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RENESAS

APPLICATION NOTE

H8SX Family

Boundary Scan: Usage

Introduction

This Application Note describes the use of the boundary scan function. See the Boundary Scan: Introduction and Boundary Scan: Application documents (Renesas Application Notes) for an overview of the boundary scan function. This document presents a simple application program that uses the boundary scan function. The boundary scan functions described in this document all apply to the H8SX/1648 microcontroller.

Contents

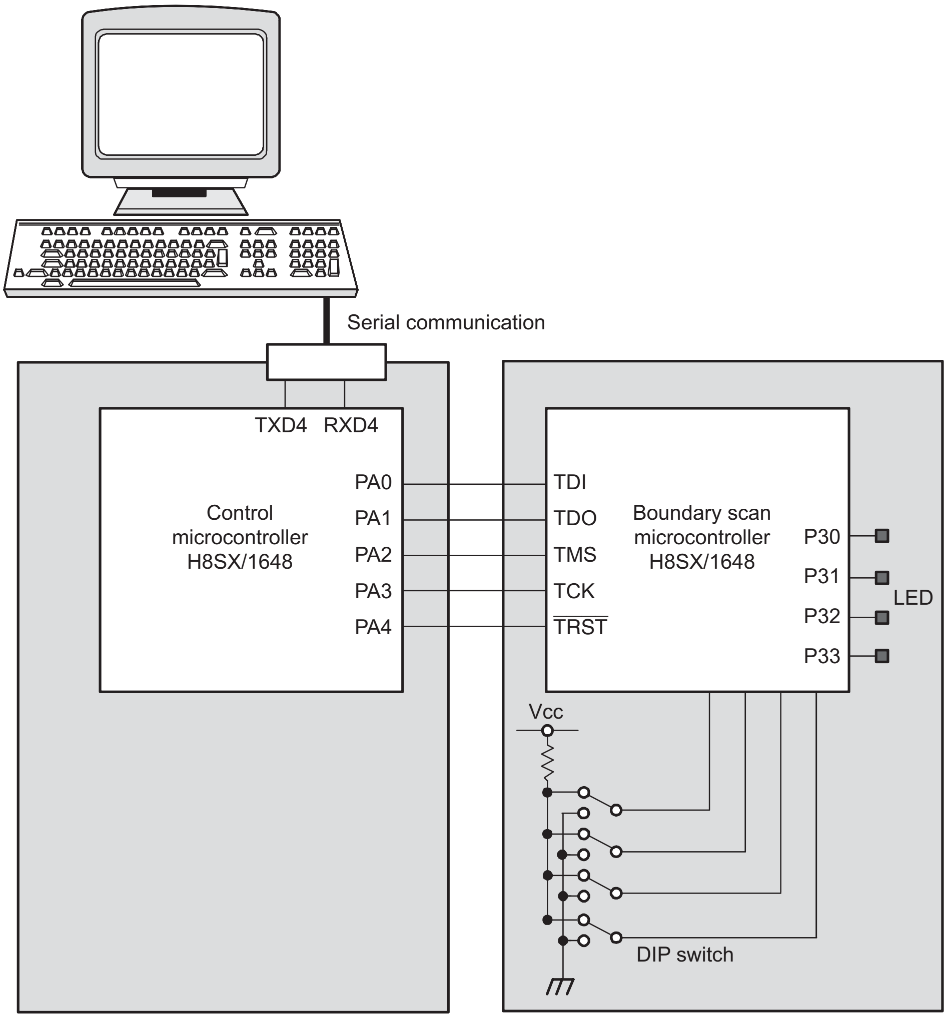
1. System Overview

This document describes an application program that performs a boundary scan by controlling microcontrollers from a personal computer.

The example presented here uses two H8SX/1648 microcontrollers: one is used for control and the other is used for the boundary scan. HyperTerminal is used on the PC for serial communication to manipulate the control microcontroller. A boundary scan is then performed by controlling the boundary scan microcontroller's TAP from the control microcontroller. The control microcontroller's port A (PA0 to PA4) is used for input to and output from the boundary scan microcontroller's TAP. Note that the boundary scan microcontroller must be held fixed in operating mode 3 (boundary scan enabled single-chip mode).

The board for this example includes a DIP switch for verifying the SAMPLE/PRELOAD instruction. The DIP switch is connected to any boundary scan pins. Whether or not the pin states are acquired by the boundary scan cells by the SAMPLE/PRELOAD instruction can be verified by modifying the pin states using this DIP switch. The board also includes LEDs to check the EXTEST and CLAMP instructions. Whether or not the EXTEST and CLAMP instructions are functioning can be verified by modifying the LED output states with the EXTEST and CLAMP instructions.

Figure 1 shows an overview of the whole system, and table 1 lists the pin connections.



Note: * The DIP switch is connected to arbitrary boundary scan pins.

Figure 1 System Overview

Table 1 Pin Connections

Role	Control Microcontroller Pin	Boundary Scan Microcontroller Pin	External Connection
TAP manipulation	PA0	TDI	—
	PA1	TDO	—
	PA2	TMS	—
	PA3	TCK	—
	PA4	$\overline{\text{TRST}}$	—
SCI communication	TXD4	—	Connected to the PC COM port over a SCI transceiver and connector.
	RXD4	—	Connected to the PC COM port over a SCI transceiver and connector.
LED verification for the EXTEST and CLAMP instructions	—	P30	Connected to a LED.
	—	P31	Connected to a LED.
	—	P32	Connected to a LED.
	—	P33	Connected to a LED.

2. Application Conditions

Tables 2-1 and 2-2 list the application conditions for this sample system. Table 3 lists the HyperTerminal settings used in this system example.

Table 2-1 Application Conditions (Control Microcontroller)

Item	Description
Microcontroller	H8SX1648 (R5F61648FPV)
Operating frequency	System clock (Iϕ) = 12 MHz (input clock x 1) External bus clock (Bϕ) = 12 MHz (input clock x 1) Peripheral module clock (Pϕ) = 12 MHz (input clock x 1)
Operating mode	Single-chip mode (mode 7)
Development tools	Renesas Technology Corp. High-Performance Embedded Workshop, version 4.04.01.001 (integrated development environment)
C/C++ compiler	Renesas Technology Corp. H8S,H8/300 Standard Toolchain (V.6.2.0.0) H8S,H8/300 C/C++ Compiler (V.6.2.0.0)
	Option settings -cpu=H8SXA:24 -object="$(CONFIGDIR)\$(FILELEAF).obj" -debug -nolist -chgincpath -nologo
Optimizing linkage editor	Renesas Technology Corp. Optimizing Linkage Editor Ver.9.03.00
	Option settings -noprelink -nodebug -rom=D=R -nomessage -list="$(CONFIGDIR)\$(PROJECTNAME).map" -nooptimize -start=PResetPRG,PIntPRG/0400,P,C,C$DSEC,C$BSEC,D/0800,B, R/0FF2000, S/0FFBE00 -nologo -output="$(CONFIGDIR)\$(PROJECTNAME).abs" -end -input="$(CONFIGDIR)\$(PROJECTNAME).abs" -form=stype -output="$(CONFIGDIR)\$(PROJECTNAME).mot" -exit

Table 2-2 Application Conditions (Boundary Scan Microcontroller)

Item	Description
Microcontroller	H8SX1648 (R5F61648FPV)
Operating frequency	System clock (Iϕ) = 12 MHz (input clock x 1) External bus clock (Bϕ) = 12 MHz (input clock x 1) Peripheral module clock (Pϕ) = 12 MHz (input clock x 1)
Operating mode	Boundary scan enabled single-chip mode (mode 3)
Development tools	None (This is because no program is written to the boundary scan microcontroller.)
C/C++ compiler	None (This is because no program is written to the boundary scan microcontroller.)
	Option settings None
Optimizing linkage editor	None (This is because no program is written to the boundary scan microcontroller.)
	Option settings None

Table 3 HyperTerminal Settings

Item	Setting
Baud rate	9600bps
Data length	8 bits
Parity	None
Stop bits	1bit
Flow control	Hardware

3. Specifications

This sample system uses six boundary scan instruction: the SAMPLE/PRELOAD, IDCODE, EXTEST, BYPASS, CLAMP, and HIGHZ instructions. It also acquires the IR status word.

When specified characters are input to HyperTerminal, instructions corresponding to the input characters are issued by the boundary scan microcontroller, and the results are displayed on the HyperTerminal screen. Outputs from boundary scan cells to pins are also performed when an EXTEST or CLAMP instruction is executed. Furthermore, the HIGHZ instruction sets all pins other than the TAP pins to the high-impedance state. Table 4 lists the correspondence between HyperTerminal input commands and the instructions used.

Table 4 Input Command and Instruction Correspondence

Command input from HyperTerminal	Instruction used (instruction code)	Operation in this sample system
"ID"	IDCODE instruction (B'0001)	The IDCODE is acquired, converted to hexadecimal, and displayed on HyperTerminal.
"SP"	SAMPLE/PRELOAD instruction (B'0100)	The pin states are acquired by the boundary scan cells and displayed on HyperTerminal.
"EX"	EXTEST instruction (B'0000)	The P30 to P33 pin output states are manipulated thus manipulating the LED on/off states.
"BY"	BYPASS instruction (B'1111)	The input data is passed through the bypass register, and the resulting data is displayed on HyperTerminal.
"CP"	CLAMP instruction (B'0010)	In the state where the P30 to P33 pin output states are manipulated thus manipulating the LED on/off states, the input data is passed through the bypass register, and the resulting data is displayed on HyperTerminal.
"HZ"	HIGHZ instruction (B'0011)	In the state where all pins other than the TAP pins are set to the high-impedance state, the input data is passed through the bypass register, and the resulting data is displayed on HyperTerminal.
"IR"	SAMPLE/PRELOAD instruction (B'0100)	The IR status word is acquired and displayed on HyperTerminal.

3.1 IDCODE Instruction Specifications

The IDCODE instruction is performed as follows.

Type "ID" at HyperTerminal and press the Enter key. The boundary scan microcontroller will then acquire the IDCODE. Then, the acquired IDCODE is converted to hexadecimal and displayed on HyperTerminal. If the IDCODE instruction fails, the system will display "IDCODE INSRUCTION FAILURE" on HyperTerminal. Figure 2 shows an overview of this operation.

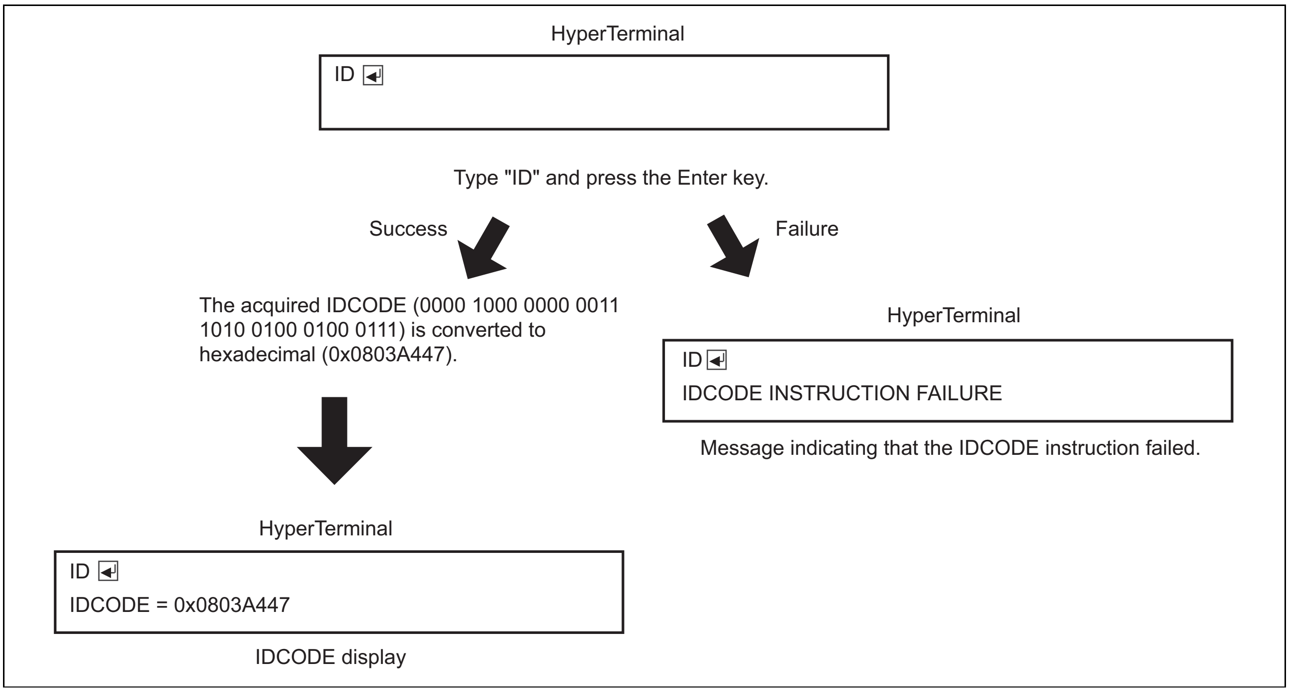


Figure 2 IDCODE Instruction Specifications

3.2 SAMPLE/PRELOAD Instruction Specifications

The SAMPLE/PRELOAD instruction is performed as follows.

Type "SP" at HyperTerminal and press the Enter key. The boundary scan microcontroller pin states will be acquired by the boundary scan cells. Then, the boundary scan cell states will be displayed as a sequence of zeros and ones on hold time. The data is displayed with a newline after every 100 characters.

If the SAMPLE/PRELOAD instruction fails, "SAMPLE INSTRUCTION FAILURE" will be displayed. Figure 3 presents an overview of this operation.

Note that the acquired boundary scan cell values will change if the DIP switch connected to arbitrary boundary scan pins is manipulated. This can be used to verify that the pin states are actually being acquired by the boundary scan cells by the SAMPLE/PRELOAD instruction.

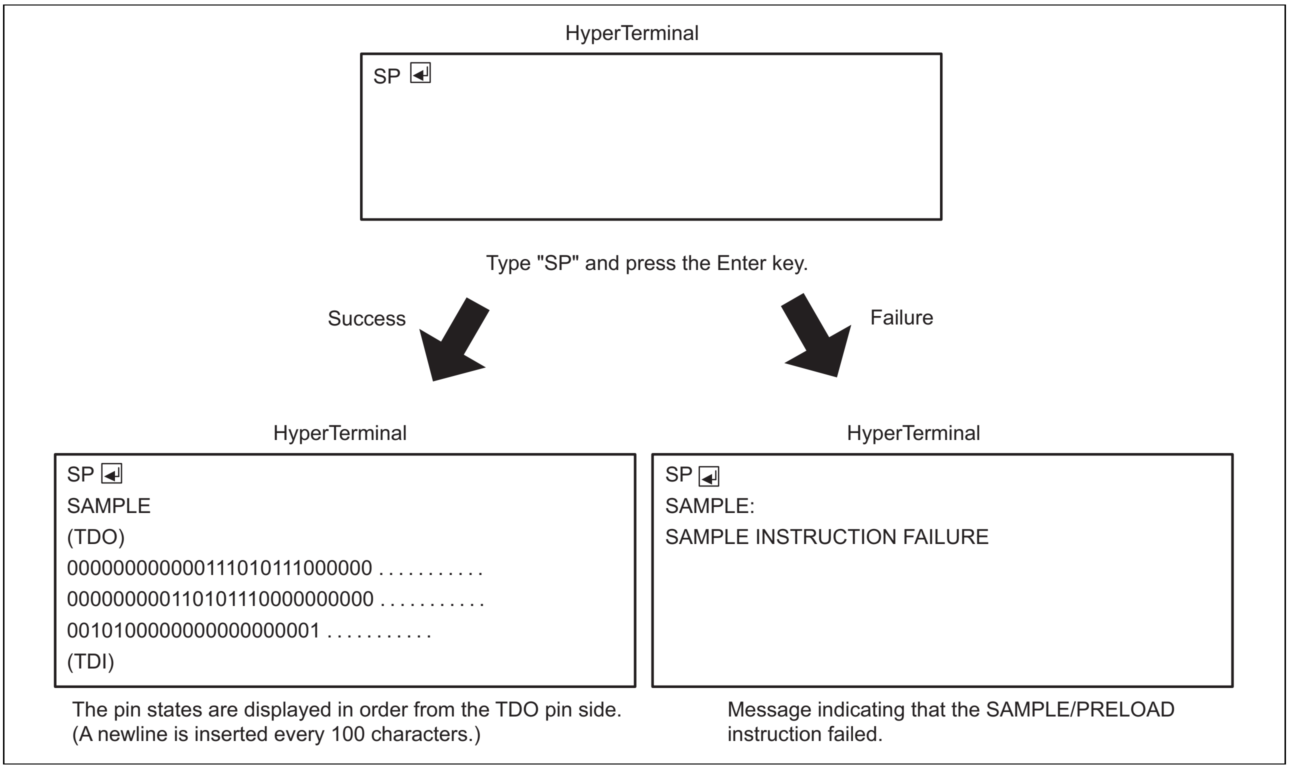


Figure 3 SAMPLE/PRELOAD Instruction Specifications

3.3 EXTEST Instruction Specifications

The IDCODE instruction is performed as follows.

Type "EX" at HyperTerminal and press the Enter key. The system will display "Please input the output setting of P3x.(H or L):" on HyperTerminal. Next, enter H for a high-level output or L for a low-level output for the specified pin (P30 to P33). If you do not want to change the pin state, enter any other character. When the output levels have been set for all four pins (P30 to P33), the on/off state of the LED corresponding to each pin will change. If the instruction succeeded, "EXTEST INSTRUCTION SUCCESS" will be displayed on HyperTerminal. If the instruction failed, "EXTEST INSTRUCTION FAILURE" will be displayed. Figure 4 shows an overview of this operation.

Since the EXTEST instruction performs a forcible output to the pins, the user must assure that no problems will occur in the system when the instruction is executed, even if there are outputs from the set pins. Also, since the EXTEST instruction is a test mode instruction, normal microcontroller operation will be stopped until the microcontroller is set to normal mode after EXTEST instruction execution.

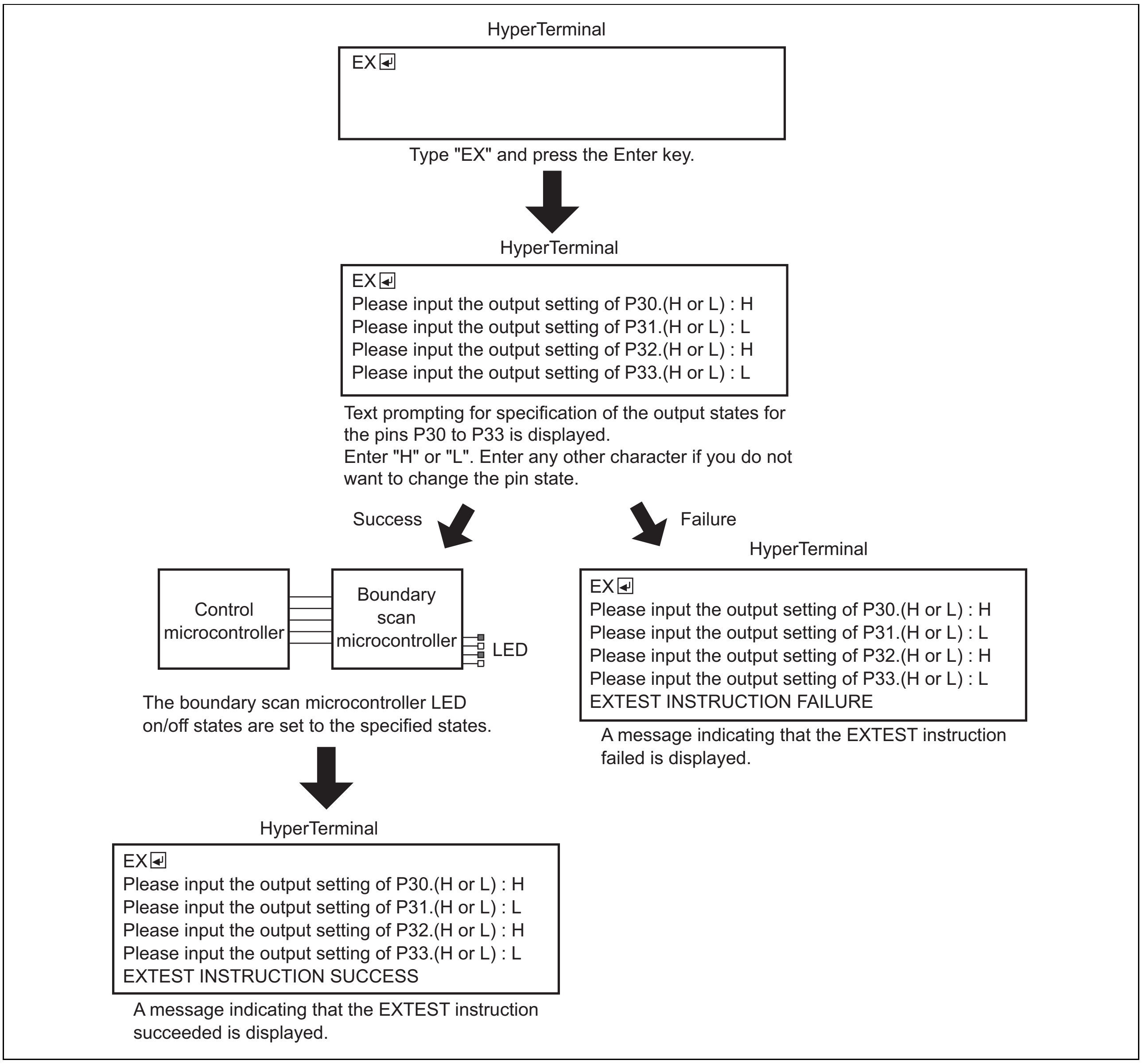


Figure 4 EXTEST Instruction Specifications

3.4 BYPASS Instruction Specifications

The BYPASS instruction is performed as follows.

Type "BY" at HyperTerminal and press the Enter key. The system will display "Please input the Bypass Data (H or L):" on HyperTerminal. Next, enter the bypass data using the letters H and L and press the Enter key. You can enter up to 100 characters. Then, the system will pass the bypass data through the bypass register and display the result on HyperTerminal. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. If the BYPASS instruction fails, "BYPASS INSTRUCTION FAILURE" will be displayed on HyperTerminal. Figure 5 shows an overview of this operation.

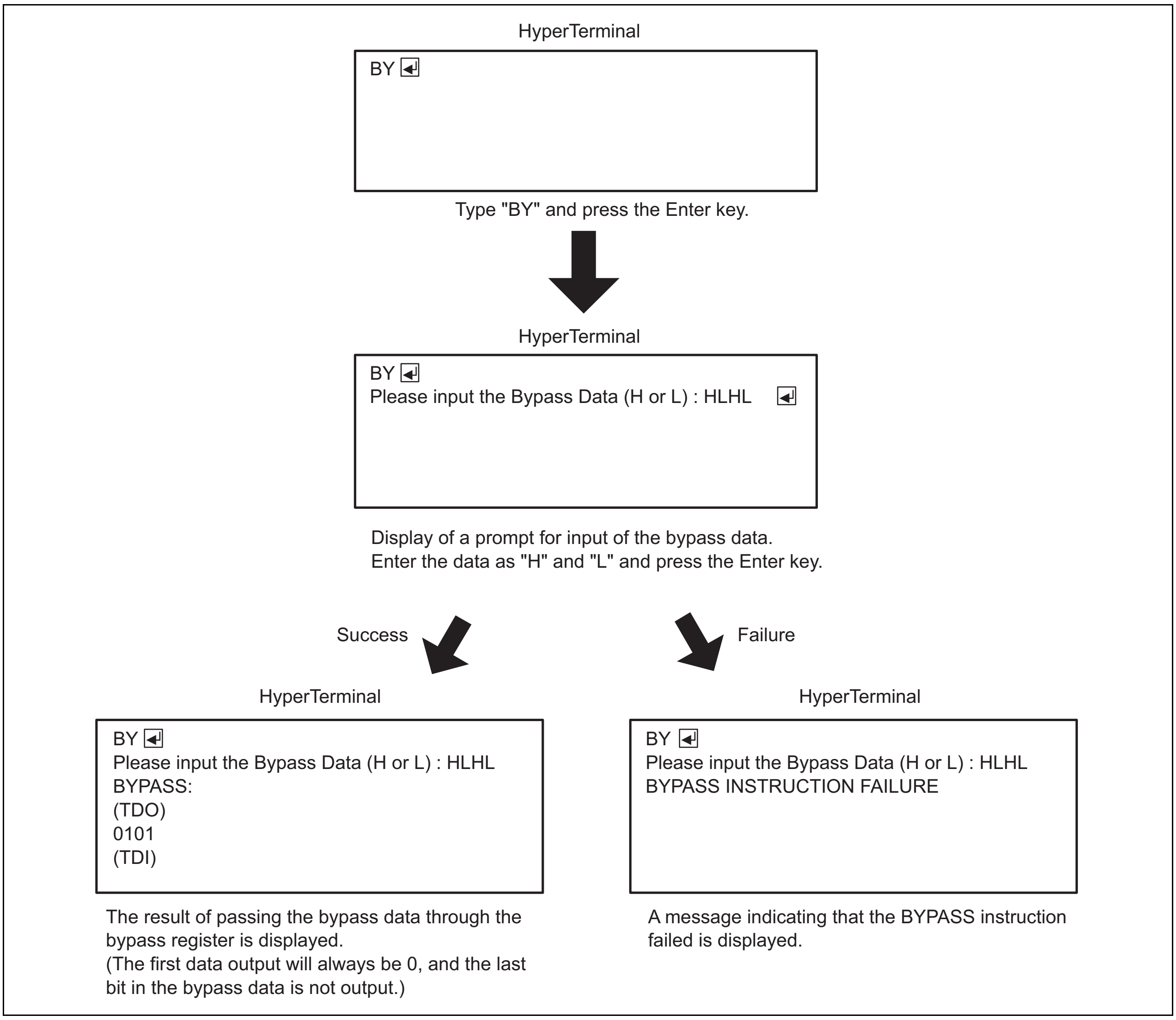


Figure 5 BYPASS Instruction Specifications

3.5 CLAMP Instruction Specifications

The CLAMP instruction is performed as follows.

Type "CP" at HyperTerminal and press the Enter key. The system will display "Please input the output setting of P3x. (H or L):" on HyperTerminal. Next, enter H for a high-level output or L for a low-level output for the specified pin (P30 to P33). If you do not want to change the pin state, enter any other character. When the output levels have been set for all four pins (P30 to P33), the system will then display "Please input the Bypass Data (H or L):" on HyperTerminal. Enter the bypass data (up to 100 characters) and press the Enter key. The on/off state of the LED corresponding to each pin will change according to the previously entered data. Then, the system will pass the bypass data through the bypass register and display the result on HyperTerminal. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. Note that if the CLAMP instruction fails, the bypass result will not be displayed on HyperTerminal, but rather the system will display "CLAMP INSTRUCTION FAILURE". Figure 6 shows an overview of this operation.

Since the CLAMP instruction performs a forcible output to the pins, the user must assure that no problems will occur in the system when the instruction is executed, even if there are outputs from the set pins. Also, since the CLAMP instruction is a test mode instruction, normal microcontroller operation will be stopped until the microcontroller is set to normal mode after CLAMP instruction execution.

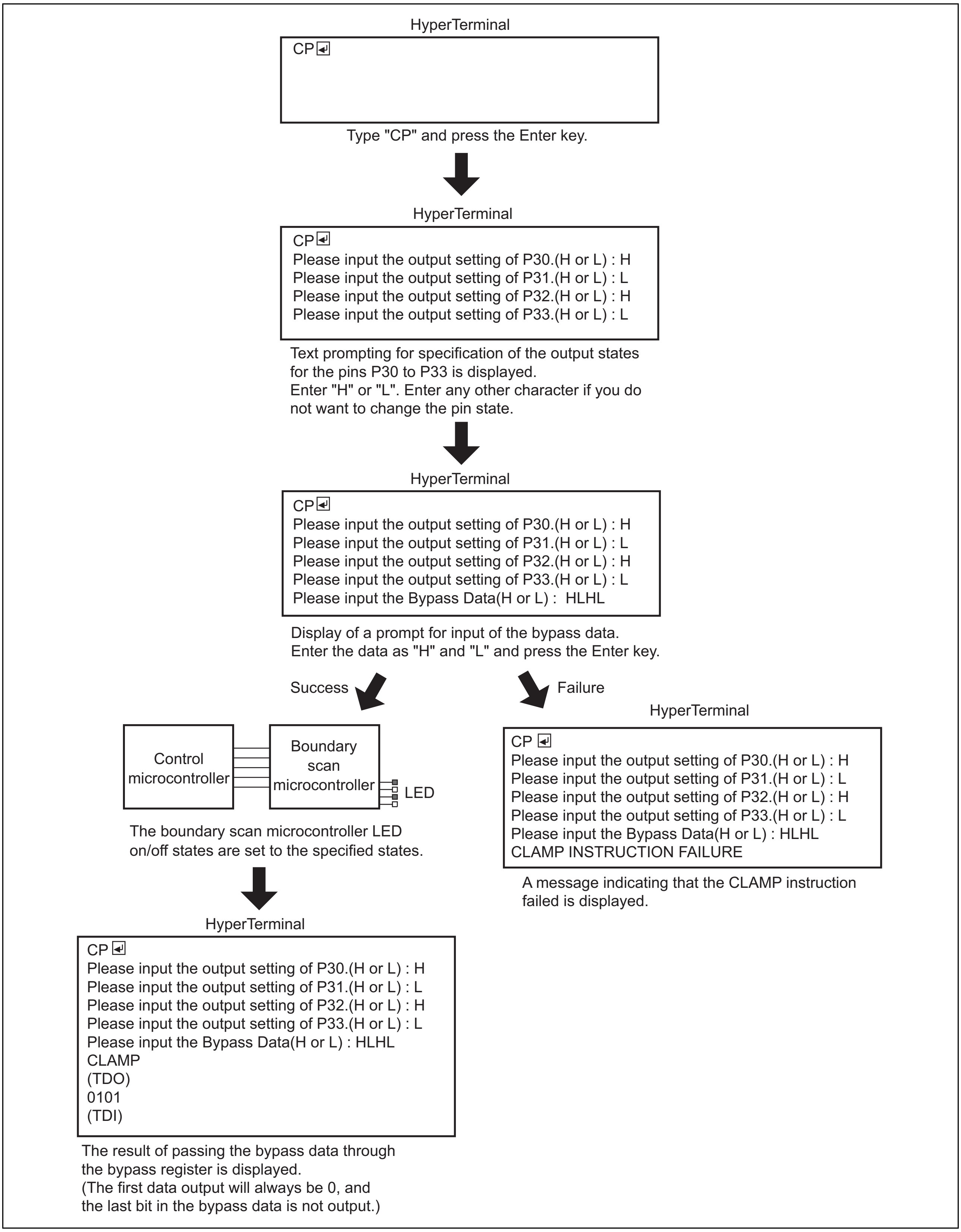


Figure 6 CLAMP Instruction Specifications

3.6 HIGHZ Instruction Specifications

The HIGHZ instruction is performed as follows.

Type "HZ" at HyperTerminal and press the Enter key. The system will then display "Please input the Bypass Data (H or L):" on HyperTerminal. Enter the bypass data (up to 100 characters) and press the Enter key. The system will pass the bypass data through the bypass register while holding all pins other than the TAP pins in the high-impedance state and display the result on HyperTerminal. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. If the HIGHZ instruction fails, "BYPASS INSTRUCTION FAILURE" will be displayed on HyperTerminal. Figure 7 shows an overview of this operation.

Since the HIGHZ instruction is a test mode instruction, normal microcontroller operation will be stopped until the microcontroller is set to normal mode after HIGHZ instruction execution.

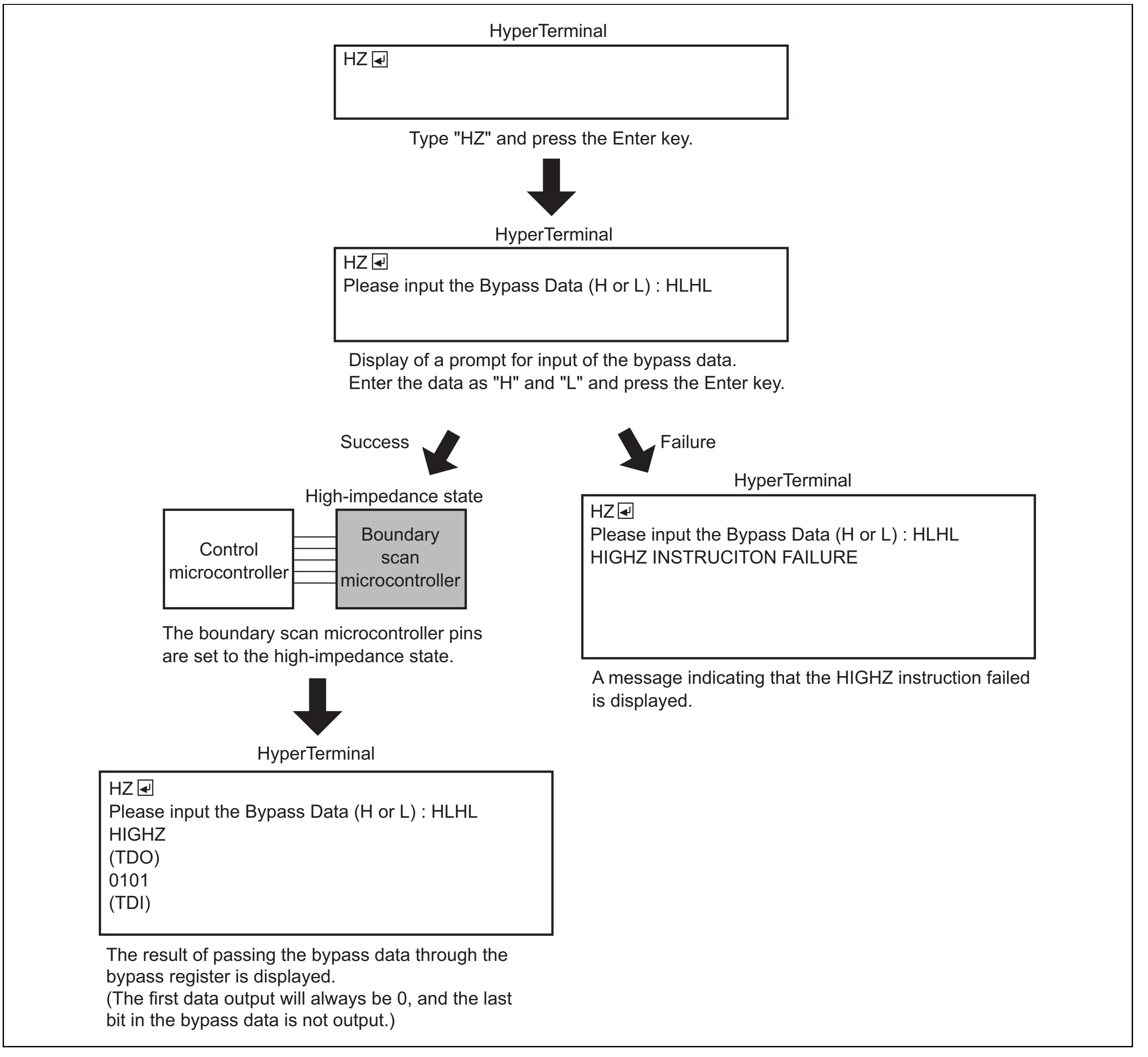


Figure 7 HIGHZ Instruction Specifications

3.7 IR Status Word Acquisition Specifications

The IR status word is acquired as follows.

Type "IR" at HyperTerminal and press the Enter key. The system will acquire the IR status word from the boundary scan microcontroller and display it on HyperTerminal in the order it is output from TDO. Figure 8 shows an overview of this operation.

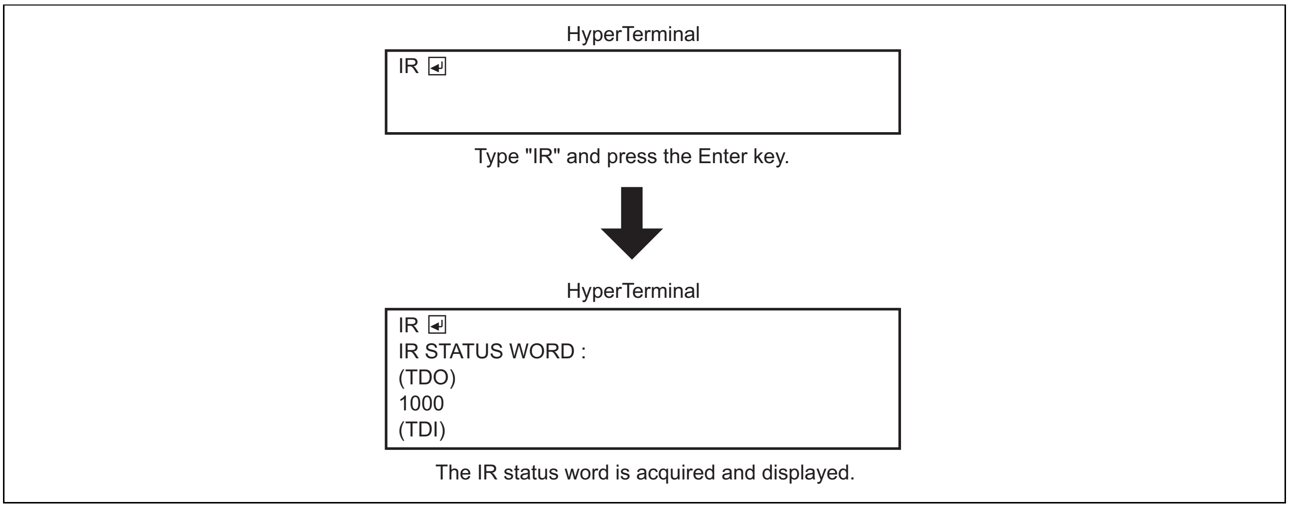


Figure 8 IR Status Word Acquisition Specifications

4. Operation

This section describes the operation of the boundary scan function as used in this sample system.

4.1 IDCODE Instruction

The IDCODE instruction operation is performed as follows in this sample system.

The IDCODE instruction code is input to the boundary scan microcontroller TDI pin, and the IDCODE instruction is executed. In the following descriptions, the procedure for issuing instructions is the same. The device IDCODE is acquired from the TDO pin by iterating the DR-Shift state the IDCODE length (32 times). Figure 9 shows the data flow for this operation.

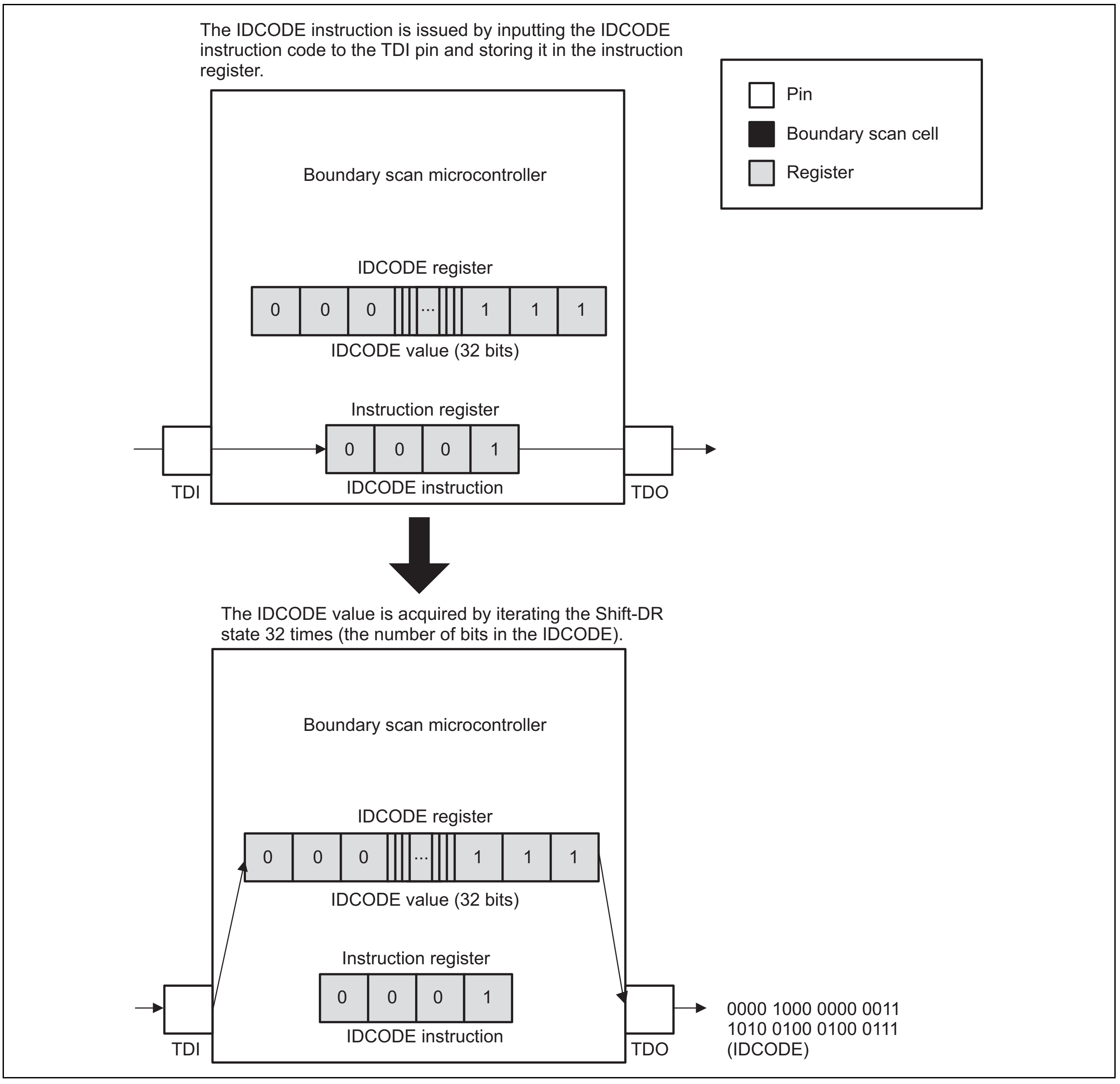


Figure 9 Data Flow for the IDCODE Instruction

4.2 SAMPLE/PRELOAD Instruction

The SAMPLE/PRELOAD instruction operation is performed as follows in this sample system.

The SAMPLE/PRELOAD instruction is issued in the boundary scan microcontroller to acquire the pin states to the boundary scan cells in the capture-DR state. Then the boundary scan cell states are acquired from the TDO pin by iterating the DR-Shift state for the number of boundary scan cells (296 times). Figure 10 shows the data flow. Note that in this figure one boundary scan cell is shown for one pin's I/O state for simplicity. In the actual device, however, there may be up to three cells for a single pin. The following figures in this section are similar in this respect.

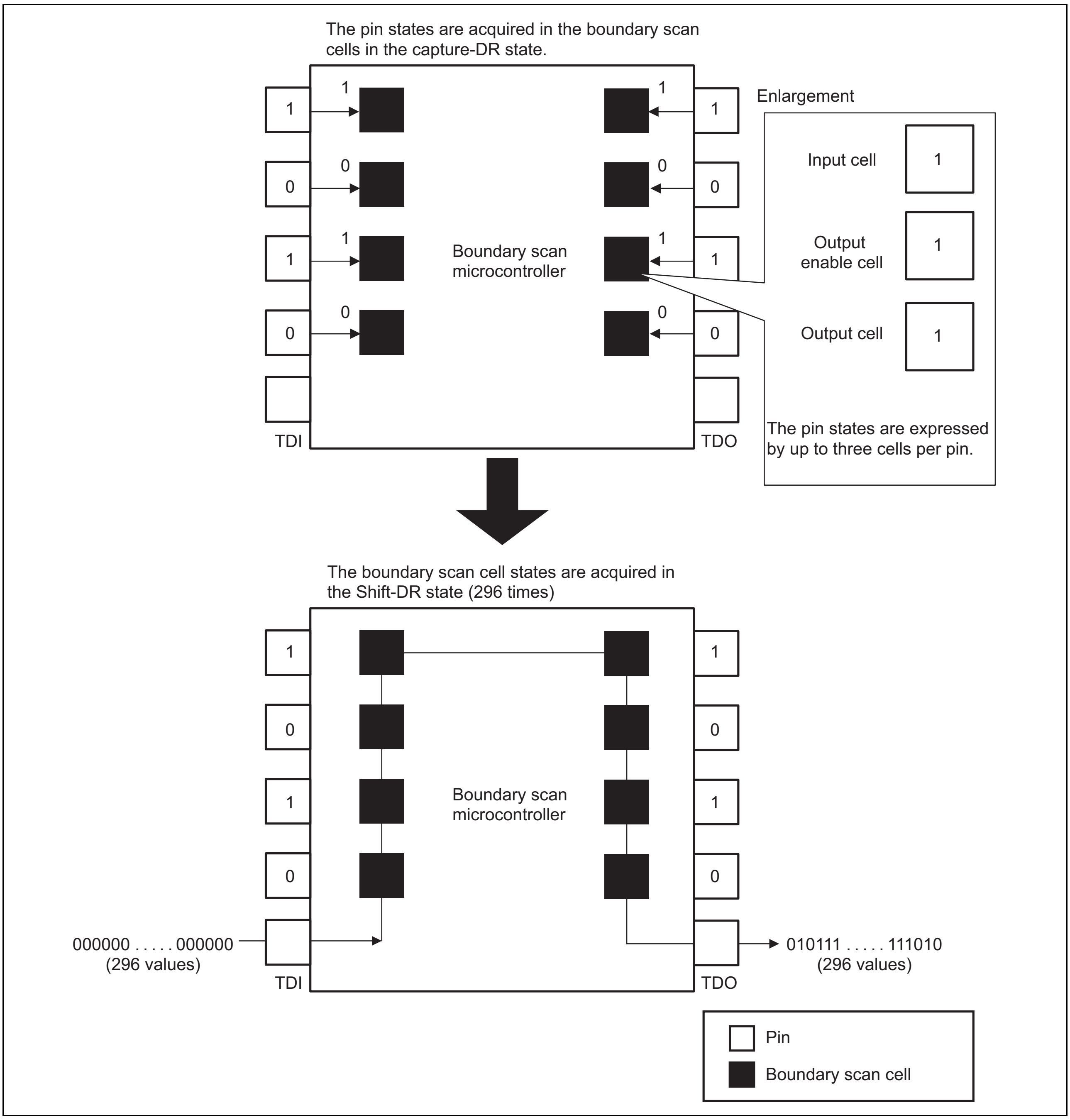


Figure 10 Data Flow for the SAMPLE/PRELOAD Instruction

4.3 EXTEST Instruction

The EXTEST instruction operation is performed as follows in this sample system.

First, the pin states are acquired in the boundary scan cells by performing a SAMPLE/PRELOAD instruction on the boundary scan microcontroller. Then, only the values whose output states are to be changed from the acquired boundary scan cell values are changed (for a high-level output, the output cell and output enable cell are changed to 1 and for a low-level output, the output cell is changed to 0 and the output enable cell is changed to 1), and the boundary scan cells are set again. An EXTEST instruction is executed to forcibly output the pin states. Figure 11 shows the data flow. Table 5 lists the boundary scan cell setting values set in the operation shown in figure 11 and pin state examples (LED on/off state manipulations only).

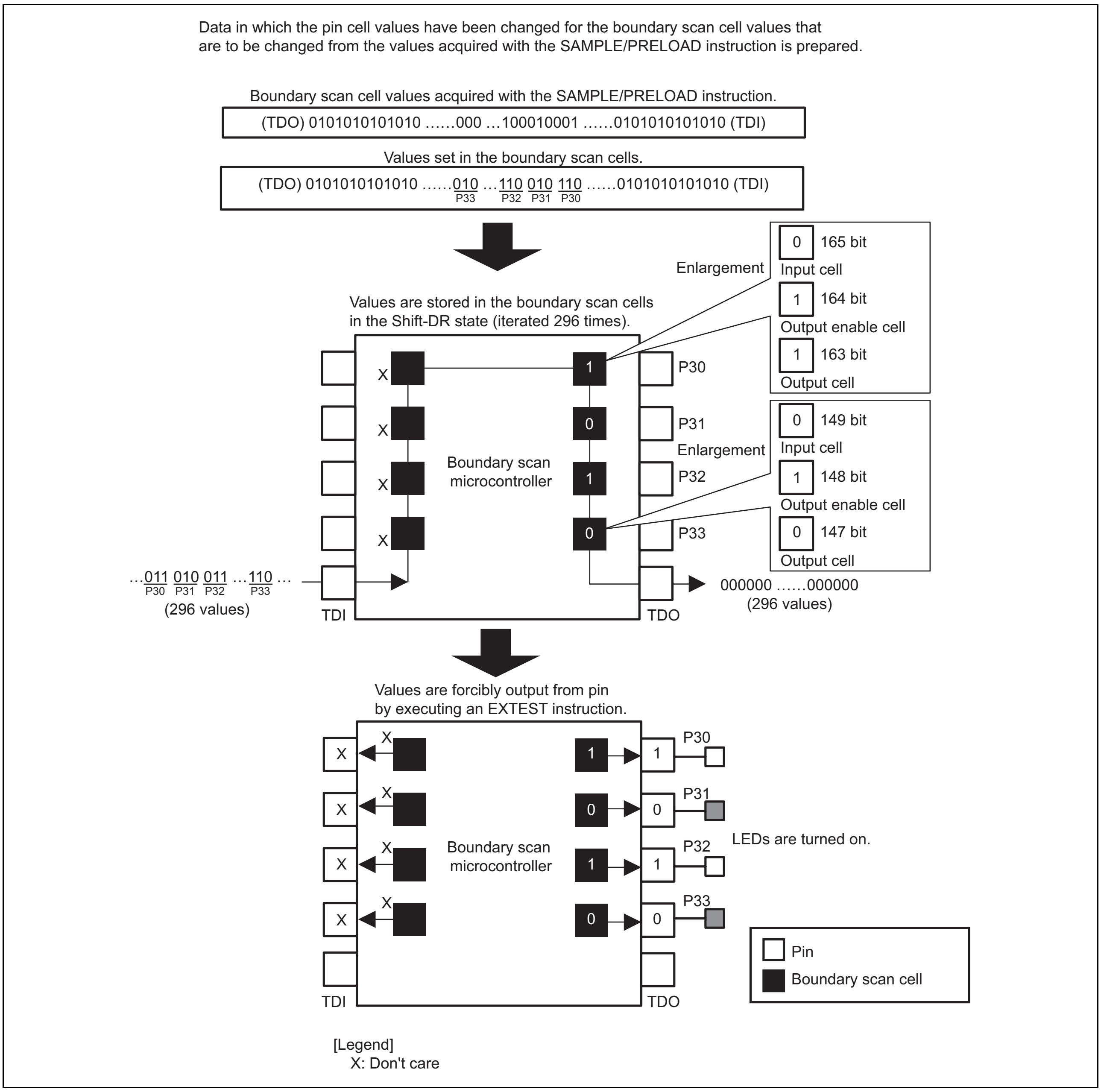


Figure 11 Data Flow for the EXTEST Instruction

Table 5 Boundary Scan Cell Set Value and Pin State Example (LED on/off state manipulations only)

Pin (pin number)	TDI		P30(56)			P31(57)			P32(58)				P33(62)				TDO
Boundary scan cell bit			165	164	163	162	161	160	159	158	157		149	148	147		
I/O		…	I	E	O	I	E	O	I	E	O	…	I	E	O	…	
Cell setting value			0	1	1	0	1	0	0	1	1		0	1	0		
Pin State			1			0			1				0				

Legend:

I: Input

E: Output enable

O: Output

4.4 BYPASS Instruction

The BYPASS instruction operation is performed as follows in this sample system.

A BYPASS instruction is issued in the boundary scan microcontroller and the values to bypass are input to the TDI pin while iterating the shift-DR state for the amount of bypass data. The bypass data passes through the bypass register and is acquired by the TDO pin. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. Figure 12 shows the data flow.

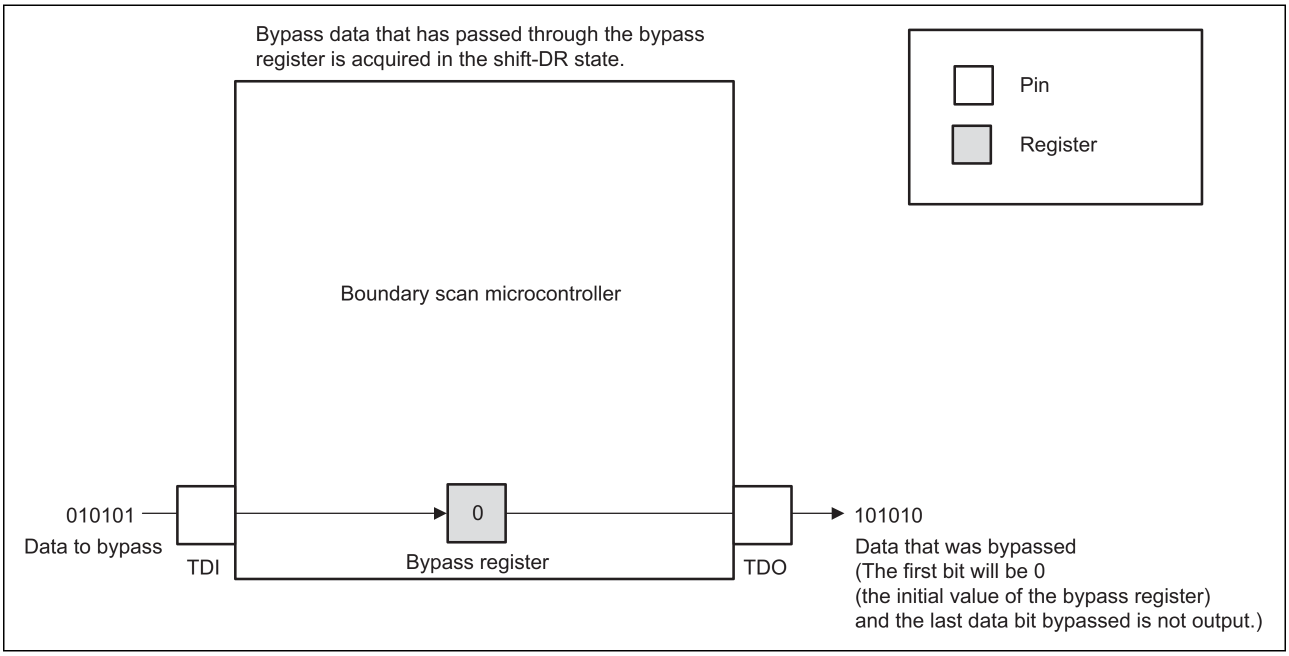


Figure 12 Data Flow for the BYPASS Instruction

4.5 CLAMP Instruction

The CLAMP instruction operation is performed as follows in this sample system.

First, the pin states are acquired in the boundary scan cells by performing a SAMPLE/PRELOAD instruction on the boundary scan microcontroller. Then, only the values whose output states are to be changed from the acquired boundary scan cell values are changed (for a high-level output, the output cell and output enable cell are changed to 1 and for a low-level output, the output cell is changed to 0 and the output enable cell is changed to 1), and the boundary scan cells are set again. Also, bypass data (up to 100 characters) is input. A CLAMP instruction is issued to force pin output and the values to bypass are input to the TDI pin while iterating the shift-DR state for the amount of bypass data. The bypass data passes through the bypass register and is acquired by the TDO pin. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. The data flow diagram is shown in figures 13-1 and 13-2. Note that the boundary scan cell data and pin states set when the operation of figures 13-1 and 13-2 are performed are the same as those in table 5.

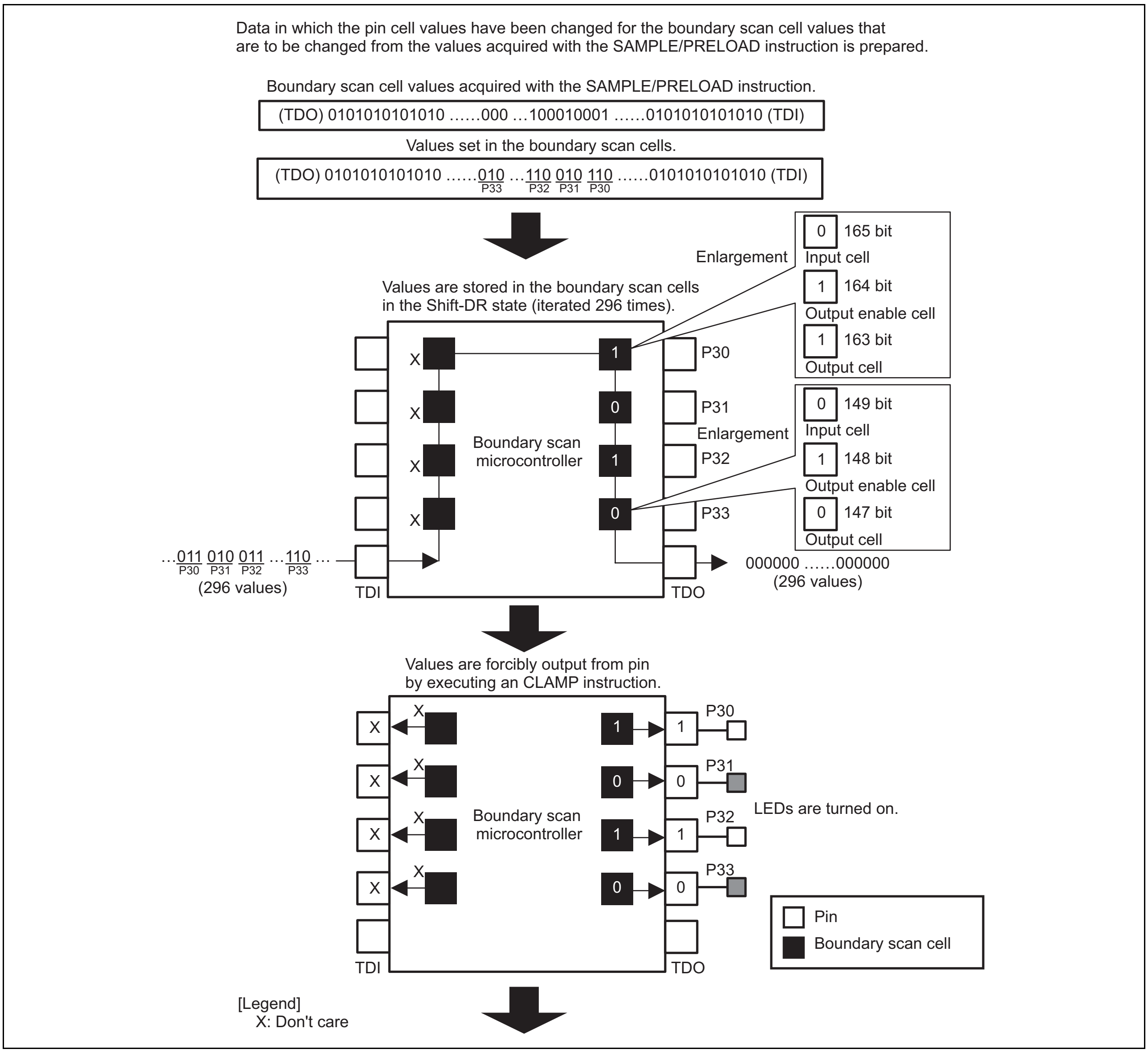


Figure 13-1 Data Flow for the Clamp Instruction

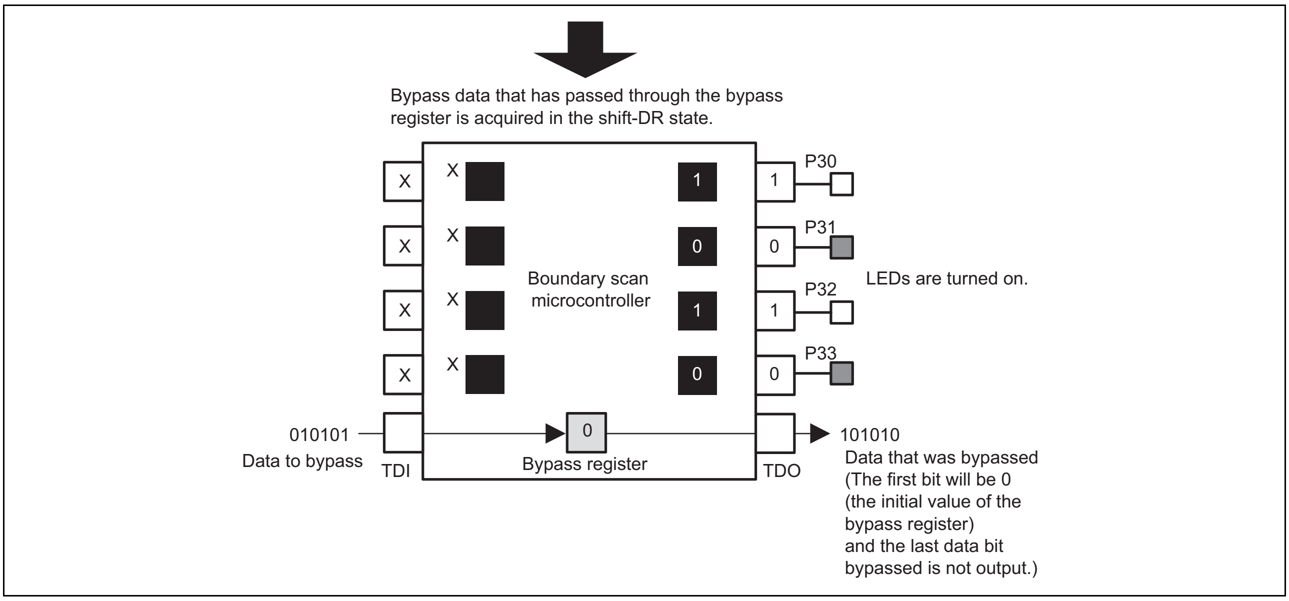


Figure 13-2 Data Flow for the Clamp Instruction

4.6 HIGHZ Instruction

The HIGHZ instruction operation is performed as follows in this sample system.

First, a HIGHZ instruction is issued in the boundary scan microcontroller to set the pins to the high-impedance state. Then the values to bypass are input to the TDI pin while iterating the shift-DR state for the amount of bypass data. The bypass data passes through the bypass register and is acquired by the TDO pin. Since this sample system performs a TAP controller reset each time an instruction is entered with HyperTerminal, the first character must be the bypass register's initial value, that is, 0. Also, since the last bit in the bypass data remains in the bypass register, it will not be output. Figure 14 shows the data flow.

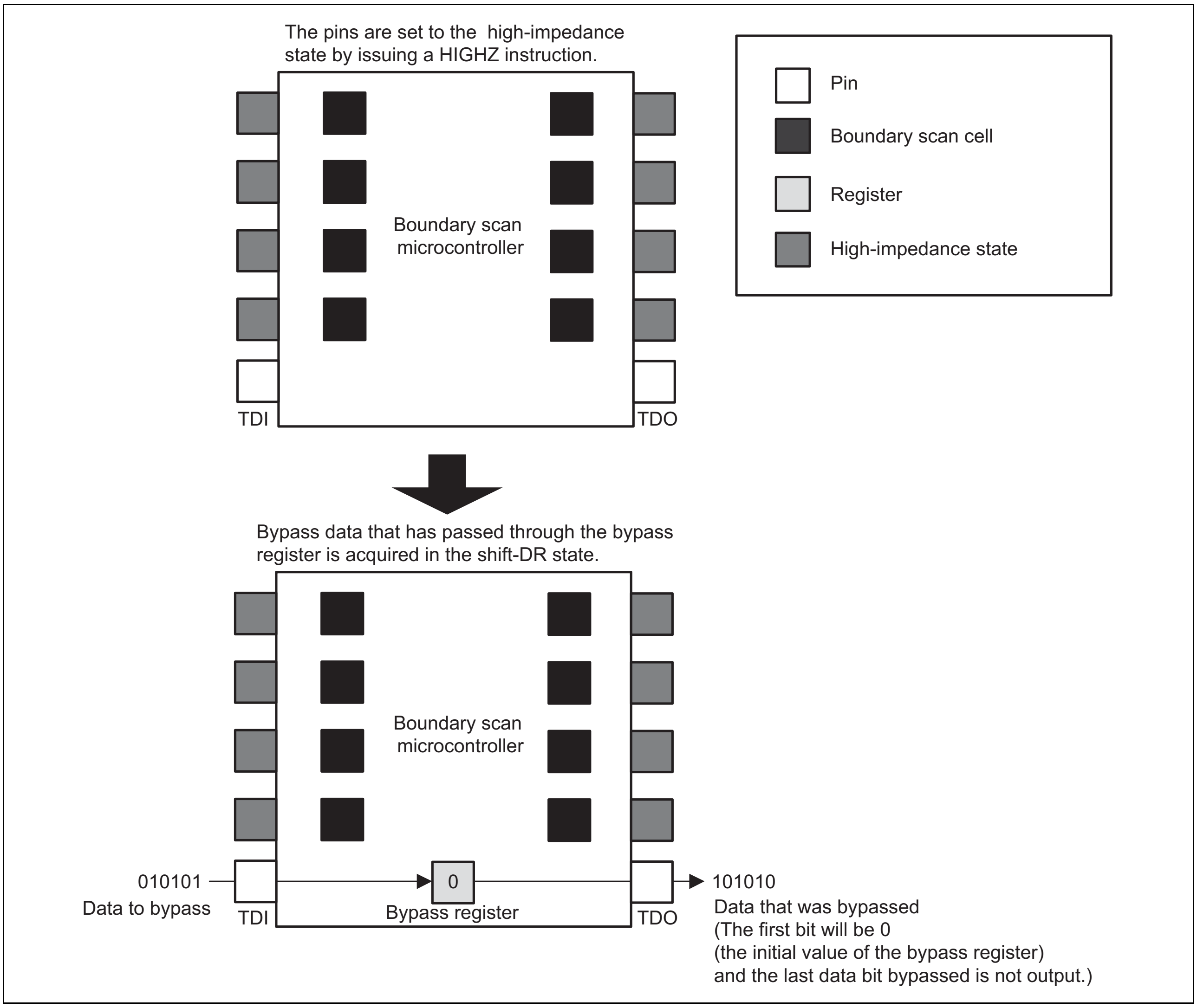


Figure 14 Data Flow for the HIGHX Instruction

4.7 IR Status Word Acquisition

In this sample system, the IR status word is acquired when a SAMPLE/PRELOAD instruction is issued.

The IR status word acquisition operation in this sample system is performed as follows.

The SAMPLE/PRELOAD instruction code is input to the TDI pin while iterating the IR-Shift state for the instruction code length (4 times) in the boundary scan microcontroller. As a result, the IR status word is acquired from the TDO pin. Figure 15 shows the data flow.

Note that while this sample system uses the SAMPLE/PRELOAD instruction to acquire the IR status word, the IR status word can also be acquired in the same manner using other instructions.

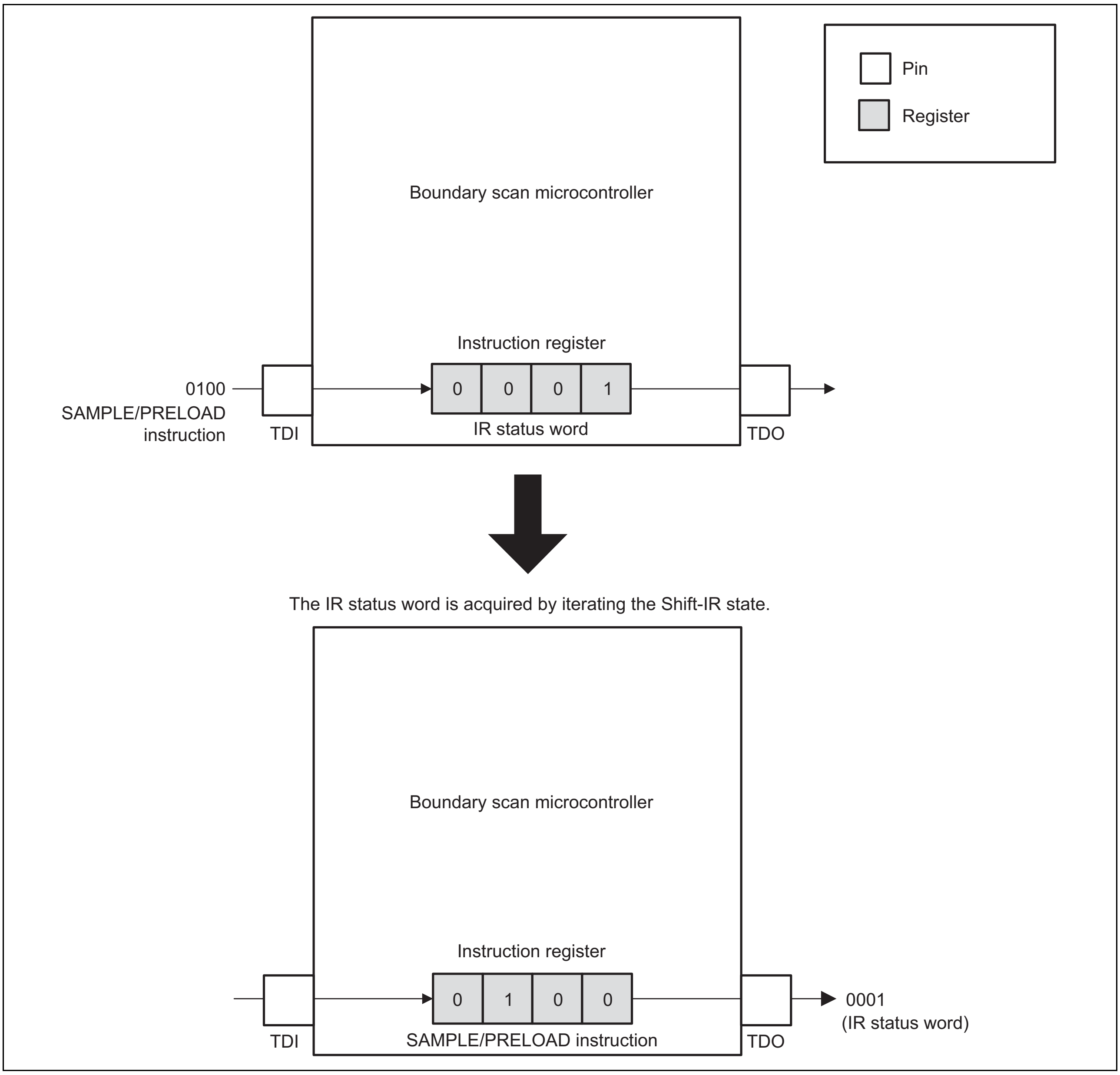


Figure 15 Data Flow for IR Status Word Acquisition

5. Software

5.1 Functions

Table 6 lists the main functions used in this sample system.

Table 6 Functions

Function	Operation
main()	Identifies the received data and calls the instructions.
tap_reset()	Resets the TAP controller
Idcode_Instruction()	IDCODE instruction processing
Sample_Instruction()	SAMPLE/PRELOAD instruction processing
Extest_Instruction()	EXTEST instruction processing
Bypass_Instruction()	BYPASS instruction processing
Clamp_Instruction()	CLAMP instruction processing
Highz_Instruction()	HIGHZ instruction processing
IRWord_Display()	Displays the acquired IR status word on the PC
execute_Instruction()	Controls the TAP controller
Get_IRword()	Acquires the IR status word

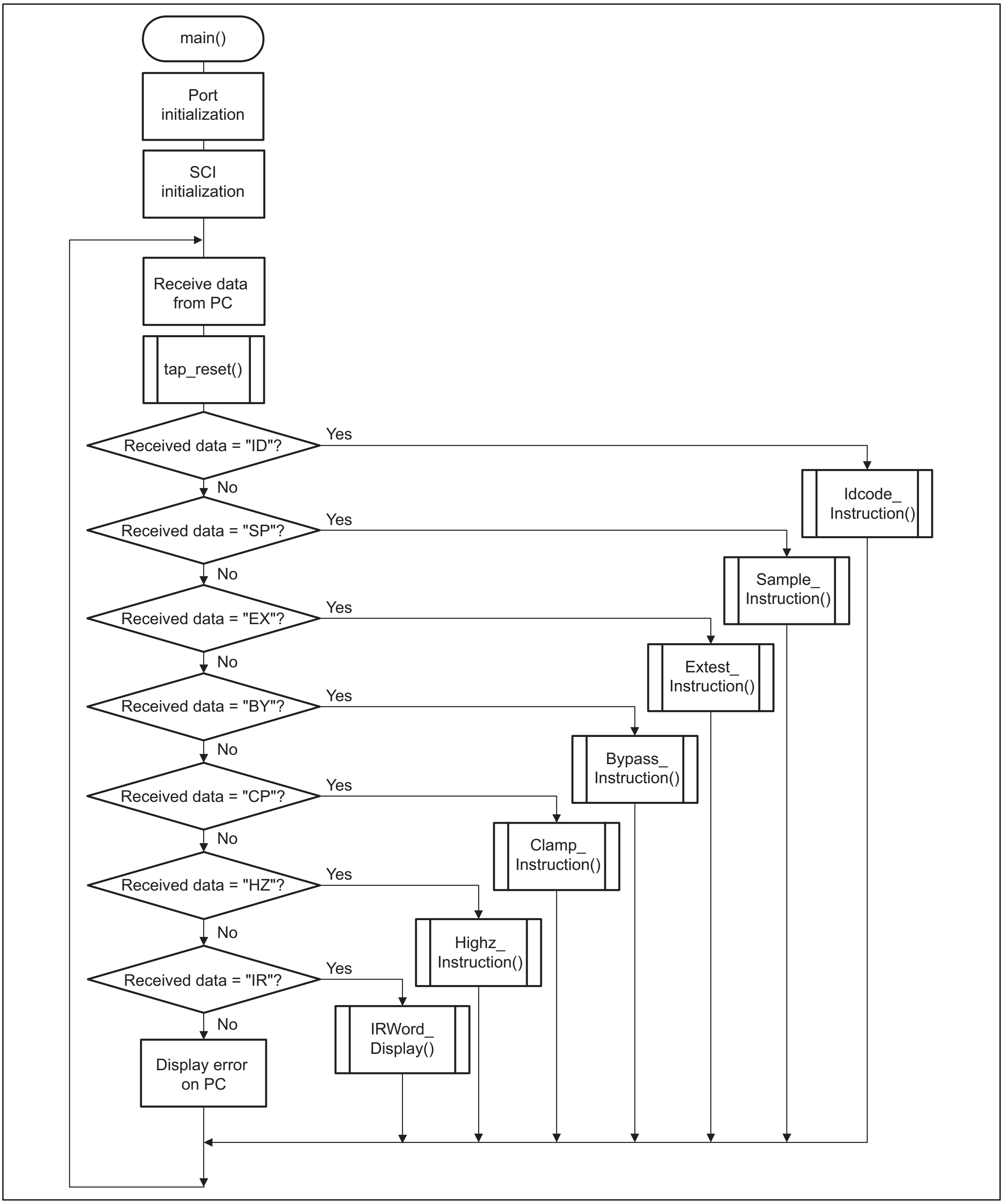
5.2 Section Settings

Table 7 Section Settings

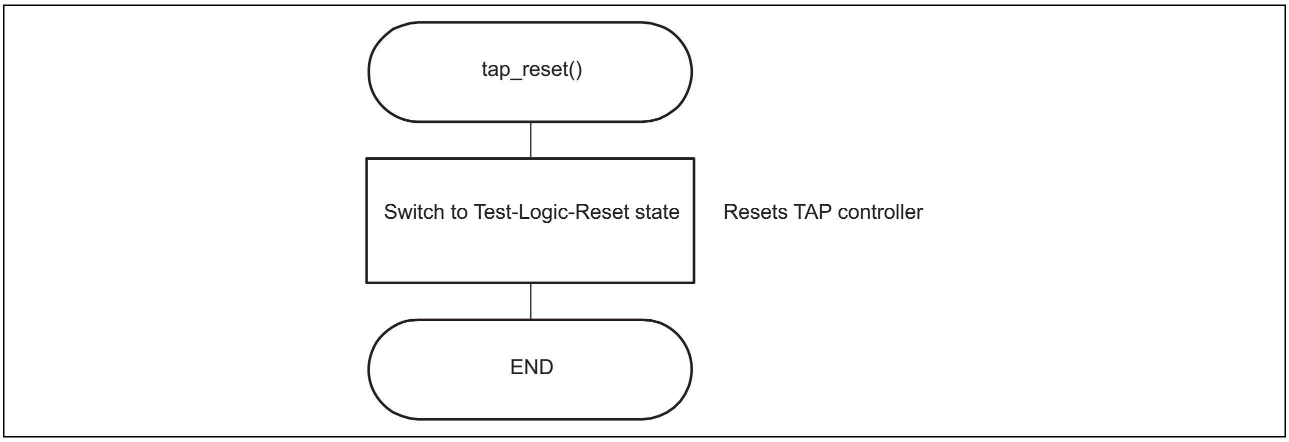
Address	Section name
H'00000400	PResetPRG,PIntPRG
H'00000800	P,C,C$DSEC,C$BSEC,D
H'00FF2000	B,R
H'00FFBE00	S

5.3 Flowcharts

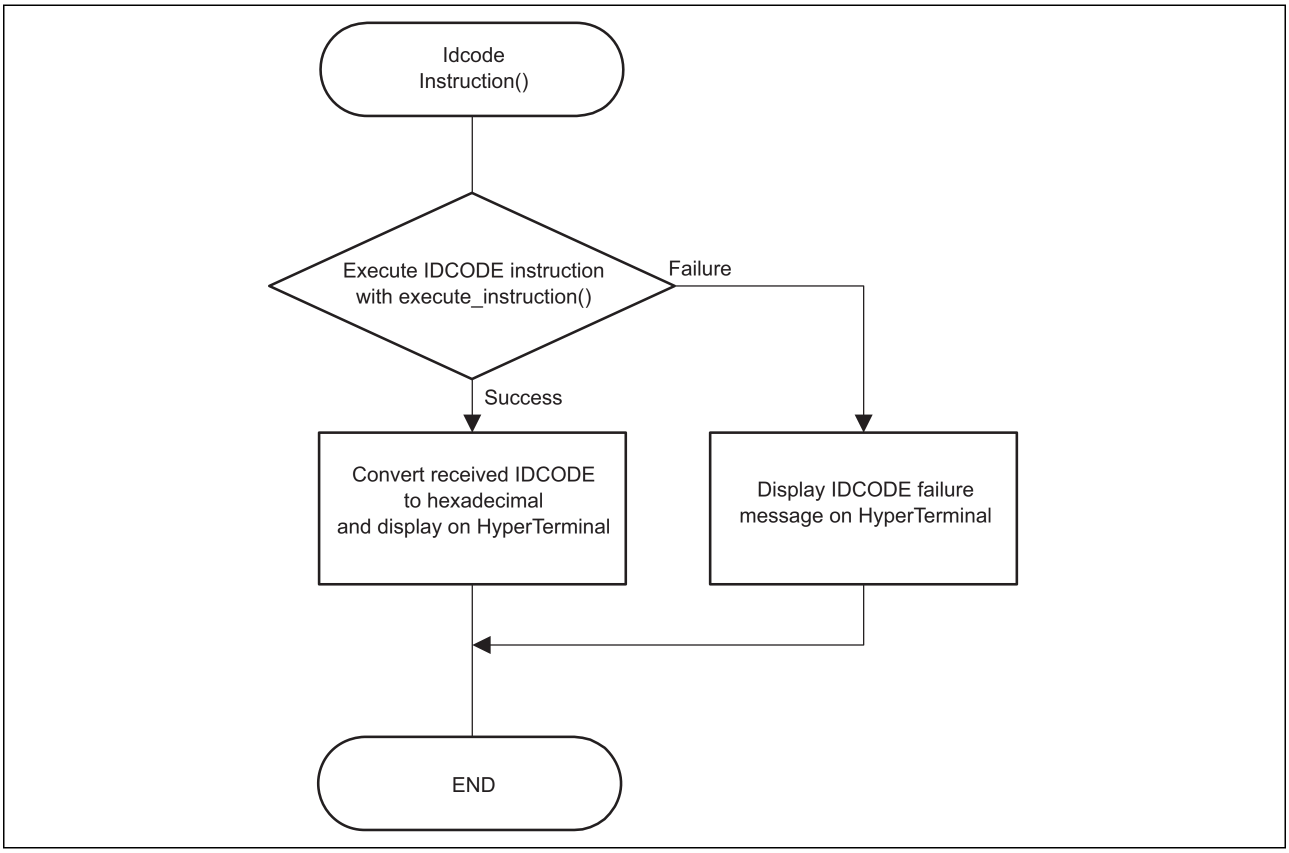
5.3.1 Main Routine



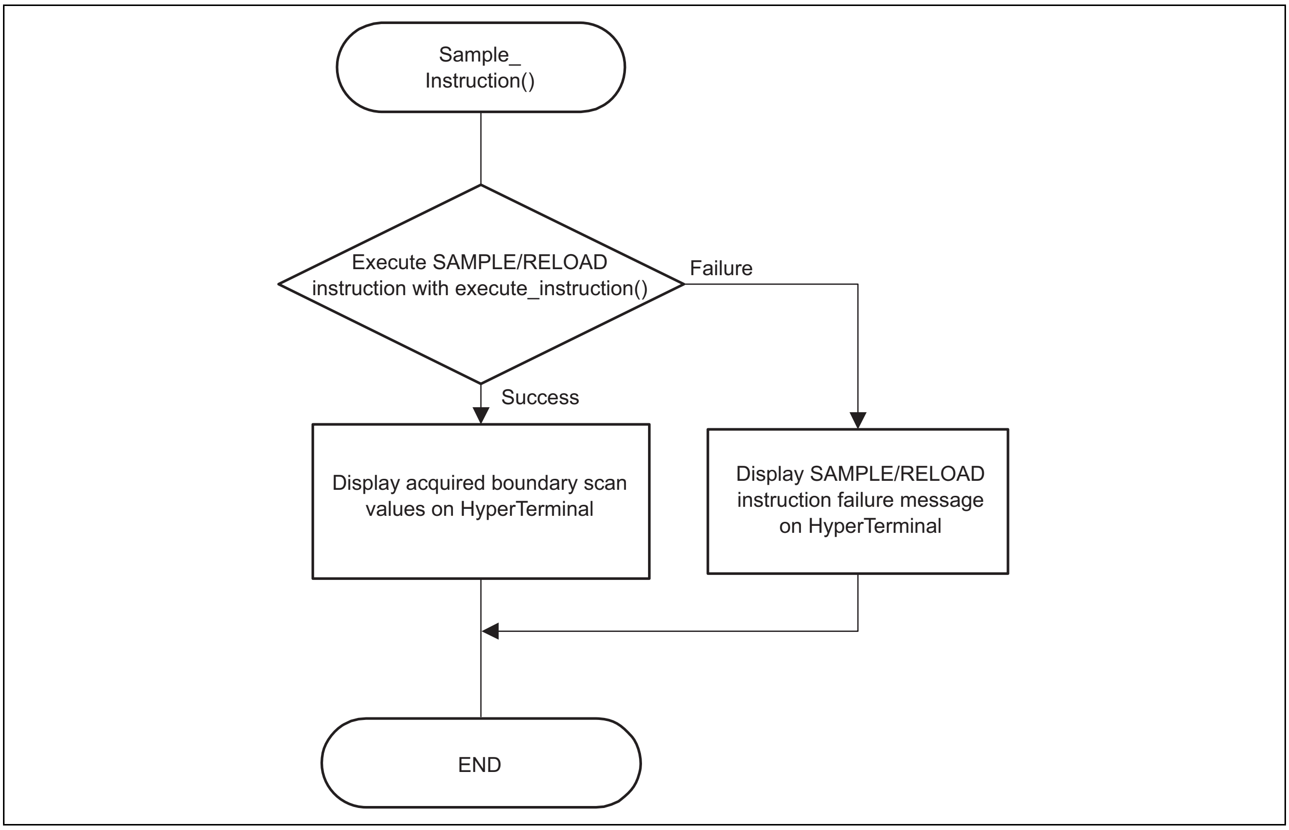
5.3.2 TAP Controller Reset Routine



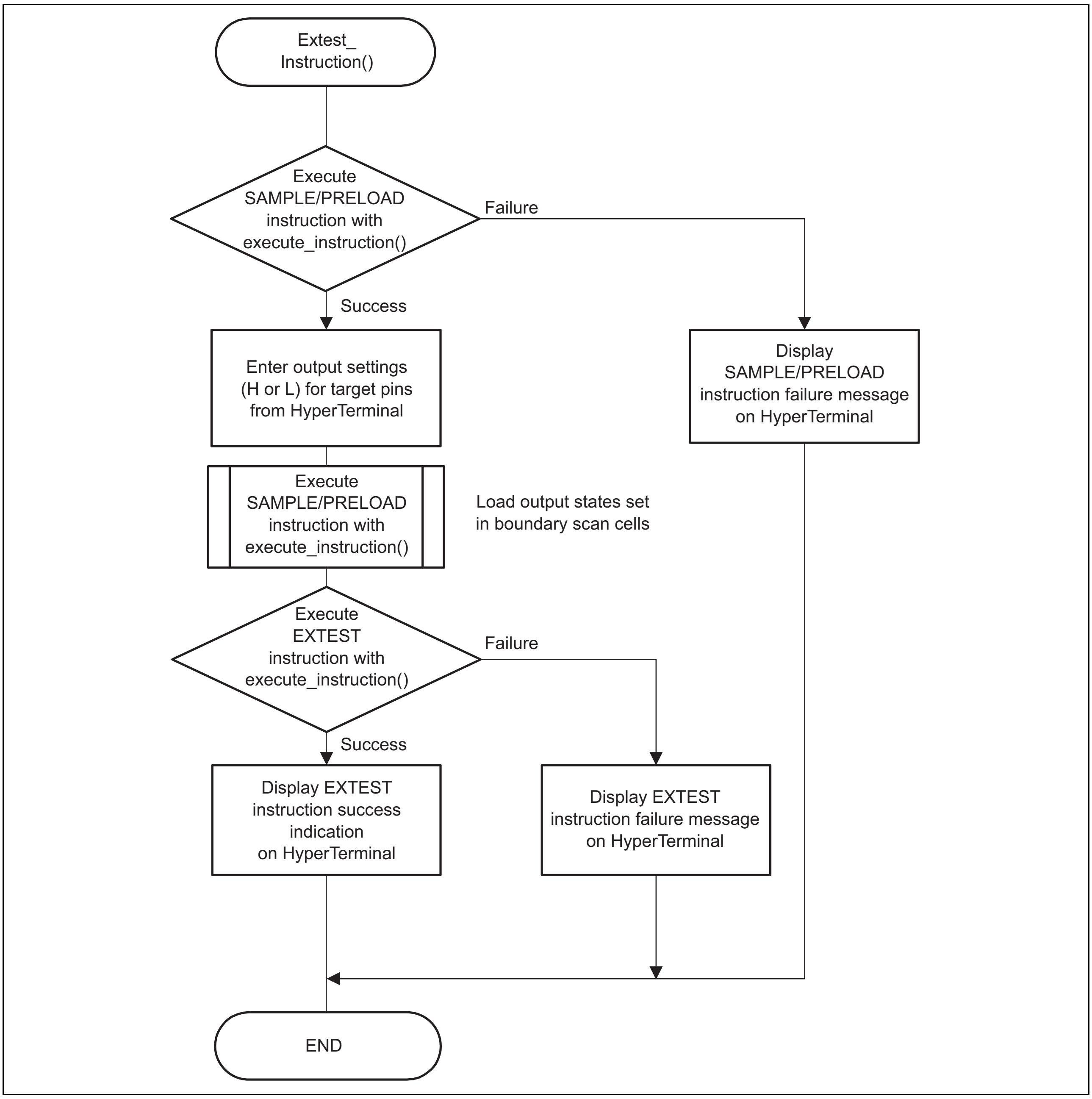
5.3.3 IDCODE Instruction Routine



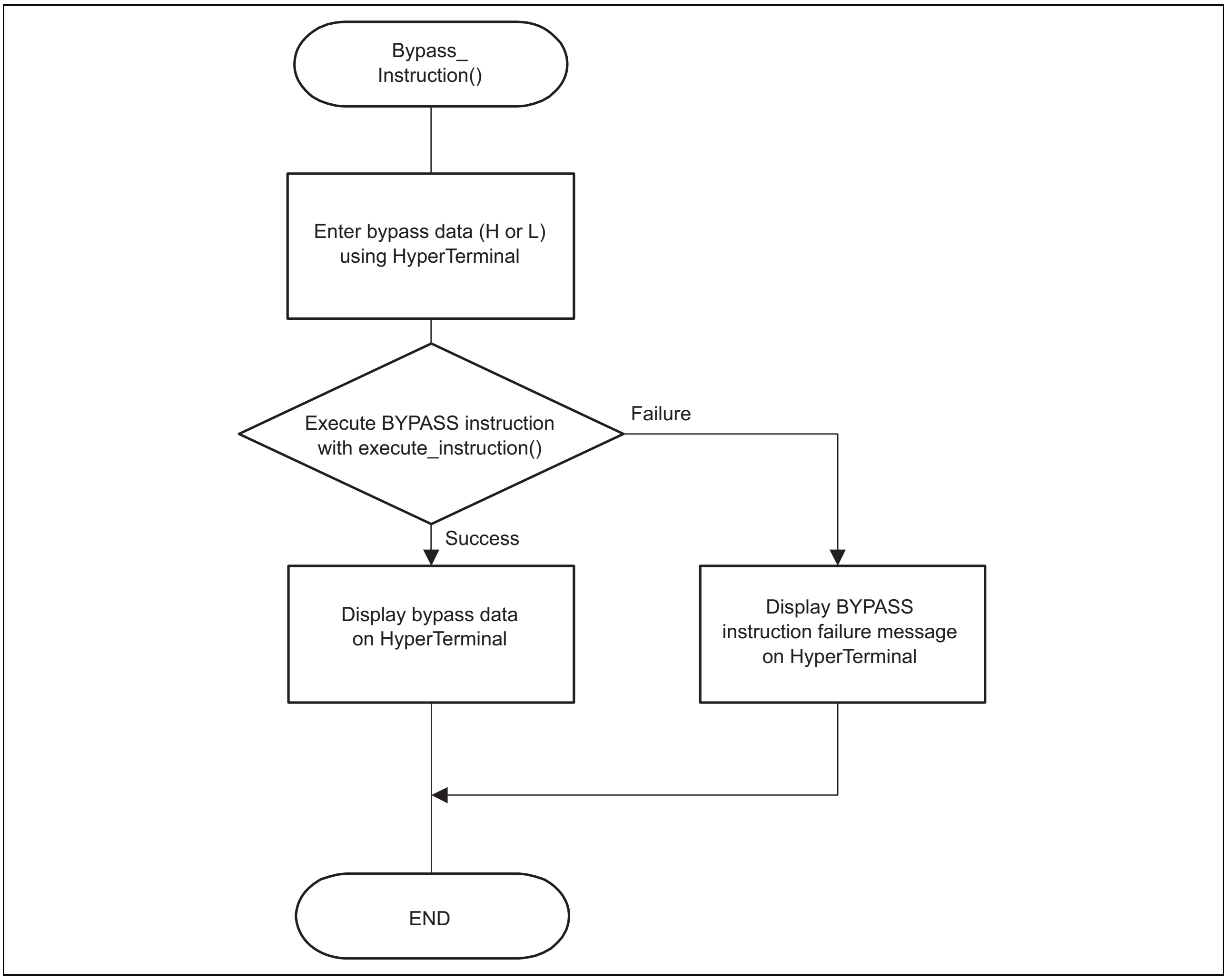
5.3.4 SAMPLE/PRELOAD Instruction Routine



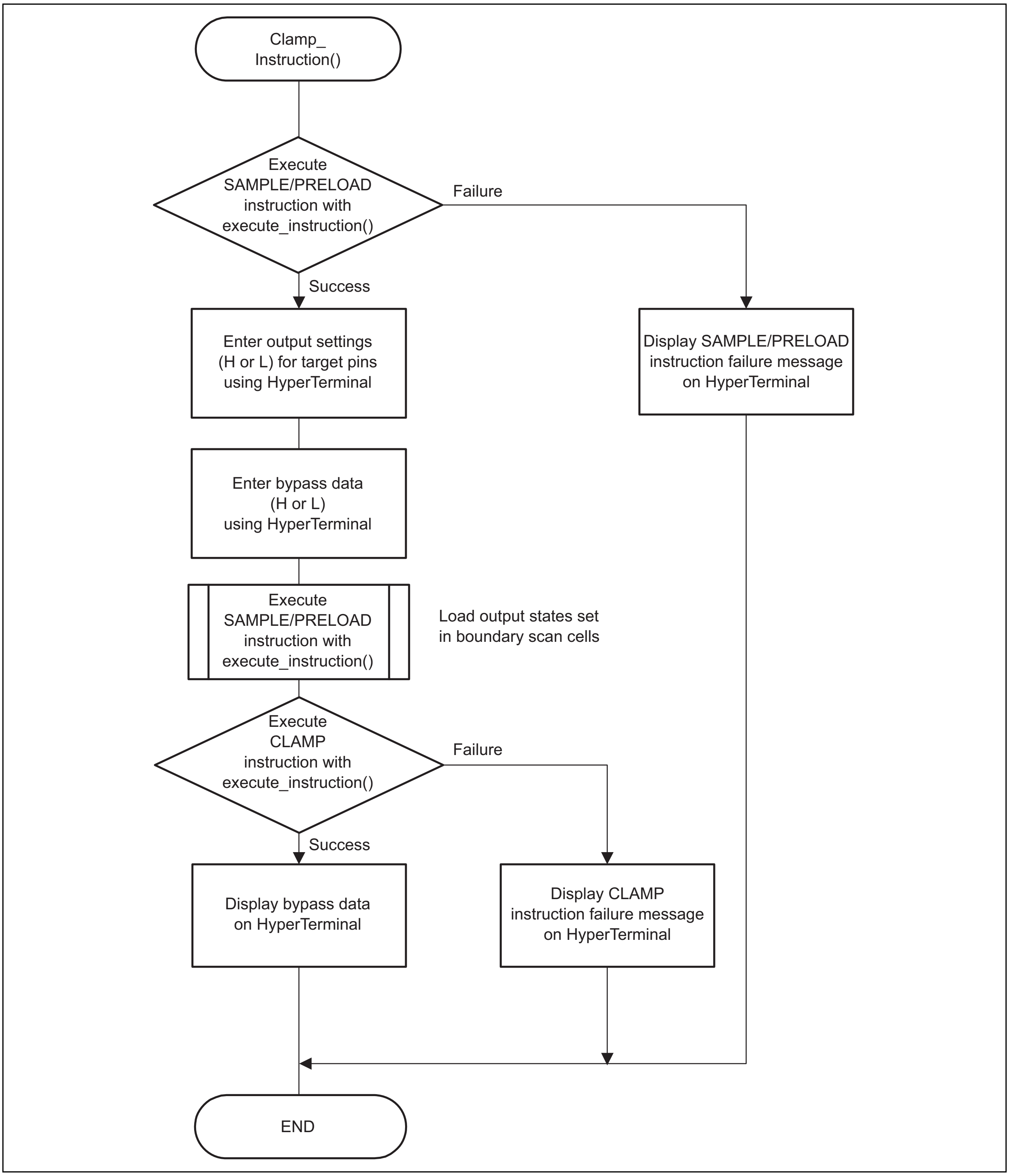
5.3.5 EXTEST Instruction Routine



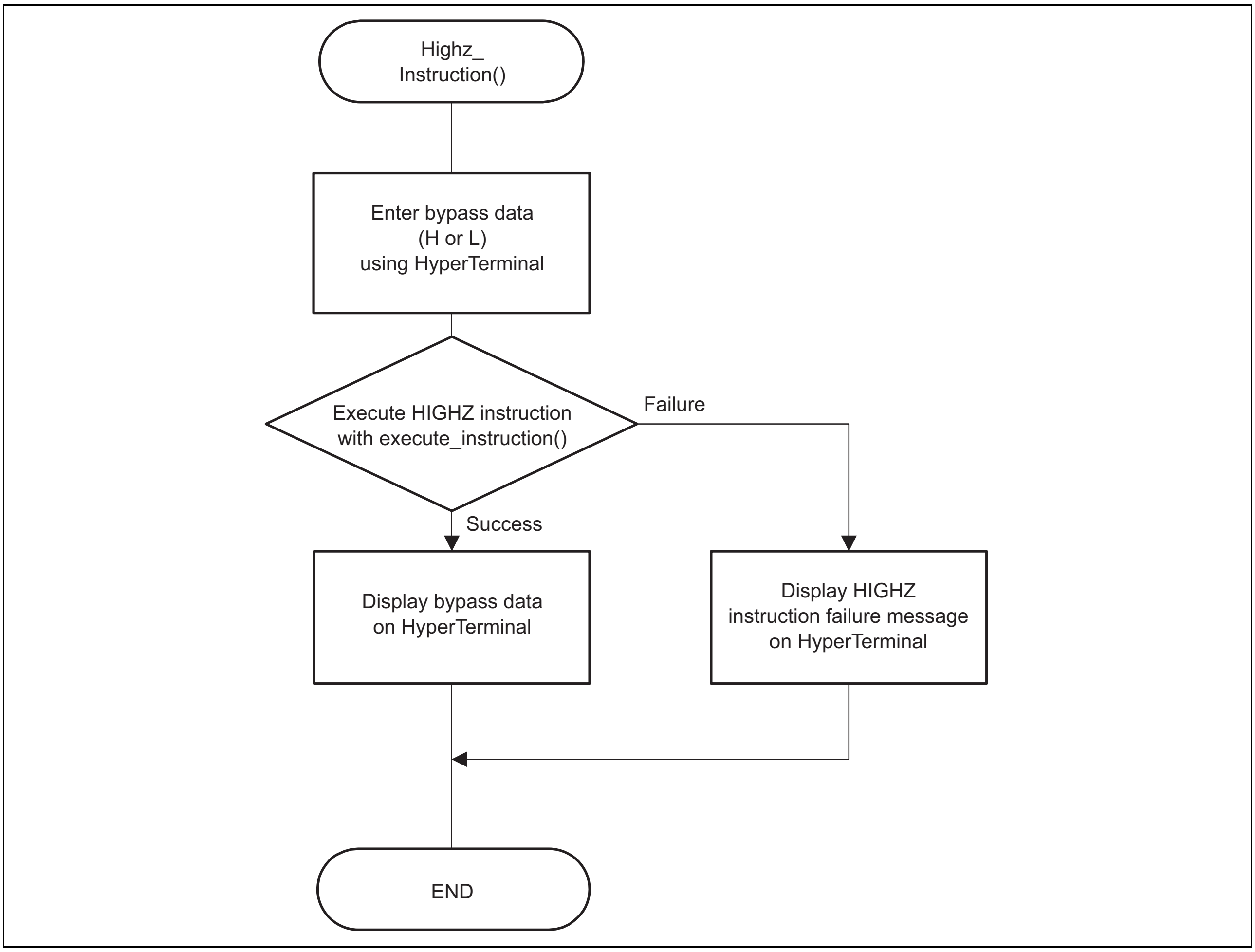
5.3.6 BYPASS Instruction Routine



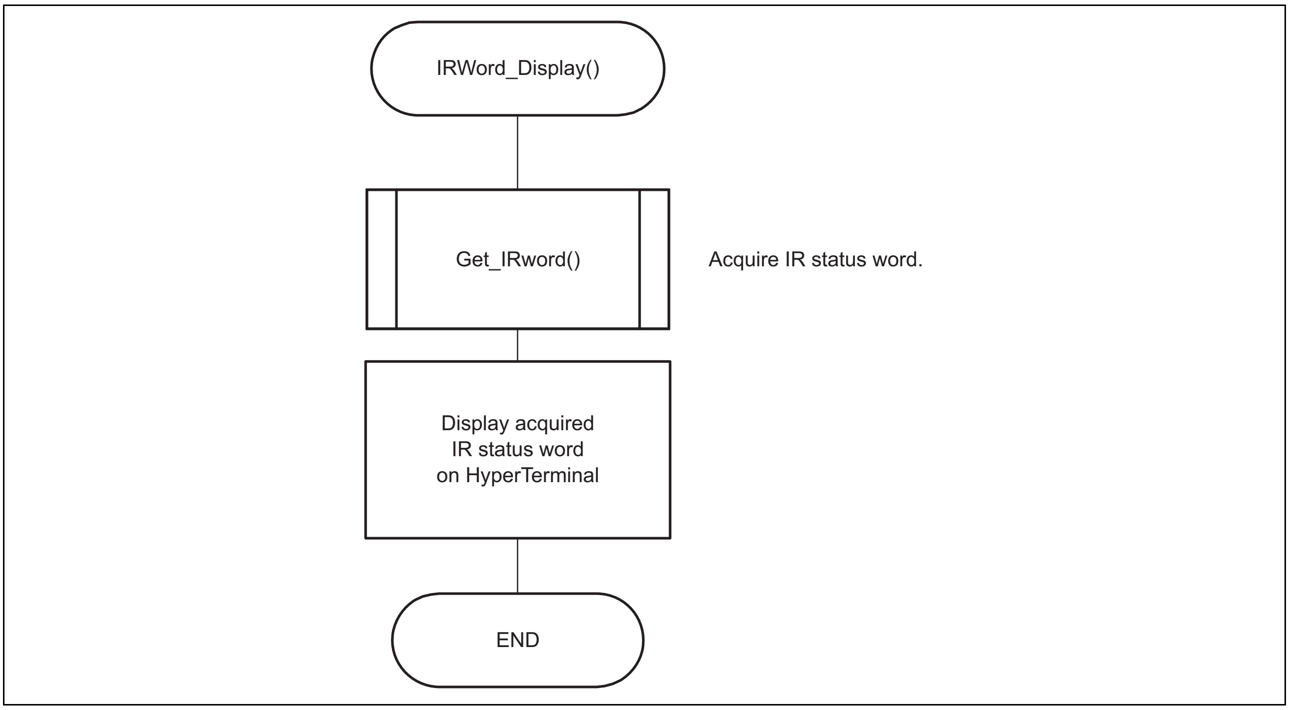
5.3.7 CLAMP Instruction Routine



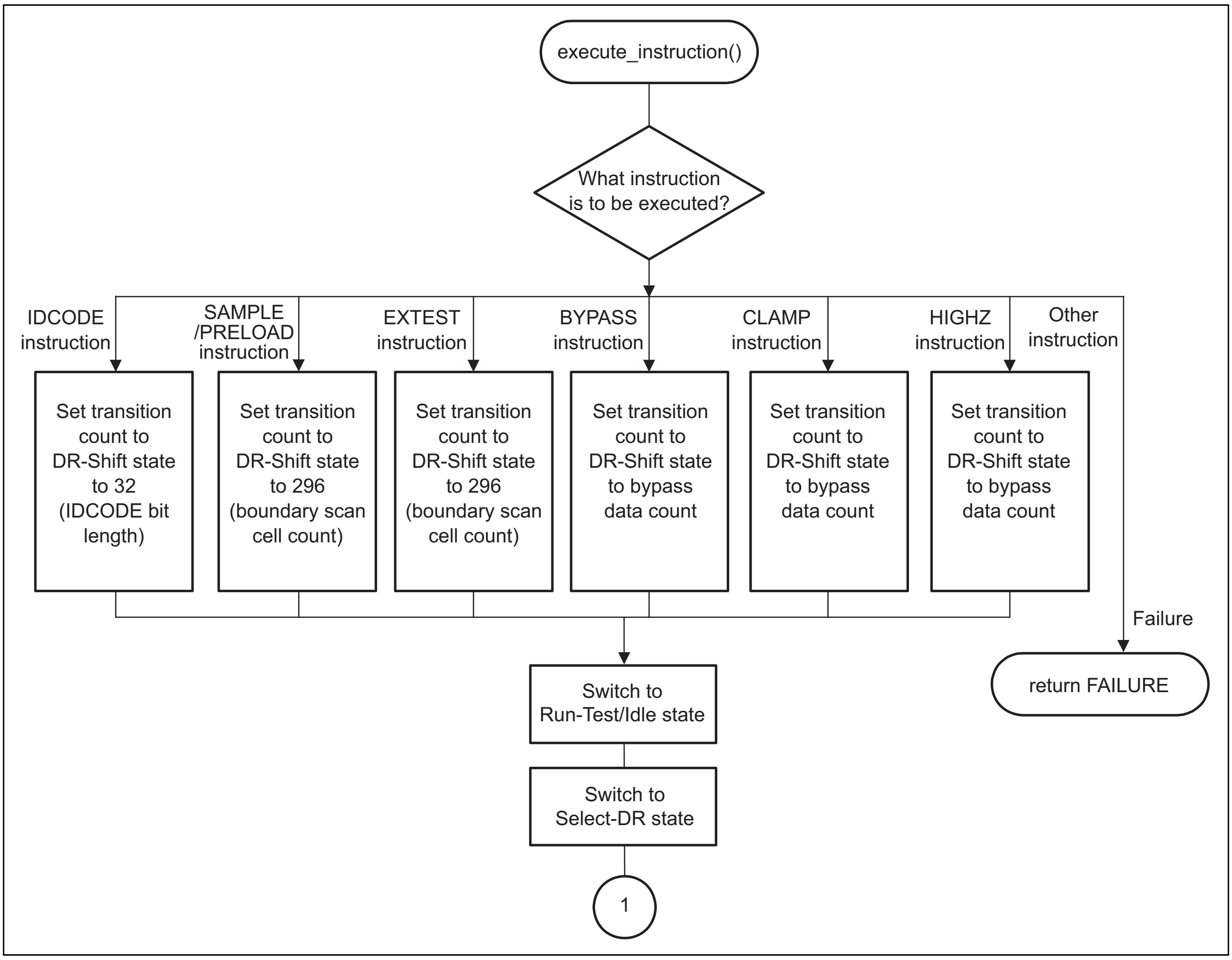
5.3.8 HIGHZ Instruction Routine

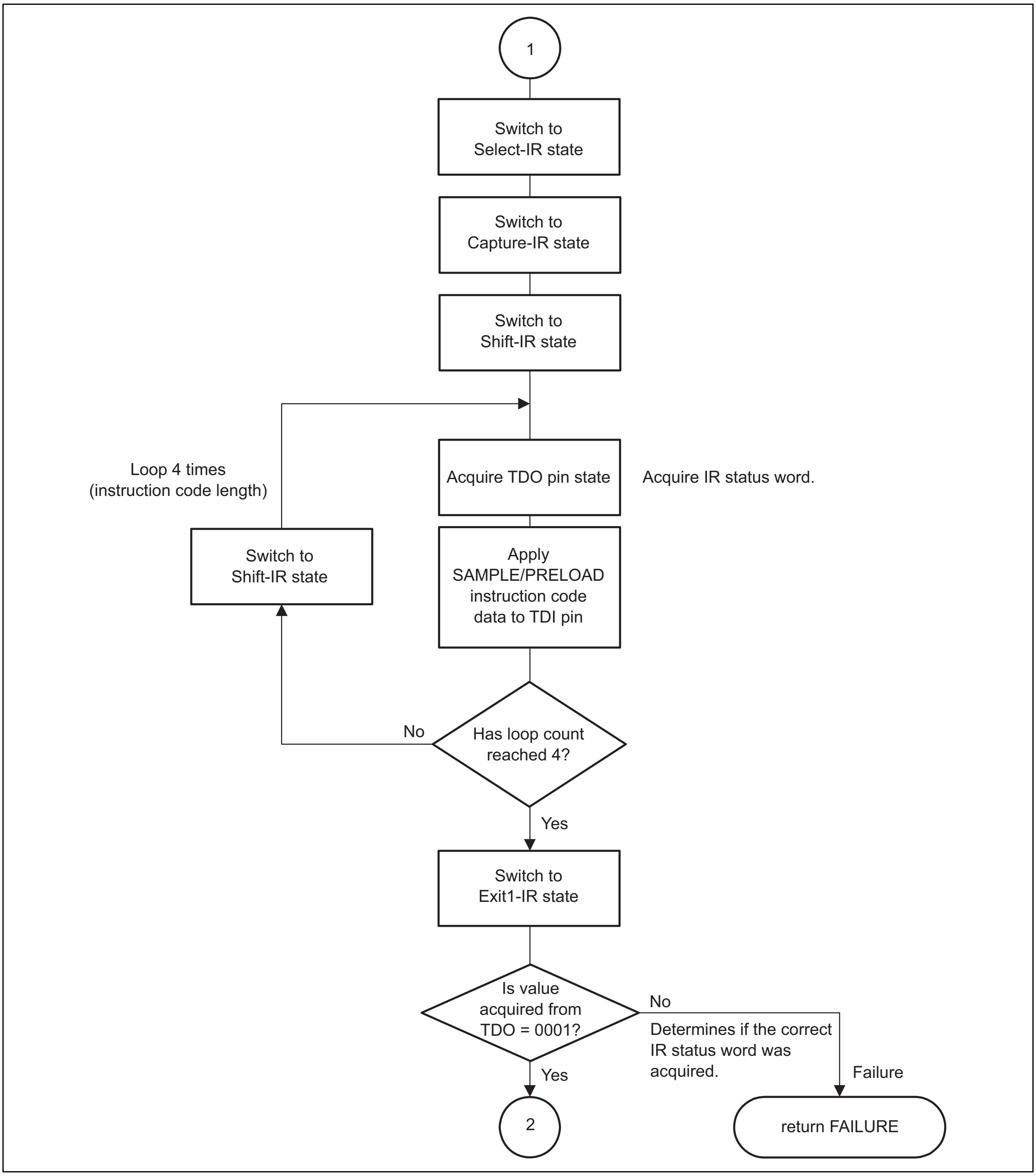


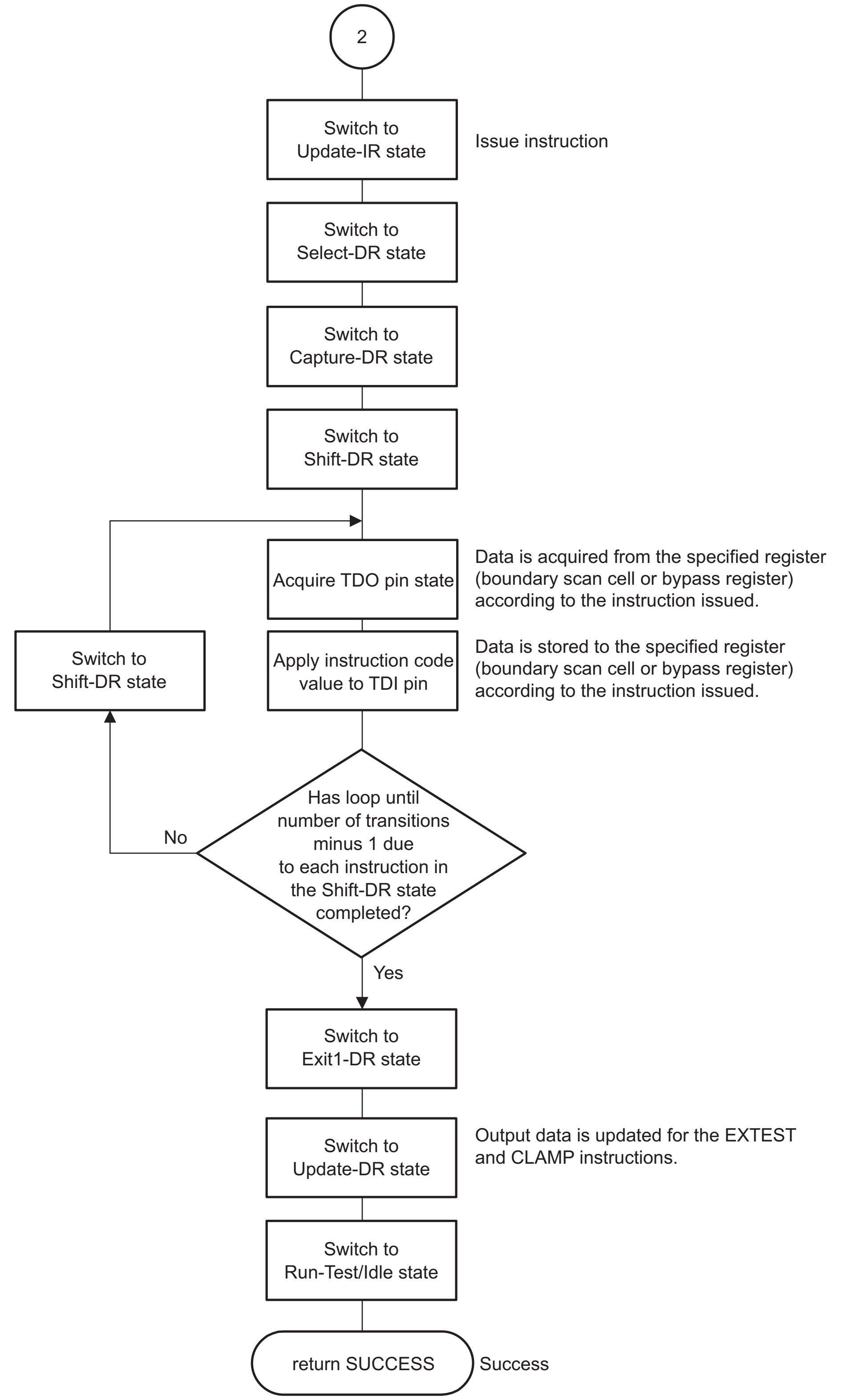
5.3.9 IR Status Word Display Routine



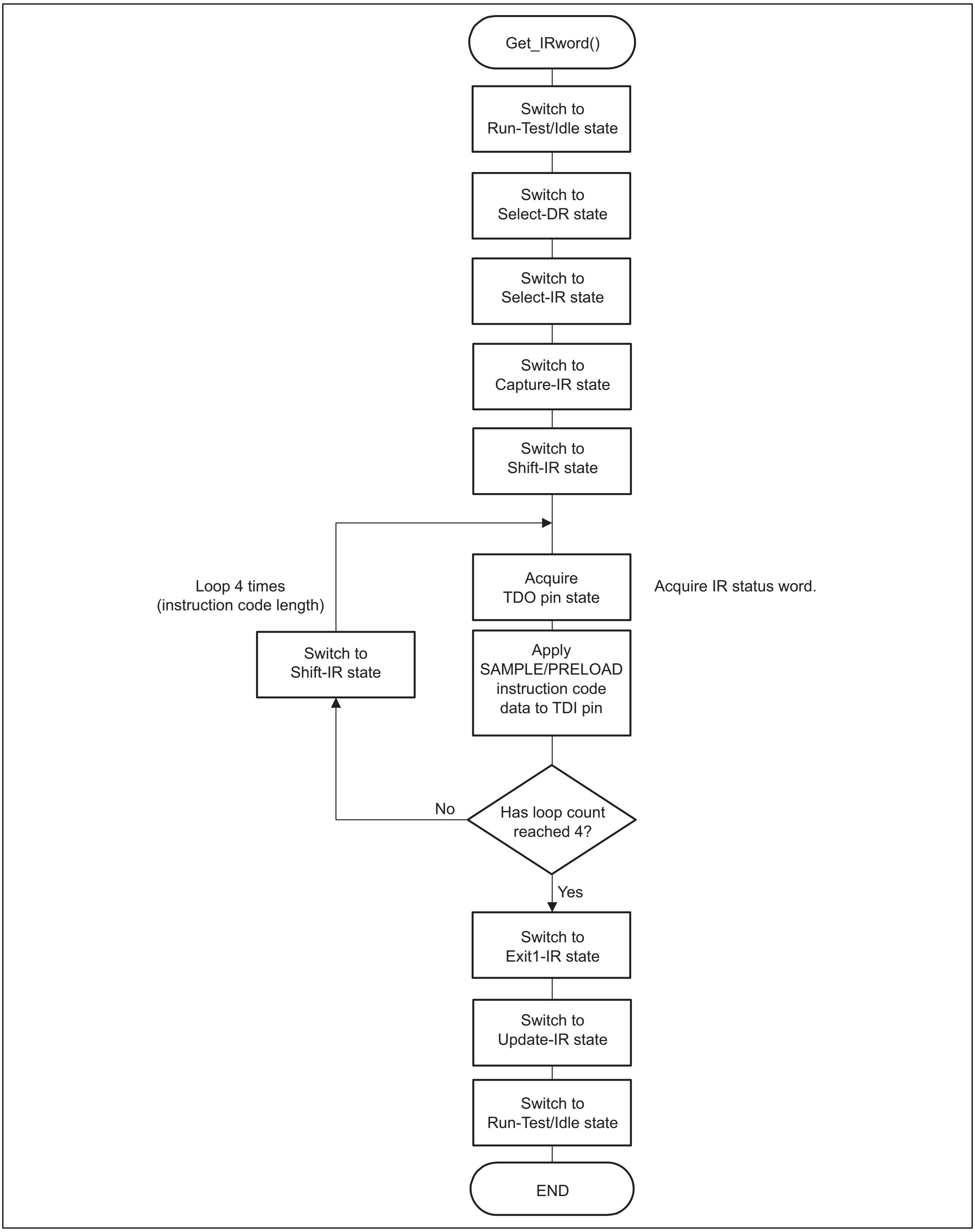
5.3.10 TAP Controller Control Routine




1
Switch to Select-IR state
Switch to Capture-IR state
Switch to Shift-IR state
Loop 4 times (instruction code length)
Acquire TDO pin state
Acquire IR status word.
Switch to Shift-IR state
Apply SAMPLE/PRELOAD instruction code data to TDI pin
No
Has loop count reached 4?
Yes
Switch to Exit1-IR state
Is value acquired from TDO = 0001?
No
Determines if the correct IR status word was acquired.
Failure
Yes
2
return FAILURE


2
Switch to Update-IR state
Issue instruction
Switch to Select-DR state
Switch to Capture-DR state
Switch to Shift-DR state
Acquire TDO pin state
Data is acquired from the specified register (boundary scan cell or bypass register) according to the instruction issued.
Switch to Shift-DR state
Apply instruction code value to TDI pin
Data is stored to the specified register (boundary scan cell or bypass register) according to the instruction issued.
Has loop until number of transitions minus 1 due to each instruction in the Shift-DR state completed?
No
Yes
Switch to Exit1-DR state
Switch to Update-DR state
Output data is updated for the EXTEST and CLAMP instructions.
Switch to Run-Test/Idle state
return SUCCESS
Success

5.3.11 IR Status Word Acquire Rutine



6. Reference Documents

- Hardware Manuals
  H8SX/1648 Group Hardware Manual
  The latest versions of this manual can be ordered from the Renesas Technology Corp. web site.
- Technical Manuals and Technical Updates
  The latest information is available on the Renesas Technology Corp. web site.

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Jan.22.09	—	First edition issued

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