8   MASTERING

Mastering is an operation performed to associate the angle of each robot axis with the pulse count value supplied from the absolute Pulsecoder connected to the corresponding axis motor. To be specific, mastering is an operation for obtaining the pulse count value corresponding to the zero position.

8.1   GENERAL

The current position of the robot is determined according to the pulse count value supplied from the Pulsecoder on each axis.
Mastering is factory-performed. It is unnecessary to perform mastering in daily operations. However, mastering becomes necessary after:

- Motor replacement.
- Pulsecoder replacement
- Reducer replacement
- Cable replacement
- Batteries for pulse count backup in the mechanical unit have gone dead

> ⚠**CAUTION**
> Robot data (including mastering data) and Pulsecoder data are backed up by
> their respective backup batteries. Data will be lost if the batteries go dead.
> Replace the batteries in the controller and mechanical units periodically. An
> alarm will be issued to warn the user of a low battery voltage.

Types of Mastering
There are five methods of the following mastering.

Table 8.1 Type of mastering

Fixture position mastering	This is performed using a mastering fixture before the machine is shipped from the factory.
Zero-position mastering (witness mark mastering)	This is performed with all axes set at the 0-degree position. A zero-position mark (witness mark) is attached to each robot axis. This mastering is performed with all axes aligned to their respective witness marks.
Quick mastering	This is performed at a user-specified position. The corresponding count value is obtained from the rotation speed of the Pulsecoder connected to the relevant motor and the rotation angle within one rotation. Quick mastering uses the fact that the absolute value of a rotation angle within one rotation will not be lost.
Single-axis mastering	This is performed for one axis at a time. The mastering position for each axis can be specified by the user. This is useful in performing mastering on a specific axis.
Mastering data entry	Mastering data is entered directly.

Once mastering is performed, it is necessary to carry out positioning, or calibration. Positioning is an operation in which the controller reads the current pulse count value to sense the current position of the robot.

This section describes zero-position mastering, quick mastering, single-axis mastering, and mastering data entry.   For more detailed mastering (fixture position mastering), contact FANUC.

> ⚠ **CAUTION**
> If mastering is performed incorrectly, the robot may behave unexpectedly. This is very dangerous. So, the Master/Cal screen is designed to appear only when the $MASTER_ENB system variable is 1 or 2. After performing positioning, press F5 [DONE] on the Master/Cal screen. The $MASTER_ENB system variable is reset to 0 automatically, thus hiding the Master/Cal screen.

> ⚠ **CAUTION**
> It is recommended that the current mastering data be backed up before mastering is performed.

> ⚠ **CAUTION**
> When the motion range is mechanically 360 degrees or more, if any of the axes (J1-axis and J4-axis) to which the cables are connected is turned one turn in the correct mastering position, the cables in the mechanical unit are damaged. If the correct rotation position is not clear because the axis is moved too much during mastering, remove the connector panel or cover, check the states of the internal cables, and perform mastering in the correct position. For the checking procedure, see Fig. 8.1 (a) and 8.1 (b).
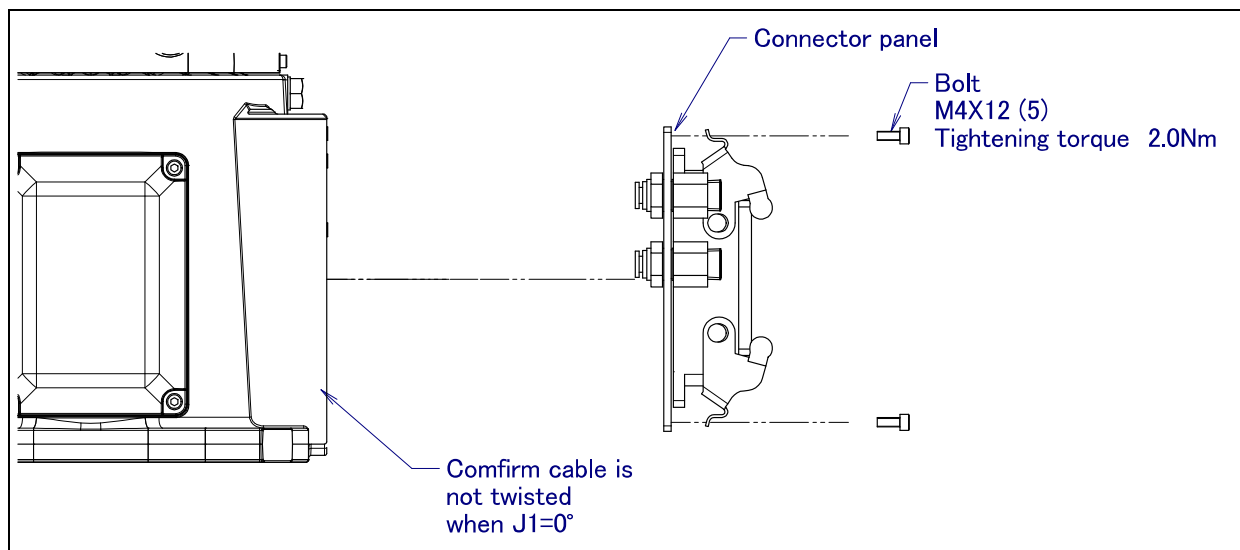

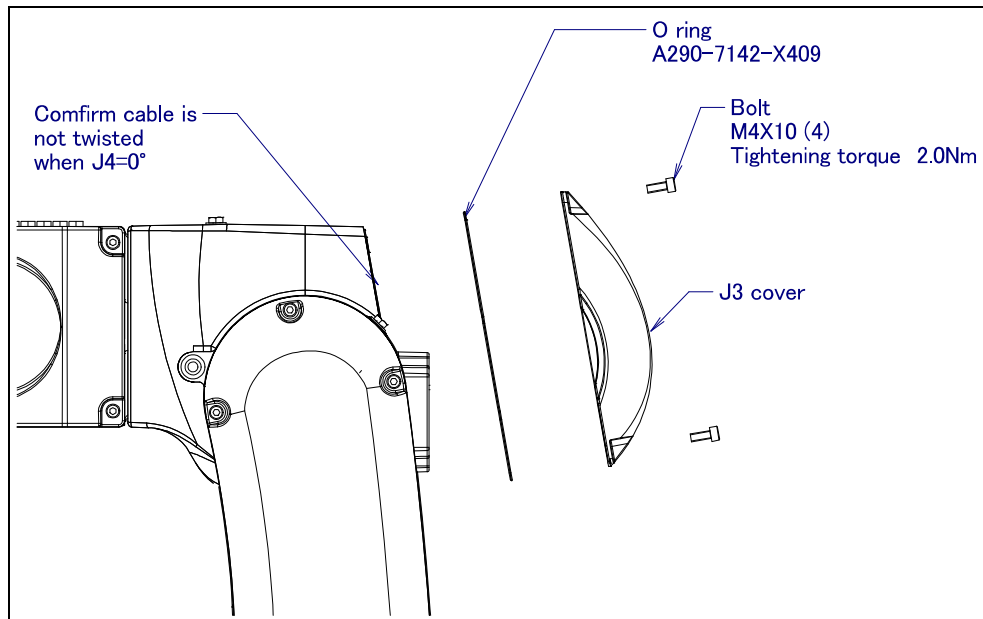**Fig. 8.1 (a) Confirming the state of cable (J1-axis)**

Fig. 8.1 (b) Confirming the state of cable (J4-axis)

8.2   RESETTING ALARMS AND PREPARING FOR MASTERING

Before performing mastering because a motor is replaced, it is necessary to release the relevant alarm and display the positioning menu.

Alarm displayed
"Servo 062 BZAL" or "Servo 075 Pulse not established"

Procedure
1   Display the positioning menu by following steps 1 to 6.
    (1)   Press [MENU] key.
    (2)   Press [0 NEXT] and select [6 SYSTEM].
    (3)   Press F1 [TYPE], and select [SYSTEM Variable] from the menu.
    (4)   Place the cursor on $MASTER_ENB, then key in "1" and press [ENTER].
    (5)   Press F1 [TYPE] again, and select [Master/Cal] from the menu.
    (6)   Select the desired mastering type from the [Master/Cal] menu.

2   To reset the "Servo 062 BZAL" alarm, follow steps 1 to 5.
    (1)   Press [MENU] key.
    (2)   Press [0 NEXT] and select [6 SYSTEM].
    (3)   Press F1 [TYPE], and select [Master/Cal] from the menu.
    (4)   Press the F3 RES_PCA, then press F4 [YES].
    (5)   Turn off the controller power and on again.

3   To reset the "Servo 075 Pulse not established" alarm, follow steps 1 to 2.
    (1)   When the controller power is turned on again, the message "Servo 075 Pulse not established" appears again.
    (2)   Move the axis for which the message mentioned above has appeared till alarm disappears when press [FAULT RESET] in either direction.
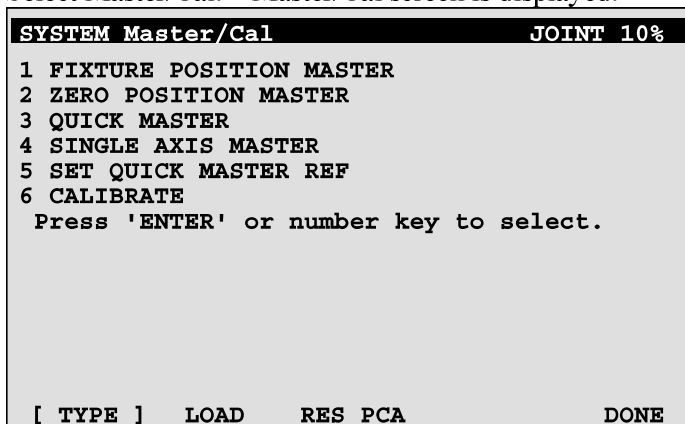
8.3   ZERO POSITION MASTERING

Zero-position mastering (witness mark mastering) is performed with all axes set at the 0-degree position. A zero-position mark (witness mark) is attached to each robot axis. This mastering is performed with all axes set at the 0-degree position using their respective witness marks.

Zero-position mastering involves a visual check. It cannot be so accurate. It should be used only as a quick-fix method.

Procedure of Zero-position Mastering

1   Press [MENU] key.
2   Select NEXT and press SYSTEM.
3   Press F1, [TYPE] to bring up the screen menu.
4   Select Master/Cal.   Master/Cal screen is displayed.

```
SYSTEM Master/Cal                    JOINT 10%
 1 FIXTURE POSITION MASTER
 2 ZERO POSITION MASTER
 3 QUICK MASTER
 4 SINGLE AXIS MASTER
 5 SET QUICK MASTER REF
 6 CALIBRATE
  Press 'ENTER' or number key to select.




 [ TYPE ]   LOAD     RES PCA              DONE
```

5   Release brake control, and jog the robot into a posture for mastering.

NOTE
Brake control can be released by setting the system variables as follows:
$PARAM_GROUP.SV_OFF_ALL: FALSE
$PARAM_GROUP.SV_OFF_ENB[*]: FALSE (for all axes)
After changing the system variables, turn off the controller power and on again.

6   Select Zero Position Master. Press F4, YES.
7   Select 6 CALIBRATE and Press F4, YES. Mastering will be performed automatically. Alternatively, turn off the controller power and on again.
8   After completing the calibration, press F5 Done.

```
                           DONE
```

F5
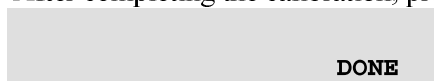
9   Return brake control to original setting, and turn off the controller power and on again.

Table 8.3   Posture with position marks aligned

Axis	Position
J1-axis	0 deg
J2-axis	0 deg
J3-axis	0 deg (When J2-axis is 0 deg.)
J4-axis	0 deg (Note 1) 90 deg (When J3-axis is 0 deg.) (Note 2)
J5-axis	0 deg
J6-axis	0 deg

(Note 1) Except 7H Downward wrist zero specification
(Note 2) 7H Downward wrist zero specification
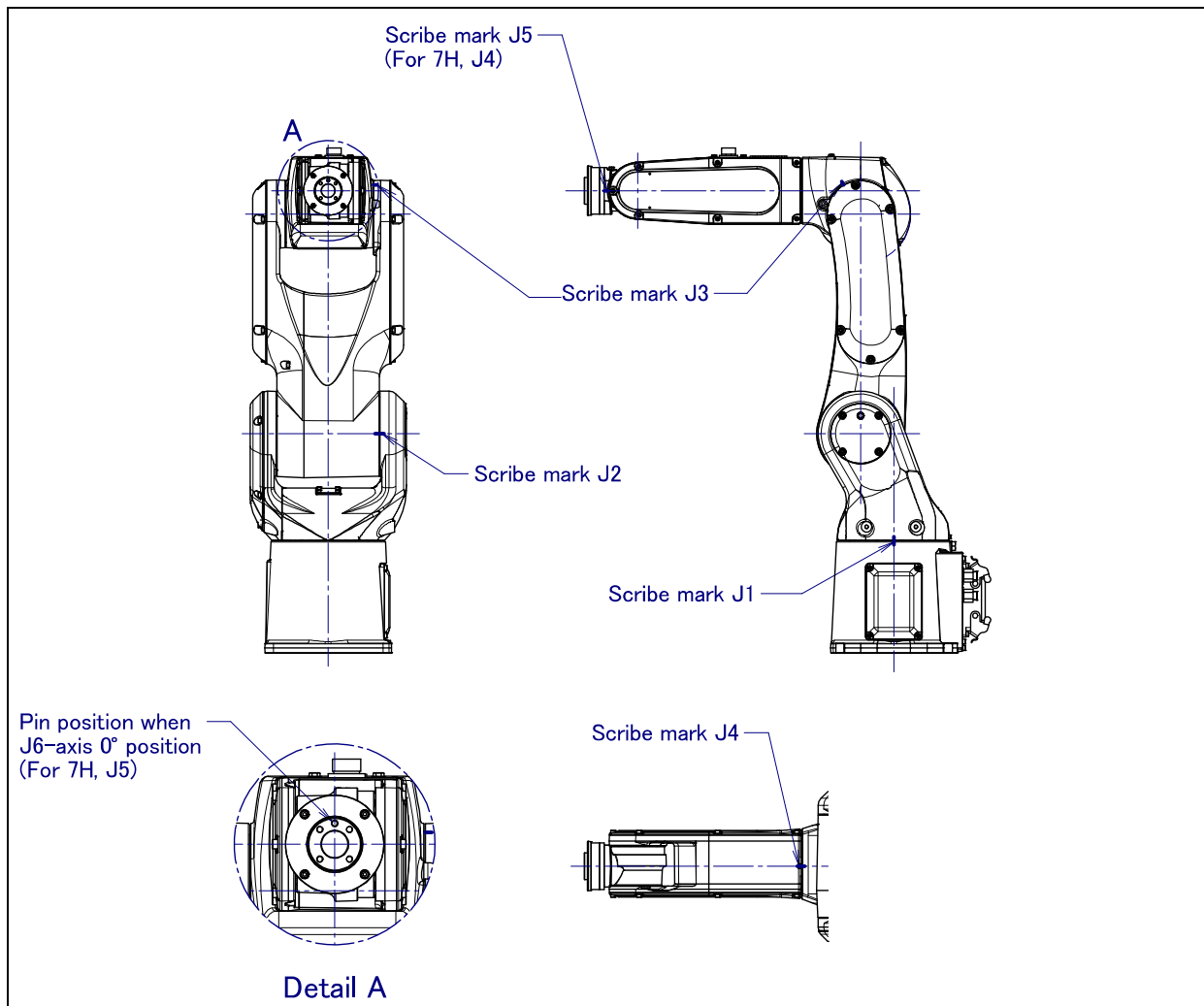
Fig. 8.3   Marking position

8.4   QUICK MASTERING

Quick mastering is performed at a user-specified position. The corresponding count value is obtained from the rotation speed of the Pulsecoder connected to the relevant motor and the rotation angle within one rotation. Quick mastering uses the fact that the absolute value of a rotation angle within one rotation will not be lost.

Quick mastering is factory-performed at the position indicated in Table 8.3. Do not change the setting unless there is any problem.

If it is impossible to set the robot at the position mentioned above, it is necessary to re-set the quick mastering reference position using the following method. (It would be convenient to set up a marker that can work in place of the witness mark.)

┌───┐
│ ⚠ **CAUTION**   │
│ 1 Quick mastering can be used, if the pulse count value is lost, for example, │
│   because a low voltage has been detected on the backup battery for the pulse │
│   counter.   │
│ 2 Quick mastering cannot be used, after the Pulsecoder is replaced or after the │
│   mastering data is lost from the robot controller.   │
└───┘

Procedure Recording the Quick Mastering Reference Position

1   Select SYSTEM.
2   Select Master/Cal.

```
SYSTEM Master/Cal                    JOINT 10%
1 FIXTURE POSITION MASTER
2 ZERO POSITION MASTER
3 QUICK MASTER
4 SINGLE AXIS MASTER
5 SET QUICK MASTER REF
6 CALIBRATE
 Press 'ENTER' or number key to select.




[ TYPE ]   LOAD    RES_PCA           DONE
```

3   Release brake control, and jog the robot to the quick mastering reference position.
4   Set quick master ref? [NO] Move the cursor to SET QUICK MASTER REF and press ENTER. Press F4, YES.

┌───┐
│ ⚠ **CAUTION**   │
│   If the robot has lost mastery due to mechanical disassembly or repair, you │
│   cannot perform this procedure.   In this case, Fixture position mastering or zero │
│   –position mastering to restore robot mastery.   │
└───┘

Procedure Quick Mastering
1   Display the Master/Cal screen.

```
SYSTEM Master/Cal                    JOINT 10%
1 FIXTURE POSITION MASTER
2 ZERO POSITION MASTER
3 QUICK MASTER
4 SINGLE AXIS MASTER
5 SET QUICK MASTER REF
6 CALIBRATE
 Press 'ENTER' or number key to select.




[ TYPE ]   LOAD    RES_PCA           DONE
```

2   Release brake control,and jog the robot to the quick mastering reference position.
3   Quick master? [NO] Move the cursor to QUICK MASTER and press ENTER. Press F4, YES. Quick mastering data is memorized.

```
Quick master? [NO]
```

4   Move the cursor to CALIBRATE and press ENTER.   Calibration is executed.Calibration is executed by power on again.
5   After completing the calibration, press F5 Done.
6   Return brake control to original setting, and turn off the controller power and on again.

8.5   SINGLE AXIS MASTERING

Single axis mastering is performed for one axis at a time. The mastering position for each axis can be specified by the user.
Single axis mastering can be used, if mastering data for a specific axis is lost, for example, because a low voltage has been detected on the pulse counter backup battery or because the Pulsecoder has been replaced.

```
SINGLE AXIS MASTER                 JOINT 33%

         ACTUAL AXIS    (MSTR POS)    (SEL)    [ST]
    J1    25.255       (0.000)       (0)      [2]
    J2    25.550       (0.000)       (0)      [2]
    J3   -50.000       (0.000)       (0)      [2]
    J4    12.500       (0.000)       (0)      [2]
    J5    31.250       (0.000)       (0)      [2]
    J6    43.382       (0.000)       (0)      [2]
    E1     0.000       (0.000)       (0)      [2]
    E2     0.000       (0.000)       (0)      [2]
    E3     0.000       (0.000)       (0)      [2]

                                    GROUP    EXE
```

Table 8.5   Items set in single axis mastering

Item	Description
Current position (Actual axis)	The current position of the robot is displayed for each axis in degree units.
Mastering position (MSTR pos)	A mastering position is specified for an axis to be subjected to single axis mastering. It would be convenient to set to it to the 0_ position.
SEL	This item is set to 1 for an axis to be subjected to single axis mastering. Usually, it is 0.
ST	This item indicates whether single axis mastering has been completed for the corresponding axis. It cannot be changed directly by the user. The value of the item is reflected in $EACHMST_DON (1 to 9). 0 :Mastering data has been lost. Single axis mastering is necessary. 1 :Mastering data has been lost. (Mastering has been performed only for the other interactive axes.) Single axis mastering is necessary. 2 :Mastering has been completed.

Procedure of Single axis mastering

1   Select SYSTEM.
2   Select Master/Cal.

```
SYSTEM Master/Cal                    JOINT 10%

1 FIXTURE POSITION MASTER
2 ZERO POSITION MASTER
3 QUICK MASTER
4 SINGLE AXIS MASTER
5 SET QUICK MASTER REF
6 CALIBRATE
  Press 'ENTER' or number key to select.




[ TYPE ]   LOAD     RES_PCA
```

3   Select 4, Single Axis Master.   You will see a screen similar to the following.

```
  SINGLE AXIS MASTER              JOINT 10%
                                    1/9
    ACTUAL POS      (MSTR POS)  (SEL)   [ST]
J1   25.255      (   0.000)    (0)     [2]
J2   25.550      (   0.000)    (0)     [2]
J3  -50.000      (   0.000)    (0)     [2]
J4   12.500      (   0.000)    (0)     [2]
J5   31.250      (   0.000)    (0)     [0]
J6   43.382      (   0.000)    (0)     [0]
E1    0.000      (   0.000)    (0)     [2]
E2    0.000      (   0.000)    (0)     [2]
E3    0.000      (   0.000)    (0)     [2]

    [ TYPE ]                  GROUP   EXE
```

4   Move the cursor to the SEL column for the unmastered axis and press the numeric key "1."   Setting
     of SEL is available for one or more axes.
5   Turn off brake control as required, then jog the robot to the mastering position
6   Enter axis data for the mastering position.

```
                    JOINT 30%        SINGLE AXIS MASTER              JOINT 30%
                         5/9                                              5/9
(0.000)   (0)    [2]     J5   31.250    (0.000)    (0)    [2]

(0.000)   (0)    [2]     J6   43.382   (90.000)    (0)    [2]
                                                    GROUP    EXEC
```

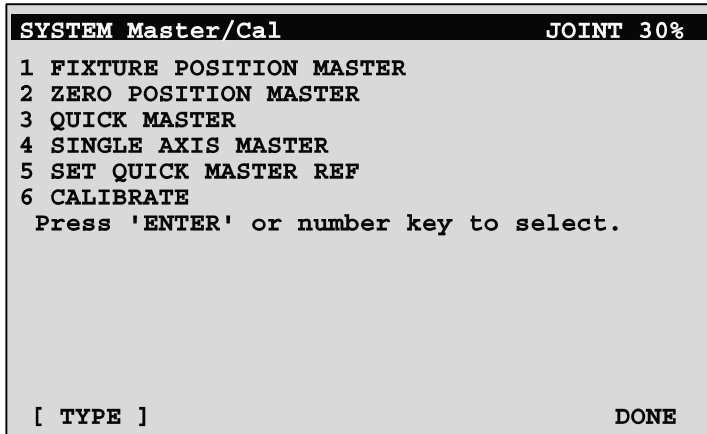7   Press F5 [EXEC]. Mastering is performed. So, SEL is reset to 0, and ST is re-set to 2 or 1.

```
                              SINGLE AXIS MASTER              JOINT 30%
            GROUP   EXEC
                                                                    1/9
                                ACTUAL AXIS    (MSTR POS)  (SEL)   [ST]
              F5              J1   25.255     (0.000)      (0)     [2]
                             J2   25.550     (0.000)      (0)     [2]
                             J3  -50.000     (0.000)      (0)     [2]
                             J4   12.500     (0.000)      (0)     [2]
                             J5    0.000     (0.000)      (0)     [2]
                             J6   90.000    (90.000)      (0)     [2]
                             E1    0.000     (0.000)      (0)     [2]
                             E2    0.000     (0.000)      (0)     [2]
                             E3    0.000     (0.000)      (0)     [2]

                                                          GROUP   EXEC
```

8   When single axis mastering is completed, press the previous page key to resume the previous screen.

```
SYSTEM Master/Cal                        JOINT 30%

1 FIXTURE POSITION MASTER
2 ZERO POSITION MASTER
3 QUICK MASTER
4 SINGLE AXIS MASTER
5 SET QUICK MASTER REF
6 CALIBRATE
 Press 'ENTER' or number key to select.




[ TYPE ]                                    DONE
```

9   Select [6 CALIBRATE], then press F4 [YES]. Positioning is performed.   Alternatively, turn off the controller power and on again. Positioning is performed.
10   After positioning is completed, press F5 [DONE].
11   Return brake control to original setting, and turn off the controller power and on again.
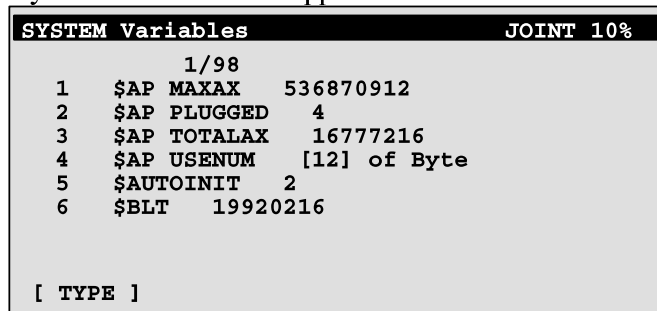
```
                      DONE
```
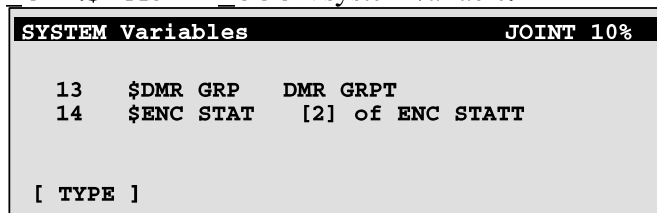
```
F5
```

8.6   MASTERING DATA ENTRY

This function enables mastering data values to be assigned directly to a system variable. It can be used if mastering data has been lost but the pulse count is preserved.
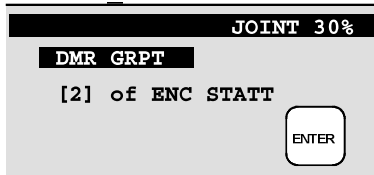
Mastering data entry method

1   Press [MENU] key, then press NEXT and select SYSTEM.
2   Press F1, [TYPE]. Select [Variables]. The system variable screen appears.

```
SYSTEM Variables                         JOINT 10%
              1/98
    1    $AP MAXAX    536870912
    2    $AP PLUGGED   4
    3    $AP TOTALAX    16777216
    4    $AP USENUM    [12] of Byte
    5    $AUTOINIT    2
    6    $BLT   19920216


[ TYPE ]
```

3   Change the mastering data.
     The mastering data is saved to the $DMR_GRP.$MASTER_COUN system variable.

```
SYSTEM Variables                         JOINT 10%

   13    $DMR GRP    DMR GRPT
   14    $ENC STAT    [2] of ENC STATT


[ TYPE ]
```

4   Select $DMR_GRP.

```
                        JOINT 30%
  DMR GRPT

   [2] of ENC STATT

                            [ENTER]
```

```
SYSTEM Variables              JOINT 10%
   $DMR   GRP                       1/1

     1    [1]                    DMR GRPT
```
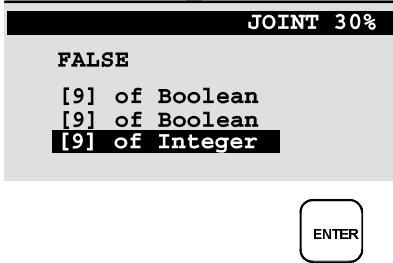
```
SYSTEM Variables              JOINT 10%
   $DMR   GRP [1]                   1/8
   1   $MASTER DONE     FALSE
   2   $OT MINUS        [9] of Boolean
   3   $OT PLUS         [9] of Boolean
   4   $MASTER COUN     [9] of Integer
   5   $REF DONE        FALSE
   6   $REF POS         [9] of Real
   7   $REF COUNT       [9] of Integer
   8   $BCKLSH SIGN     [9] of Boolean


  [ TYPE ]                  TRUE   FALSE
```
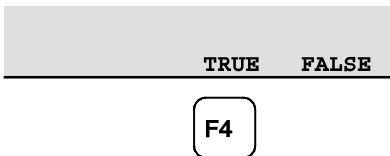
5   Select $MASTER_COUN, and enter the mastering data you have recorded.

```
                        JOINT 30%

  FALSE

  [9] of Boolean
  [9] of Boolean
  [9] of Integer


                            [ENTER]
```

```
SYSTEM Variables              JOINT 10%
   $DMR   GRP [1].$MASTER COUN    1/9

     1   [1]    95678329
     2   [2]    10223045
     3   [3]    3020442
     4   [4]    304055030
     5   [5]    20497709
     6   [6]    2039490
     7   [7]    0
     8   [8]    0
     9   [9]    0
```
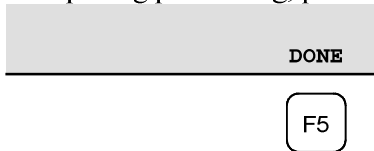
6   Press the PREV key.
7   Set $MASTER_DONE to TRUE.

```
                   TRUE    FALSE

                    [F4]
```

```
SYSTEM Variables              JOINT 10%
   $DMR   GRP [1]                   1/8
   1   $MASTER DONE       TRUE
   2   $OT MINUS          [9] of Boolean


  [ TYPE ]                  TRUE   FALSE
```

8   Display the positioning screen, and select [6 CALIBRATE], then press F4 [YES].
9   After completing positioning, press F5 [DONE].

```
                          DONE

                    [F5]
```

8.7   CHECKING THE MASTERING

1   Checking whether mastering has been made correctly
Usually, positioning is performed automatically at power-on. To check whether mastering has been made correctly, note whether the displayed current position agrees with the actual robot position. Use the procedure described below:

(1) Reproduce a particular point in a program. Check whether the point agrees with the specified position.

(2) Set all axes of the robot to their 0-degree (0rad) positions. Check that the zero-degree position marks indicated in Section 8.3 are aligned. There is no need to use any visual aid.

(3) Using fixtures, set the robot to the mastering position in the same way as when performing mastering. Check that the displayed current position agrees with the actual mastering position.

If the displayed and actual positions do not match, the counter value for a Pulsecoder may have been invalidated as a result of an alarm described below 2. Alternatively, the mastering data in system variable $DMR_GRP.$MASTER_COUN may have been overwritten as a result of an operation error or some other reason.

Compare the data with the values indicated on the supplied data sheet. This system variable is overwritten whenever mastering is performed. Whenever mastering is performed, record the value of the system variable on the data sheet.

2   Alarms that may be output during mastering and remedy for it

(1) BZAL alarm
This alarm is output if the voltage of the Pulsecoder's backup battery falls to 0 V while the power to the controller is disconnected. Also, if Pulsecoder connector is removed for replacing cables etc. this alarm is output because voltage becomes to 0. To clear the alarm, fit a new battery, execute the pulse reset (See section 8.2.), then turn the power off then on again and confirm alarm is not output.
Battery might be weak if you can't reset alarm, then replace battery to new one , perform pulse reset , turn off and on the controller power. Note that, if this alarm occurs, all data originally held by the Pulsecoder will have been lost. Mastering must be performed again.

(2) BLAL alarm
This alarm is output if the voltage of the Pulsecoder's backup battery has fallen to a level where backup is no longer possible. If this alarm is output, fit a new battery immediately while keeping the power turned on. Check whether the current position data is valid, using the procedure described in 1.

(3) CKAL, RCAL, PHAL, CSAL, DTERR, CRCERR, STBERR, and SPHAL, alarms
Contact the FANUC because the Pulsecoder may be defective.