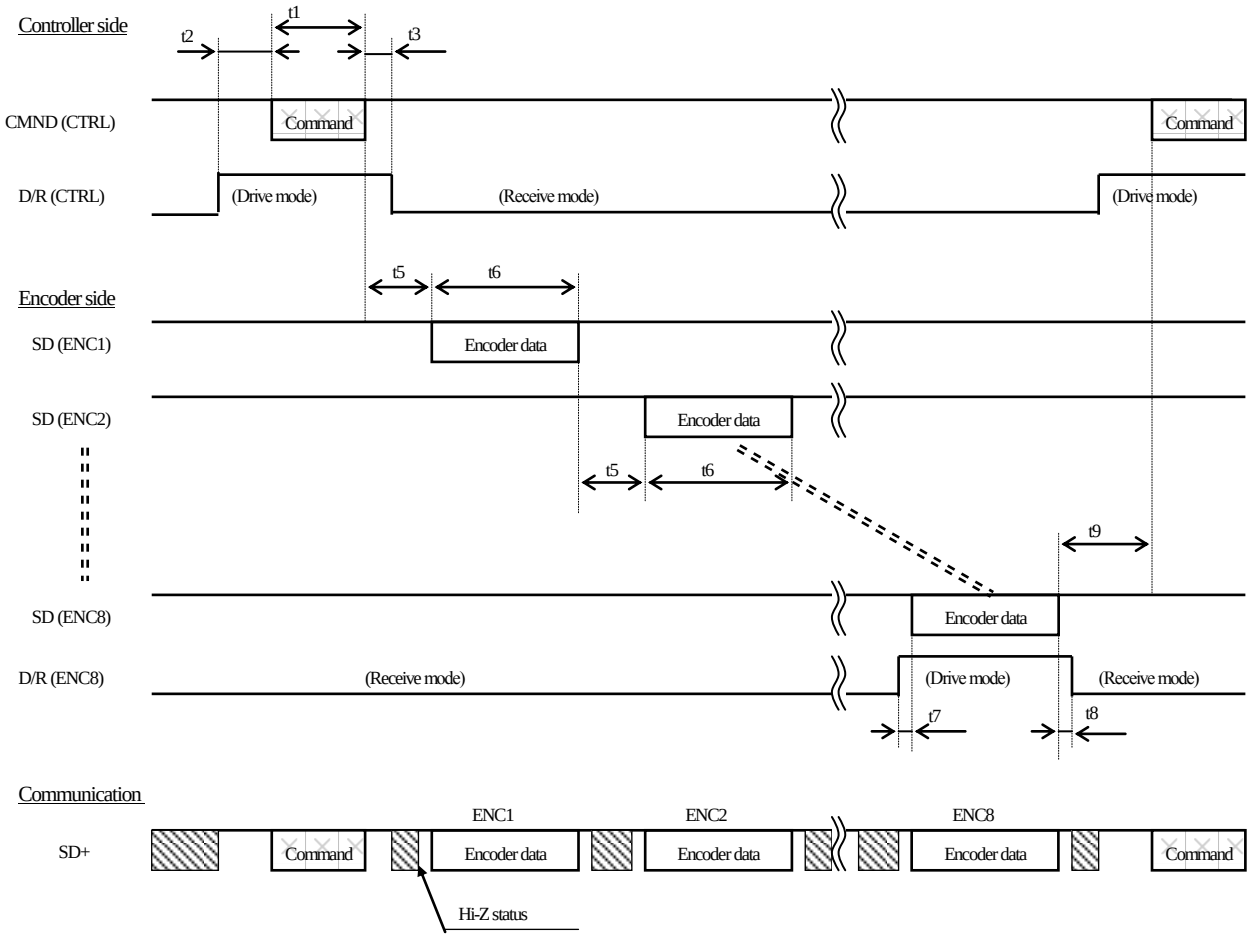
Note) The timing specifications conform to 3.4.3, "Examples of Send/Receive Circuits." Take note that transmission path delays and transmission delays in send/receive circuits are assumed as "0."

Note 1) Commands CDF0, CDF27, CDF29 (four-field data)

Note 2) Commands CDF1 to 3, CDF8 to 20 (three-field data)

Note 3) Command CDF21 (two-field data)

(3) Bus connection/multiple transmission mode



Time	Transmission rate		Remarks	Time	Transmission rate		Remarks
	2.5 Mbps	4 Mbps			2.5 Mbps	4 Mbps	
t1	7.2 µs	4.5 µs		t6	28.8 µs	18 µs	Note 1
t2	7.5 µs (MIN)	5 µs (MIN)			21.6 µs	13.5 µs	Note 2
					14.4 µs	9 µs	Note 3
t3	1.5 µs (MAX)	1 µs (MAX)		t7	200 ns	50 ns	
t4	—	—		t8	200 ns	150 ns	
t5	3 µs	2 µs		t9	10 µs (MIN)	7 µs (MIN)	

Note) The timing specifications conform to 3.4.3, "Examples of Send/Receive Circuits." Take note that transmission path delays and transmission delays in send/receive circuits are assumed as "0."

Note 1) Commands CDF4, CDF28, CDF30 (four-field data)

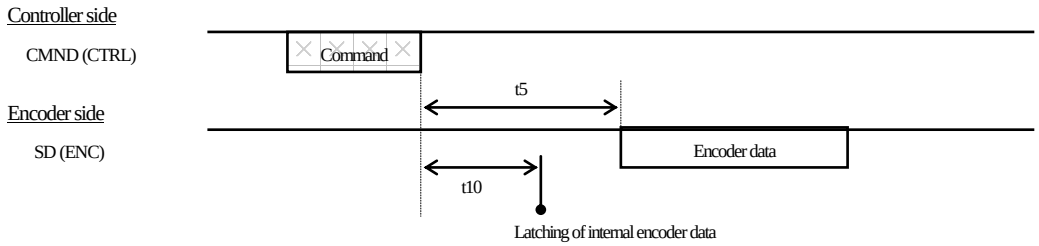
Note 2) Commands CDF5 to 7 (three-field data)

Note 3) Command CDF22 (two-field data)

7.5.2 Latch Timing of Internal Encoder Data (t10)

Internal data is latched within 2 µs ± 0.5 µs (at 2.5 Mbps) (or 1.5 µs ± 0.5 µs at 4 Mbps) after a command is detected (= its frames end).

With the command "CDF2" or "CDF6," however, internal data is not latched and the last latched data is output.



7.5.3 Command Data Detection Specifications

(1) Detection of command data frame

[1] Checking of idling for tidle µs or longer

↓**OK**

[2] Detection of start bit

↓**OK**

[3] Checking of sync code

↓**OK**

[4] Checking of frame code --- Frame code "00"

↓**OK**

[5] Checking of CRC code, stop bit

↓**OK**

[6] Valid command

Idle detection time: tidle

Model	2.5 Mbps	4 Mbps
One-on-one connection specification	0.7 µs	0.5 µs
Bus connection specification	7.2 µs	4.5 µs

* tidle varies depending on the encoder model.

Commands are detected according to the above flow. If any deviation is found from this flow, the command is deemed invalid and the encoder does not send data.

(2) Detection of memory data frame

[1] Checking of idling for 7.2 µs or longer (or 4.5 µs or longer at 4 Mbps)

↓**OK**

[2] Detection of start bit

↓**OK**

[3] Checking of sync code

↓**OK**

[4] Checking of frame code

Frame code "11" for data read

For data write, identification code write and encoder address setting II, @the frame code is checked@ in the order of "01" -> "10" -> "11."@

↓**OK**

[5] Checking of CRC code, stop bit

↓**OK**

[6] Valid command

Commands are detected according to the above flow. If any deviation is found from this flow, the command is deemed invalid and the encoder does not send data.