Data Sheet, DS 1, Feb. 2003

SBCX-X

S/T Bus Interface Circuit Extended

PEB 3081, Version 1.4

Wired Communications

Infineon technologies

Never stop thinking.

Edition 2003-02-04

Published by Infineon Technologies AG,
St.-Martin-Strasse 53,
81669 München, Germany

Attention please!

The information herein is given to describe certain components and shall not be considered as warranted characteristics.

Terms of delivery and rights to technical change reserved.

We hereby disclaim any and all warranties, including but not limited to warranties of non-infringement, regarding circuits, descriptions and charts stated herein.

Infineon Technologies is an approved CECC manufacturer.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office in Germany or our Infineon Technologies Representatives worldwide (**www.infineon.com**).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.

Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

Data Sheet

Revision History: **2003-02-04** DS 1

Previous Version: Data Sheet, DS1, V1.3, 2000-07-21

Page	Subjects (major changes since last revision)
Chapter 1	Comparison SBCX/SBCX-X
Chapter 3.3.6.2	S- Transceiver Synchronization New
Chapter 3.3.10	Test Functions extended
Chapter 3.7.1.1	CDA Handler Description extended
Chapter 3.7.5.1	TIC Bus Access Control: Note added
Chapter 5.6	IOM-2 Interface Timing: Explanation added
Chapter 5.9	S-Transceiver
Chapter 5.10	Recommended Transformer Specification: Changed
Chapter 5.11	Line Overload Protection added
Chapter 5.12	EMC/ESD added

Table of Contents **Page**

1 Overview . . . 11
1.1 Features . . . 14
1.2 Logic Symbol . . . 15
1.3 Typical Applications . . . 16

2 Pin Configuration . . . 17

3 Description of Functional Blocks . . . 23
3.1 General Functions and Device Architecture . . . 23
3.2 Microcontroller Interface . . . 25
3.2.1 Serial Control Interface (SCI) . . . 26
3.2.2 Programming Sequences . . . 27
3.2.3 Interrupt Structure . . . 29
3.2.4 Reset Generation . . . 31
3.2.5 Timer Modes . . . 33
3.2.6 Activation Indication via Pin ACL . . . 35
3.3 S/T-Interface . . . 36
3.3.1 S/T-Interface Coding . . . 38
3.3.2 S/T-Interface Multiframing . . . 40
3.3.3 Data Transfer and Delay between IOM-2 and S/T . . . 42
3.3.4 Transmitter Characteristics . . . 45
3.3.5 Receiver Characteristics . . . 46
3.3.6 S/T Interface Circuitry . . . 47
3.3.6.1 External Protection Circuitry . . . 47
3.3.6.2 S-Transceiver Synchronization . . . 49
3.3.7 S/T Interface Delay Compensation (TE/LT-T Mode) . . . 50
3.3.8 Level Detection Power Down . . . 50
3.3.9 Transceiver Enable/Disable . . . 50
3.3.10 Test Functions . . . 51
3.4 Clock Generation . . . 53
3.4.1 Description of the Receive PLL (DPLL) . . . 56
3.4.2 Jitter . . . 56
3.4.3 Oscillator Clock Output C768 . . . 57
3.5 Control of Layer-1 . . . 58
3.5.1 State Machine TE and LT-T Mode . . . 60
3.5.1.1 State Transition Diagram (TE, LT-T) . . . 60
3.5.1.2 States (TE, LT-T) . . . 62
3.5.1.3 C/I Codes (TE, LT-T) . . . 64
3.5.1.4 Infos on S/T (TE, LT-T) . . . 66
3.5.2 State Machine LT-S Mode . . . 67
3.5.2.1 State Transition Diagram (LT-S) . . . 67
3.5.2.2 States (LT-S) . . . 68
3.5.2.3 C/I Codes (LT-S) . . . 69

Table of Contents **Page**

3.5.2.4 Infos on S/T (LT-S) . . . 70
3.5.3 State Machine NT Mode . . . 71
3.5.3.1 State Transition Diagram (NT) . . . 71
3.5.3.2 States (NT) . . . 72
3.5.3.3 C/I Codes (NT) . . . 73
3.5.4 Command / Indicate Channel Codes (C/I0) - Overview . . . 75
3.6 Control Procedures . . . 76
3.6.1 Example of Activation/Deactivation . . . 76
3.6.2 Activation initiated by the Terminal . . . 77
3.6.3 Activation initiated by the Network Termination NT . . . 78
3.7 IOM-2 Interface . . . 79
3.7.1 IOM-2 Handler . . . 82
3.7.1.1 Controller Data Access (CDA) . . . 84
3.7.2 Serial Data Strobe Signal and Strobed Data Clock . . . 94
3.7.2.1 Serial Data Strobe Signal . . . 94
3.7.2.2 Strobed IOM-2 Bit Clock . . . 96
3.7.3 IOM-2 Monitor Channel . . . 97
3.7.3.1 Handshake Procedure . . . 98
3.7.3.2 Error Treatment . . . 101
3.7.3.3 MONITOR Channel Programming as a Master Device . . . 103
3.7.3.4 MONITOR Channel Programming as a Slave Device . . . 103
3.7.3.5 MONITOR Time-Out Procedure . . . 104
3.7.3.6 MONITOR Interrupt Logic . . . 105
3.7.4 C/I Channel Handling . . . 106
3.7.5 D-Channel Access Control . . . 107
3.7.5.1 TIC Bus D-Channel Access Control . . . 108
3.7.5.2 S-Bus Priority Mechanism for D-Channel . . . 110
3.7.5.3 S-Bus D-Channel Control in LT-T . . . 112
3.7.5.4 D-Channel Control in the Intelligent NT (TIC- and S-Bus) . . . 112
3.7.6 Activation/Deactivation of IOM-2 Interface . . . 116
3.8 Auxiliary Interface . . . 118

4 Detailed Register Description . . . 120
4.1 Transceiver and C/I Registers . . . 126
4.1.1 TR_MODE2 - Transceiver Mode Register 2 . . . 126
4.1.2 CIR0 - Command/Indication Receive 0 . . . 127
4.1.3 CIX0 - Command/Indication Transmit 0 . . . 128
4.1.4 CIR1 - Command/Indication Receive 1 . . . 128
4.1.5 CIX1 - Command/Indication Transmit 1 . . . 129
4.1.6 TR_CONF0 - Transceiver Configuration Register 0 . . . 129
4.1.7 TR_CONF1 - Transceiver Configuration Register 1 . . . 131
4.1.8 TR_CONF2 - Transmitter Configuration Register 2 . . . 131
4.1.9 TR_STA - Transceiver Status Register . . . 133

Table of Contents **Page**

4.1.10 TR_CMD - Transceiver Command Register 134
4.1.11 SQRR1 - S/Q-Channel Receive Register 1 135
4.1.12 SQXR1- S/Q-Channel TX Register 1 136
4.1.13 SQRR2 - S/Q-Channel Receive Register 2 136
4.1.14 SQXR2 - S/Q-Channel TX Register 2 137
4.1.15 SQRR3 - S/Q-Channel Receive Register 3 137
4.1.16 SQXR3 - S/Q-Channel TX Register 3 137
4.1.17 ISTATR - Interrupt Status Register Transceiver 137
4.1.18 MASKTR - Mask Transceiver Interrupt 138
4.1.19 TR_MODE - Transceiver Mode Register 1 139
4.2 Auxiliary Interface Registers 140
4.2.1 ACFG1 - Auxiliary Configuration Register 1 140
4.2.2 ACFG2 - Auxiliary Configuration Register 2 140
4.2.3 AOE - Auxiliary Output Enable Register 141
4.2.4 ARX - Auxiliary Interface Receive Register 141
4.2.5 ATX - Auxiliary Interface Transmit Register 142
4.3 IOM-2 and MONITOR Handler 142
4.3.1 CDAxy - Controller Data Access Register xy 142
4.3.2 XXX_TSDPxy - Time Slot and Data Port Selection for CHxy 143
4.3.3 CDAx_CR - Control Register Controller Data Access CH1x 144
4.3.4 TR_CR - Control Register Transceiver Data (IOM_CR.CI_CS=0) . . . 145
4.3.5 TRC_CR - Control Register Transceiver C/I0 (IOM_CR.CI_CS=1) . . . 146
4.3.6 DCI_CR - Control Register for CI1 Handler (IOM_CR.CI_CS=0) 146
4.3.7 DCIC_CR - Control Register for CI0 Handler (IOM_CR.CI_CS=1) . . . 147
4.3.8 MON_CR - Control Register Monitor Data 148
4.3.9 SDSx_CR - Control Register Serial Data Strobe x 149
4.3.10 IOM_CR - Control Register IOM Data 150
4.3.11 STI - Synchronous Transfer Interrupt 152
4.3.12 ASTI - Acknowledge Synchronous Transfer Interrupt 153
4.3.13 MSTI - Mask Synchronous Transfer Interrupt 153
4.3.14 SDS_CONF - Configuration Register for Serial Data Strobes 154
4.3.15 MCDA - Monitoring CDA Bits 155
4.3.16 MOR - MONITOR Receive Channel 155
4.3.17 MOX - MONITOR Transmit Channel 155
4.3.18 MOSR - MONITOR Interrupt Status Register 156
4.3.19 MOCR - MONITOR Control Register 156
4.3.20 MSTA - MONITOR Status Register 157
4.3.21 MCONF - MONITOR Configuration Register 157
4.4 Interrupt and General Configuration 158
4.4.1 ISTA - Interrupt Status Register 158
4.4.2 MASK - Mask Register 159
4.4.3 AUXI - Auxiliary Interrupt Status Register 159

Table of Contents **Page**

4.4.4 AUXM - Auxiliary Mask Register 160
4.4.5 MODE1 - Mode1 Register 160
4.4.6 MODE2 - Mode2 Register 162
4.4.7 ID - Identification Register 163
4.4.8 SRES - Software Reset Register 163
4.4.9 TIMR - Timer Register 164

5 Electrical Characteristics 165
5.1 Absolute Maximum Ratings 165
5.2 DC Characteristics 166
5.3 Capacitances 166
5.4 Oscillator Specification 168
5.5 AC Characteristics 169
5.6 IOM-2 Interface Timing 169
5.7 Serial Control Interface (SCI) Timing 172
5.8 Reset 173
5.9 S-Transceiver 174
5.10 Recommended Transformer Specification 175
5.11 Line Overload Protection 176
5.12 EMC / ESD Aspects 177

6 Package Outlines 178

7 Appendix 180

List of Figures

Page

Figure 1 Logic Symbol of the SBCX-X . . . 15
Figure 2 Applications of the SBCX-X . . . 16
Figure 3 Pin Configuration of the SBCX-X (P-MQFP-44) . . . 17
Figure 4 Pin Configuration of the SBCX-X (P-TQFP-48) . . . 18
Figure 5 Functional Block Diagram of the SBCX-X . . . 24
Figure 6 Serial Control Interface Timing . . . 26
Figure 7 Serial Control Interface Timing . . . 27
Figure 8 Interrupt Status and Mask Registers . . . 30
Figure 9 Reset Generation . . . 31
Figure 10 Timer Interrupt Status Registers . . . 33
Figure 11 Timer Register . . . 34
Figure 12 ACL Indication of Activated Layer 1 on TE Side . . . 35
Figure 13 ACL Configuration . . . 35
Figure 14 Wiring Configurations in User Premises . . . 37
Figure 15 S/T-Interface Line Code . . . 38
Figure 16 Frame Structure at Reference Points S and T (ITU I.430) . . . 39
Figure 17 Data Delay between IOM-2 and S/T Interface (TE mode only) . . . 42
Figure 18 Data Delay between IOM-2 and S/T Interface with S/G Bit Evaluation (TE mode only) . . . 43
Figure 19 Data Delay between IOM-2 and S/T Interface with 8 IOM Channels (LT-S/NT mode only) . . . 44
Figure 20 Data Delay between IOM-2 and S/T Interface with 3 IOM Channels and Maximum Receive Delay (LT-S/NT mode only) . . . 44
Figure 21 Equivalent Internal Circuit of the Transmitter Stage . . . 45
Figure 22 Equivalent Internal Circuit of the Receiver Stage . . . 46
Figure 23 Connection of Line Transformers and Power Supply to the SBCX-X . . . 47
Figure 24 External Circuitry for Transmitter . . . 48
Figure 25 External Circuitry for Symmetrical Receivers . . . 48
Figure 26 External Circuitry for Symmetrical Receivers . . . 49
Figure 27 Disabling of S/T Transmitter . . . 51
Figure 28 External Loop at the S/T-Interface . . . 52
Figure 29 Clock System of the SBCX-X . . . 53
Figure 30 Phase Relationships of SBCX-X Clock Signals . . . 56
Figure 31 Buffered Oscillator Clock Output . . . 57
Figure 32 Layer-1 Control . . . 58
Figure 33 State Diagram Notation . . . 59
Figure 34 State Transition Diagram (TE, LT-T) . . . 61
Figure 35 State Transition Diagram of Unconditional Transitions (TE, LT-T) . . . 62
Figure 36 State Transition Diagram (LT-S) . . . 67
Figure 37 State Transition Diagram (NT) . . . 71
Figure 38 Example of Activation/Deactivation Initiated by the Terminal . . . 76

List of Figures **Page**

Figure 39 Example of Activation/Deactivation initiated by the Terminal (TE). Activation/Deactivation completely under Software Control 77
Figure 40 Example of Activation/Deactivation initiated by the Network Termination (NT). Activation/Deactivation completely under Software Control 78
Figure 41 IOM®-2 Frame Structure in Terminal Mode. 80
Figure 42 Multiplexed Frame Structure of the IOM-2 Interface in Non-TE Timing Mode 81
Figure 43 Architecture of the IOM Handler (Example Configuration). 83
Figure 44 Data Access via CDAx1 and CDAx2 Register Pairs 85
Figure 45 Examples for Data Access via CDAxy Registers. 86
Figure 46 Data Access when Looping TSa from DU to DD 87
Figure 47 Data Access when Shifting TSa to TSb on DU (DD) 88
Figure 48 Example for Monitoring Data 89
Figure 49 Interrupt Structure of the Synchronous Data Transfer 91
Figure 50 Examples for the Synchronous Transfer Interrupt Control with one Enabled STIxy 92
Figure 51 Data Strobe Signal. 95
Figure 52 Strobed IOM-2 Bit Clock. Register SDS_CONF Programmed to 01H. 96
Figure 53 Examples of MONITOR Channel Applications in IOM-2 TE Mode . . . 97
Figure 54 MONITOR Channel Protocol (IOM-2) 99
Figure 55 Monitor Channel, Transmission Abort Requested by the Receiver . . 102
Figure 56 Monitor Channel, Transmission Abort Requested by the Transmitter 102
Figure 57 Monitor Channel, Normal End of Transmission 102
Figure 58 MONITOR Interrupt Structure 105
Figure 59 CIC Interrupt Structure. 107
Figure 60 Applications of TIC Bus in IOM-2 Bus Configuration 108
Figure 61 Structure of Last Octet of Ch2 on DU 109
Figure 62 Structure of Last Octet of Ch2 on DD 110
Figure 63 D-Channel Access Control on the S-Interface 111
Figure 64 Data Flow for Collision Resolution Procedure in Intelligent NT 115
Figure 65 Deactivation of the IOM-2 Interface 116
Figure 66 Activation of the IOM-2 interface 117
Figure 67 Register Mapping of the SBCX-X 120
Figure 68 Oscillator Circuits 168
Figure 69 Input/Output Waveform for AC Tests. 169
Figure 70 IOM-2 Timing (TE mode) 169
Figure 71 IOM-2 Timing (LT-S, LT-T, NT mode) 170
Figure 72 Definition of Clock Period and Width 171
Figure 73 SCI Interface 172
Figure 74 Reset Signal RES 173
Figure 75 Maximum Line Input Current 176
Figure 76 Transformer Circuitry 177

List of Tables

Page

Table 1 Comparison of the SBCX-X with the Previous Version SBCX 11
Table 2 SBCX-X Pin Definitions and Functions 19
Table 3 Host Interface Selection 25
Table 4 Header Byte Code 27
Table 5 Reset Source Selection 32
Table 6 SBCX-X Timer 33
Table 7 S/Q-Bit Position Identification and Multiframe Structure 40
Table 8 Clock Modes 54
Table 9 Examples for Synchronous Transfer Interrupts 91
Table 10 CDA Register Combinations with Correct Read/Write Access 93
Table 11 Transmit Direction 98
Table 12 Receive Direction 98
Table 13 SBCX-X Configuration Settings in Intelligent NT Applications 113
Table 14 AUX Pin Functions 118
Table 15 IOM-2 Channel Selection 119

1 Overview

The S/T Bus Interface Circuit Extended (SBCX-X) implements the four-wire S/T interface used to link voice/data ISDN terminals, network terminators and PBX trunk lines to a central office. It is based on the SBCX PEB 2081, and provides enhanced features and functionality.

The SBCX-X provides the electrical and functional link between the analog S/T interface (compliant to the ITU recommendation I.430) and the IOM-2 interface.

It provides an S/T interface operating in TE, LT-T, LT-S, NT and intelligent NT modes, a serial control interface (SCI) for host programming, three general purpose I/O pins and one LED output which is capable to indicate the activation status of the S-interface automatically or can be programmed by the host.

The SBCX-X is produced in advanced CMOS technology.

Table 1 Comparison of the SBCX-X with the Previous Version SBCX

	SBCX-X PEB 3081	**SBCX PEB 2081**
Operating modes	TE, LT-T, LT-S, NT, Int. NT	TE, LT-T, LT-S, NT
Supply voltage	3.3 V ± 5%	5 V ± 5%
Technology	CMOS	CMOS
Package	P-MQFP-44 / P-TQFP-48	P-LCC-28 / P-DIP-28
Transceiver Transformer ratio for the transmitter receiver	 1:1 1:1	 2:1 2:1
Test Functions	- Analog loop (LP_A - bit EXLP - bit, ARL)	- Analog loop (ARL)
Microcontroller Interface	Serial interface (SCI)	Not provided
Host programming	SCI or MON channel (MONITOR slave mode)	MON channel (MONITOR slave mode)
Command structure of the register access	Header/address/data	Address/data
Crystal	7.68 MHz	7.68 MHz
Buffered 7.68 MHz output	Provided	Not provided

Table 1 Comparison of the SBCX-X with the Previous Version SBCX (cont'd)

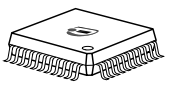
	SBCX-X PEB 3081	SBCX PEB 2081
Controller data access to IOM-2 timeslots	All timeslots; various possibilities of data access	Not provided
Data control and manipulation	Various possibilities of data control and data manipulation (enable/disable, shifting, looping, switching)	Shifting B-channel to channel 0 and direction control
Auxiliary Interface	AUX0-2 (general purpose I/Os)	MAI0-7 (general purpose I/Os and several mode dependent functions)
IOM channel select (LT modes)	Channel select pins multiplexed on AUX0-2	X0-2
LED pin	$\overline{\text{ACL}}$ (host controlled or automatic indication of layer 1 activated state)	Not provided
Output pin for D-channel active indication	Provided	Not provided
Control input pin for D-channel inhibit	Provided	Not provided
Stop/Go bit output pin	Provided	Provided
IOM-2		
IOM-2 Interface	Double clock (DCL), bit clock (BCL), serial data strobe 1 (SDS1) serial data strobe 2 (SDS2)	Double clock (DCL), bit clock (BCL)
Monitor channel programming	Provided (MON0, 1, 2, ..., 7)	Provided (MON0 or 1)
C/I channels	CI0 (4 bit), CI1 (4/6 bit)	CI0 (4 bit), CI1 (6 bit)

Table 1 Comparison of the SBCX-X with the Previous Version SBCX (cont'd)

	SBCX-X PEB 3081	SBCX PEB 2081
Layer 1 state machine	With changes for correspondence with the actual ITU specification	
Layer 1 state machine in software	Possible	Not possible
Reset Signals	$\overline{\text{RES}}$ input signal $\overline{\text{RSTO}}$ output signal	$\overline{\text{RST}}$ input signal
Reset Sources	$\overline{\text{RES}}$ Input Watchdog C/I Code Change $\overline{\text{EAW}}$ Pin Software Reset	$\overline{\text{RST}}$ Input C/I Code Change
Interrupt Output Signals	$\overline{\text{INT}}$ low active (open drain) by default, reprogrammable to high active (push-pull)	Not provided
Pin SCLK	1.536 MHz	512 kHz

Version 1.4

1.1 Features



P-MQFP-44

P-TQFP-48

- Full duplex 2B + D S/T interface transceiver according to ITU-T I.430
- Successor of SBCX PEB 2081 in 3.3 V technology
- Conversion of the frame structure between the S/T-interface and IOM-2
- IOM-2 interface supporting TE, LT-T, LT-S, NT and intelligent NT modes
- Single and double clocks on IOM-2
- Two serial data strobe signals
- Serial control interface (SCI)
- Microcontroller access to all IOM-2 timeslots
- Monitor channel handler (master/slave)
- IOM-2 MONITOR and C/I-channel protocol to control peripheral devices
- Receive timing recovery
- D-channel access control
- Activation and deactivation procedures with automatic activation from power down state
- Access to S and Q bits of S/T-interface
- Adaptively switched receive thresholds
- 3 general purpose I/O pins multiplexed with channel select pins
- Three pins for D-channel active indication, Stop/Go bit output and E-bit control on S
- One programmable timer
- Watchdog timer
- Software Reset
- One LED pin automatically indicating layer 1 activated state
- Test loops
- Sophisticated power management for restricted power mode

Type	Package
PEB 3081 H	P-MQFP-44
PEB 3081 F	P-TQFP-48

- Power supply 3.3 V
- 3.3 V output drivers, inputs are 5 V safe
- Advanced CMOS technology

1.2 Logic Symbol

The logic symbol gives an overview of the SBCX-X functions. It must be noted that not all functions are available simultaneously, but depend on the selected mode.

Pins which are marked with a " * " are multiplexed and not available in all modes.

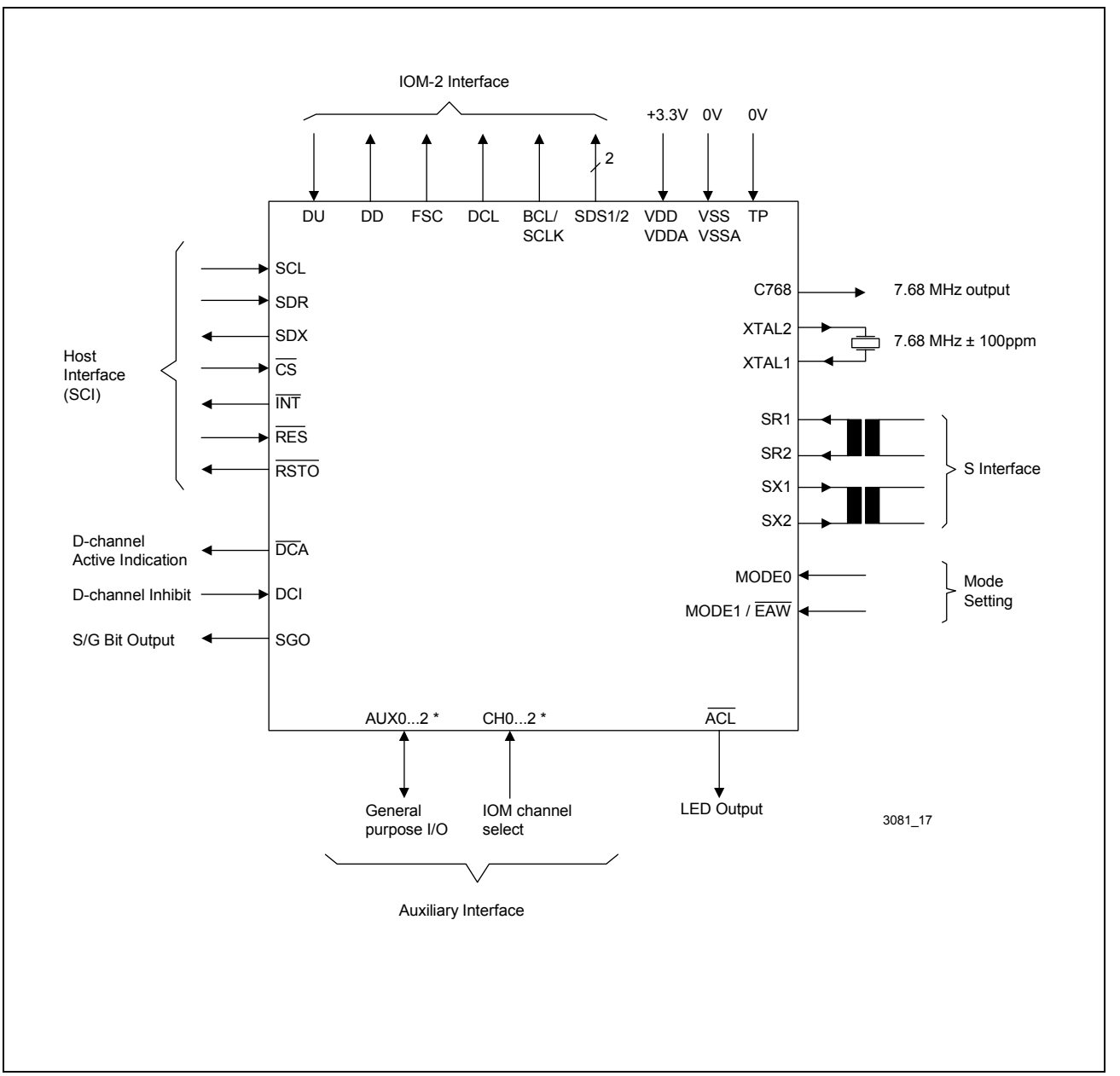


Figure 1 Logic Symbol of the SBCX-X

1.3 Typical Applications

The SBCX-X is designed for the user area of the ISDN basic access. By programming the corresponding operating mode it may be used at both ends of these interfaces.

Figure 2 illustrates the general application fields of the SBCX-X:

- ISDN terminals (TE mode)
- ISDN network termination (NT) for a link between the S/T interface and the U interface
- ISDN subscriber line termination (LT-S)
- ISDN trunk line termination (LT-T), i.e. PBX connection to central office

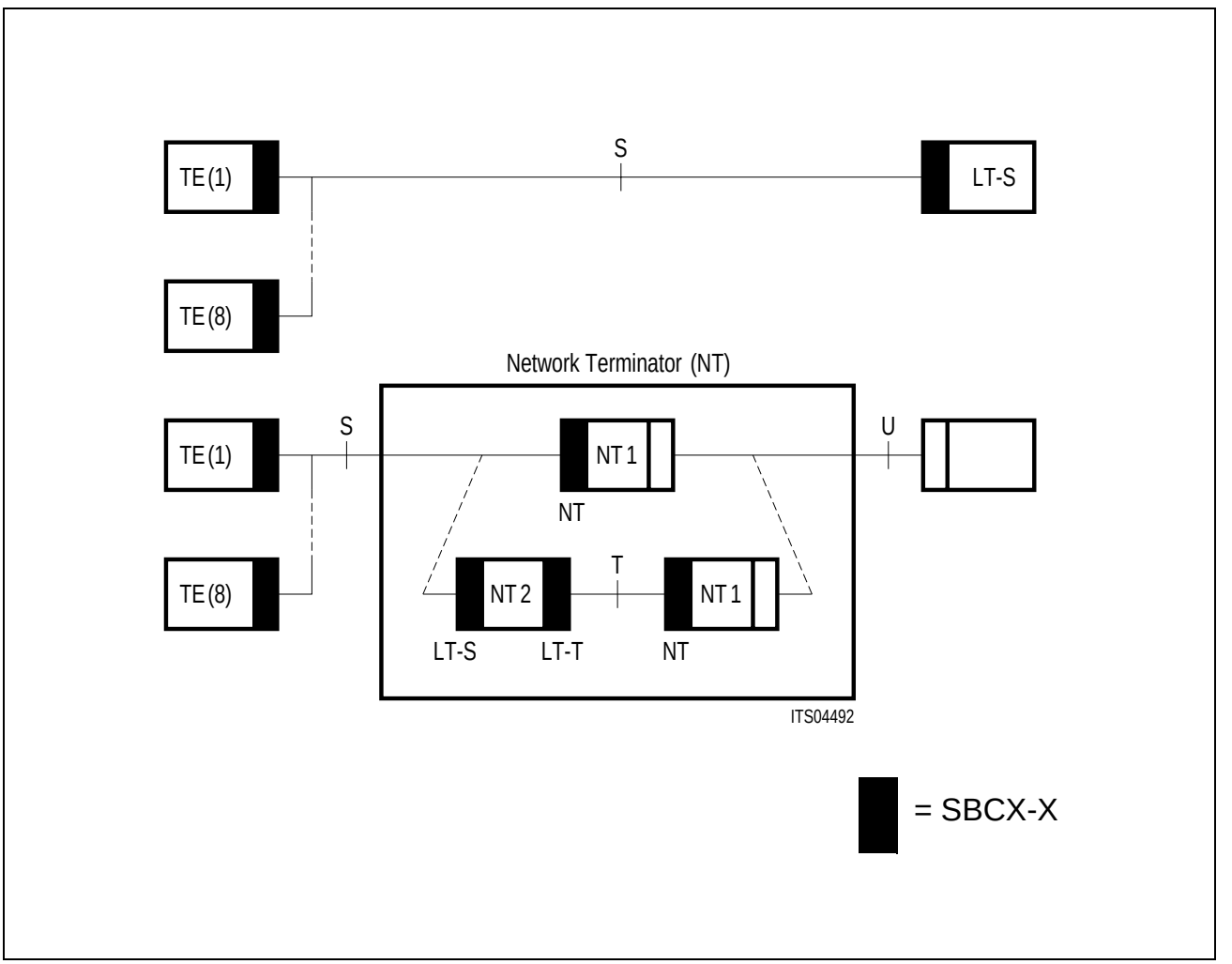


Figure 2 Applications of the SBCX-X

2 Pin Configuration

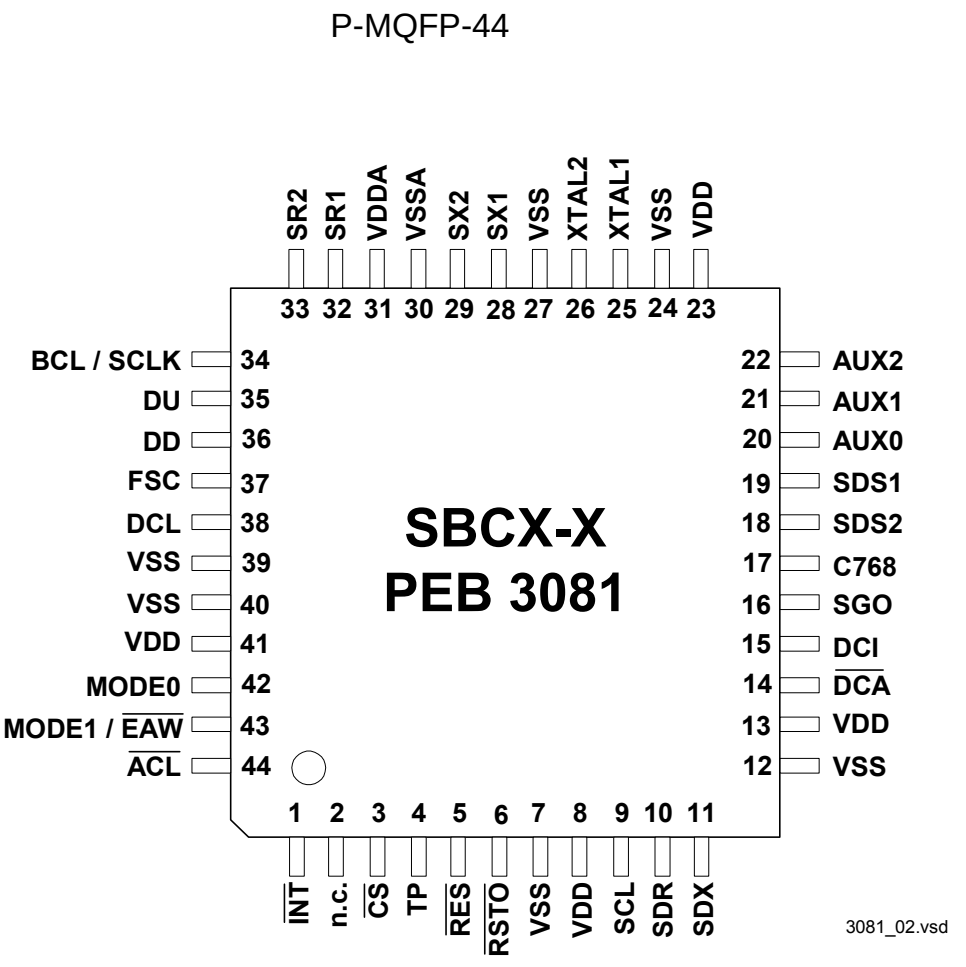


Figure 3 Pin Configuration of the SBCX-X (P-MQFP-44)

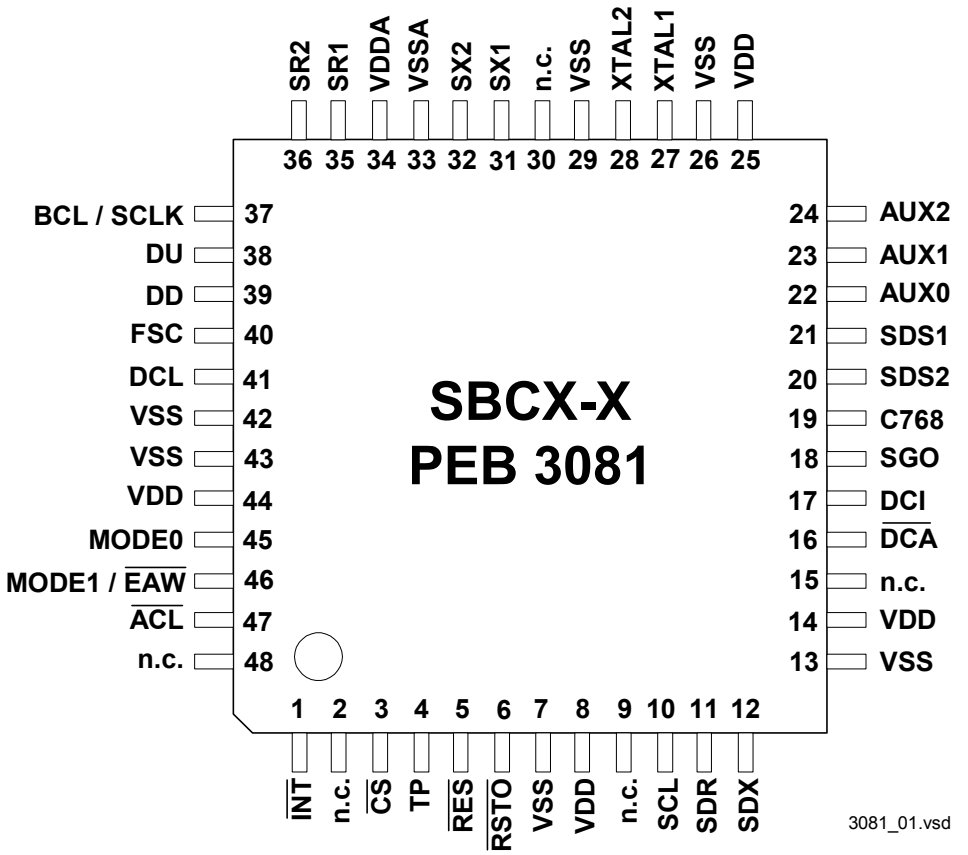


Figure 4 Pin Configuration of the SBCX-X (P-TQFP-48)

Table 2 SBCX-X Pin Definitions and Functions

Pin No.		Symbol	Input (I) Output (O) Open Drain (OD)	Function
MQFP-44	TQFP-48			
Host Interface				
9	10	SCL	I	**SCL - Serial Clock** Clock signal of the SCI interface if a serial interface is selected.
10	11	SDR	I	**SDR - Serial Data Receive** Receive data line of the SCI interface if a serial interface is selected.
11	12	SDX	OD	**SDX - Serial Data Transmit** Transmit data line of the SCI interface if a serial interface is selected.
3	3	CS	I	**Chip Select** A low level indicates a microcontroller access to the SBCX-X.
1	1	INT	O (OD)	**Interrupt Request** $\overline{\text{INT}}$ becomes active (low) if the SBCX-X requests an interrupt (open drain characteristic). The polarity can be reprogrammed to high active with push-pull characteristic.
5	5	RES	I	**Reset** A LOW on this input forces the SBCX-X into a reset state.
IOM-2 Interface				
37	40	FSC	I/O	**Frame Sync** 8-kHz frame synchronization signal.
38	41	DCL	I/O	**Data Clock** IOM-2 interface clock signal (double clock, e.g. 1.536 MHz in TE mode).

Table 2 SBCX-X Pin Definitions and Functions (cont'd)

Pin No.		Symbol	Input (I) Output (O) Open Drain (OD)	Function
MQFP-44	**TQFP-48**			
34	37	BCL/ SCLK	O	**Bit Clock/S-Clock** **TE-Mode:** Bit clock output, identical to IOM-2 data rate (DCL/2). **LT-T Mode:** 1.536 MHz output synchronous to S-interface. **NT / LT-S Mode:** Bit clock output derived from the DCL input clock divided by 2.
36	39	DD	I/O (OD)	**Data Downstream** IOM-2 data signal in downstream direction.
35	38	DU	I/O (OD)	**Data Upstream** IOM-2 data signal in upstream direction.
19	21	SDS1	O	**Serial Data Strobe 1** Programmable strobe signal for time slot and/or D-channel indication on IOM-2.
18	20	SDS2	O	**Serial Data Strobe 2** Programmable strobe signal for time slot and/or D-channel indication on IOM-2.

Miscellaneous

28 29	31 32	SX1 SX2	O O	**S-Bus Transmitter Output (positive)** **S-Bus Transmitter Output (negative)**
32 33	35 36	SR1 SR2	I I	**S-Bus Receiver Input** **S-Bus Receiver Input**
25	27	XTAL1	I	**Crystal 1** Connection for a crystal or used as external clock input. 7.68 MHz clock or crystal required.
26	28	XTAL2	O	**Crystal 2** Connection for a crystal. Not connected if an external clock is supplied to XTAL1

Table 2 SBCX-X Pin Definitions and Functions (cont'd)

Pin No.		Symbol	Input (I) Output (O) Open Drain (OD)	Function
MQFP-44	**TQFP-48**			
20 21 22	22 23 24	AUX0 AUX1 AUX2	I/O (OD) I/O (OD) I/O (OD)	**TE-Mode:** **Auxiliary Port 0 - 2 (input/output)** These pins are individually programmable as general input/output. The state of the pin can be read from (input) / written to (output) a register. **LT-T/LT-S/NT Mode:** **CH0-2 - IOM-2 Channel Select (input)** These pins select one of eight channels on the IOM-2 interface.
42	45	MODE0	I	**Mode 0 Select** A LOW selects TE-mode and a HIGH selects LT-T / LT-S mode (see MODE1/ $\overline{\text{EAW}}$).
43	46	MODE1 EAW	I I	The pin function depends on the setting of MODE0. If MODE0=1: **Mode 1 Select** A LOW selects LT-T mode and a HIGH selects LT-S mode. If MODE0=0: **External Awake** If a falling edge on this input is detected, the SBCX-X generates an interrupt and, if enabled, a reset pulse.
6	6	RSTO	OD	**Reset Output** Low active reset output, either from a watchdog timeout or programmed by the host.
17	19	C768	O	**Clock Output** A 7.68 MHz clock is output to support other devices. This clock is not synchronous to the S interface.
14	16	DCA	O	**DCA - D-Channel Active Indication** This pin provides an output of the D-channel bits on the S-bus receive line.

Table 2 SBCX-X Pin Definitions and Functions (cont'd)

Pin No.		Symbol	Input (I) Output (O) Open Drain (OD)	Function
MQFP-44	**TQFP-48**			
15	17	DCI	I	**DCI - D-Channel Inhibit** If this bit is set to '1' the E-bits are inverted, i.e. the D-channel is blocked (only in NT/LT-S mode). This pin has the same function as the D-channel inhibit bit (see TR_MODE.DCH_INH).
16	18	SGO	O	**SGO - Stop/Go Bit Output** A S/G bit output with programmable polarity and length (TR_CONF2 register) is provided.
44	47	ACL	O	**Activation LED** This pin can either function as a programmable output or it can automatically indicate the activated state of the S interface by a logic '0'. An LED with pre-resistance may directly be connected to $\overline{\text{ACL}}$.
4	4	TP	I	**Test Pin** Must be connected to V_{SS}.
2	2, 9, 15, 30, 48	n.c.		**Not Connected**
Power Supply				
8, 13, 23, 41	8, 14, 25, 44	V_{DD}	–	**Digital Power Supply Voltage** (3.3 V ± 5 %)
31	34	V_{DDA}	–	**Analog Power Supply Voltage** (3.3 V ± 5 %)
7, 12, 24, 27, 39, 40	7, 13, 26, 29, 42, 43	V_{SS}	–	**Digital Ground** (0 V)
30	33	V_{SSA}	–	**Analog Ground** (0 V)

3 Description of Functional Blocks

3.1 General Functions and Device Architecture

Figure 5 shows the architecture of the SBCX-X containing the following functions:

- S/T-interface transceiver supporting TE, LT-T, LT-S, NT and intelligent NT modes
- Serial Control Interface (SCI)
- IOM-2 interface for terminal, linecard and NT applications, with single/double clock
- Two serial data strobe signals
- IOM handler with controller data access registers (CDA) allows flexible access to IOM timeslots for reading/writing, looping and shifting data
- Synchronous transfer interrupts (STI) allow controlled access to IOM timeslots
- MONITOR channel handler on IOM-2 for master mode, slave mode or data exchange
- C/I-Channel handler
- D-channel access mechanism
- 3-pin auxiliary port for general purpose I/O pins or channel select pins
- LED connected to pin $\overline{\text{ACL}}$ indicates S-interface activation status automatically or can be controlled by the host
- Output for D-channel active indication (output of received D-bits on S)
- Stop/Go bit output with programmable polarity and length
- D-channel inhibit input pin to control inversion of E-bits on S to block other terminals
- Level detect circuit on the S interface reduces power consumption in power down mode
- Timer for periodic or single interrupts
- Clock and timing generation
- Digital PLL to synchronize the transceiver to the S/T interface
- Buffered 7.68 MHz oscillator clock output allows connection of further devices and saves another crystal on the system board
- Reset generation (watchdog timer)

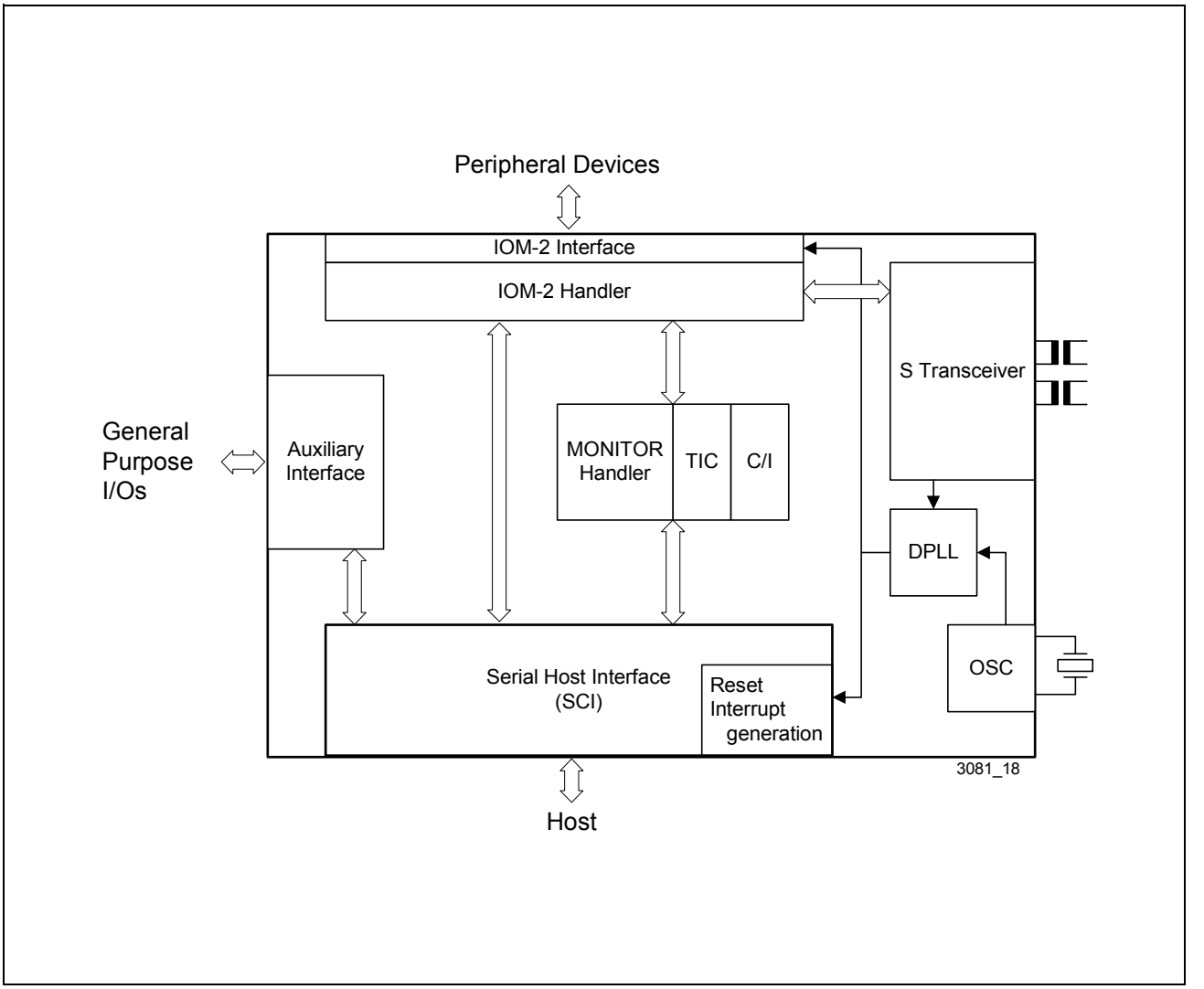


Figure 5 Functional Block Diagram of the SBCX-X

3.2 Microcontroller Interface

The SBCX-X supports a serial micrcontroller interface. For applications where no controller is connected to the SBCX-X programming is done via the IOM-2 MONITOR channel from a master device. In such applications the SBCX-X operates in the IOM-2 slave mode (refer to the corresponding chapter of the IOM-2 MONITOR handler). This mode is suitable for control functions (e.g. programming registers of the S/T transceiver), but the bandwidth is not sufficient to transfer B- and D-channel data.

The interface selection is done by pinstrapping of the chip select signal $\overline{CS}$ (see **Table 3**). The selection pins are evaluated when the reset input $\overline{RES}$ is active. For the pin levels stated in the table the following is defined:

'High': dynamic pin; value must be 'High' only during reset
V_{SS}: static pin; pin must statically be strapped to 'Low' level

Table 3 Host Interface Selection

CS	Interface Mode
'High'	Serial Control Interface (SCI)
V_{SS}	IOM-2 MONITOR Channel (Slave Mode)

The interfaces contain all circuitry necessary for the access to programmable registers. The mapping of all these registers can be found in **Chapter 4**.
The microcontroller interface also provides an interrupt request at pin $\overline{INT}$ which is low active by default but can be reprogrammed to high active, a reset input pin $\overline{RES}$ and a reset output pin $\overline{RSTO}$.
The interrupt request pin $\overline{INT}$ becomes active if the SBCX-X requests an interrupt and this can occur at any time.

3.2.1 Serial Control Interface (SCI)

The serial control interface (SCI) is compatible to the SPI interface of Motorola or Siemens C510 family of microcontrollers.
The SCI consists of 4 lines: SCL, SDX, SDR and $\overline{CS}$. Data is transferred via the lines SDR and SDX at the rate given by SCL. The falling edge of $\overline{CS}$ indicates the beginning of a serial access to the registers. The SBCX-X latches incoming data at the rising edge of SCL and shifts out at the falling edge of SCL. Each access must be terminated by a rising edge of $\overline{CS}$. Data is transferred in groups of 8 bits with the MSB first.
Figure 6 shows the timing of a one byte read/write access via the serial control interface.

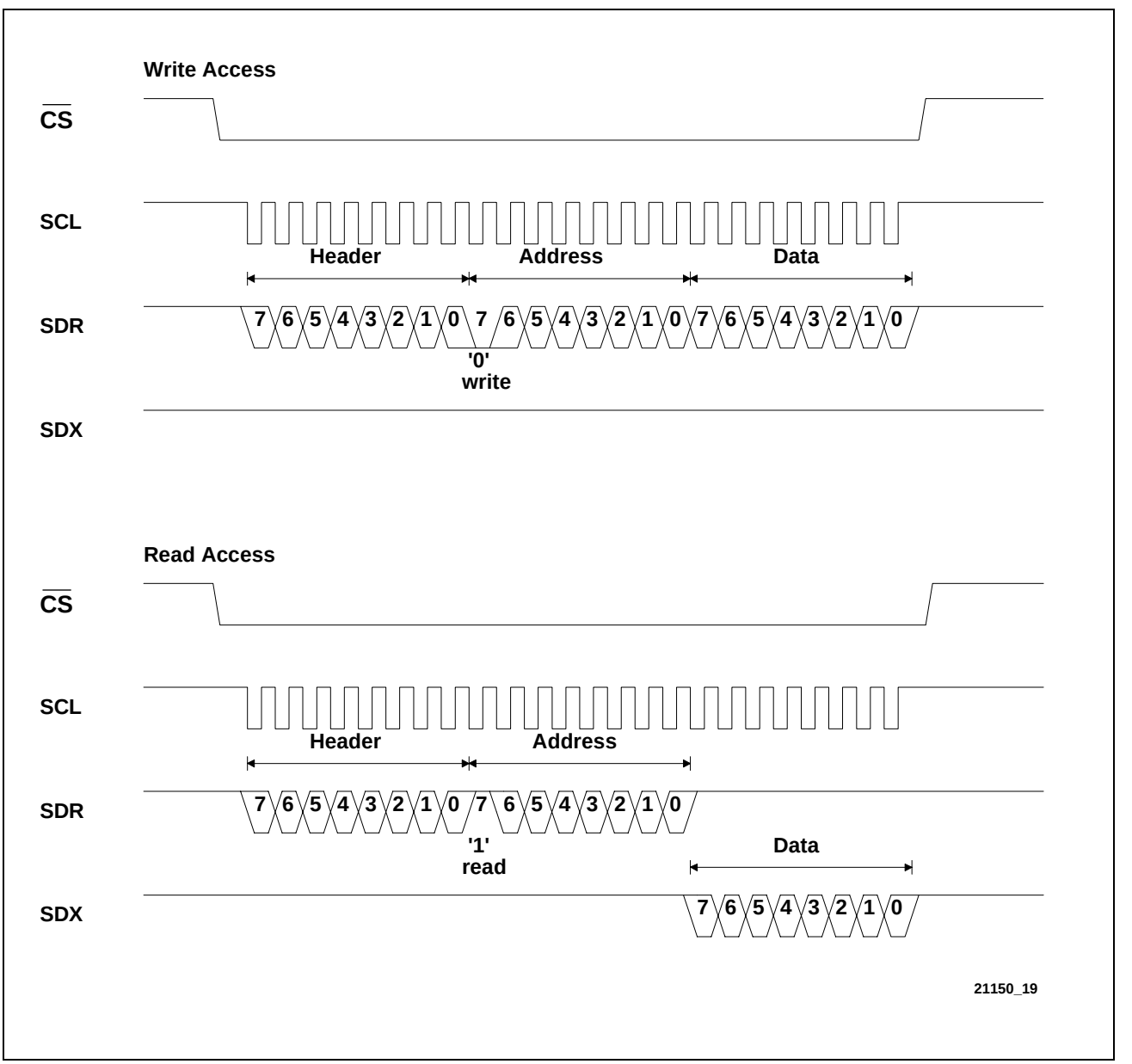


Figure 6 Serial Control Interface Timing

3.2.2 Programming Sequences

The basic structure of a read/write access to the SBCX-X registers via the serial control interface is shown in **Figure 7**.

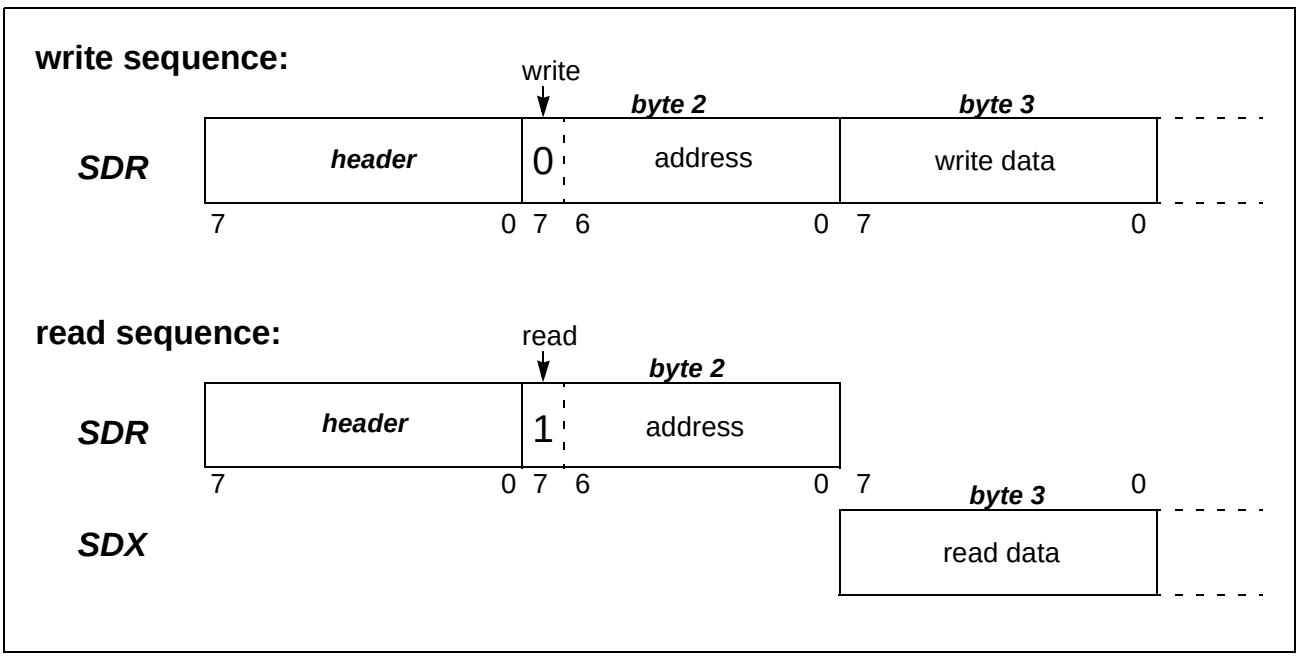


Figure 7 Serial Control Interface Timing

A new programming sequence starts with the transfer of a header byte. The header byte specifies different programming sequences allowing a flexible and optimized access to the individual functional blocks of the SBCX-X.

The possible sequences for access to the complete address range 00_H-$7F_H$ are listed in **Table 4** and described after that.

Table 4 Header Byte Code

Header Byte	Sequence	Sequence Type
$40_H/44_H$	Adr-Data-Adr-Data	Alternating Read/Write (non-interleaved)
$48_H/4C_H$		Alternating Read/Write (interleaved)
$43_H/47_H$	Adr-Data-Data-Data	Read-only/Write-only (constant address)
$41_H/45_H$		Read and following Write-only (non-interleaved)
$49_H/4D_H$		Read and following Write-only (interleaved)

Note: In order to access the address range 00_H-$7F_H$ bit 2 of the header byte must be set to '0' (header bytes 40_H, 48_H, 43_H, 41_H, 49_H), and for the addresses 80_H-FF_H bit 2 must be set to '1' (header bytes 44_H, $4C_H$, 47_H, 45_H, $4D_H$).

Header 40_H: Non-interleaved A-D-A-D Sequences

The non-interleaved A-D-A-D sequence gives direct read/write access to the complete address range and can have any length. In this mode SDX and SDR can be connected together allowing data transmission on one line.
Example for a read/write access with header 40_H:

SDR	header	wradr	wrdata	rdadr		rdadr		wradr	wrdata	
SDX					rddata		rdata			

Header 48_H: Interleaved A-D-A-D Sequences

The interleaved A-D-A-D sequence gives direct read/write access to the complete address range and can have any length. This mode allows a time optimized access to the registers by interleaving the data on SDX and SDR (SDR and SDX must not be connected together).
Example for a read/write access with header 48_H:

SDR	header	wradr	wrdata	rdadr	rdadr	wradr	wrdata			
SDX					rddata	rddata				

Header 43_H: Read-/Write- only A-D-D-D Sequence (Constant Address)

This mode can be used for a fast access to the HDLC FIFO data. Any address (rdadr, wradr) in the range 00_H-$1F_H$ and $6A_H$/$7A_H$ gives access to the current FIFO location selected by an internal pointer which is automatically incremented with every data byte following the first address byte. The sequence can have any length and is terminated by the rising edge of $\overline{CS}$.

Example for a write access with header 43_H:

SDR	header	wradr	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)
SDX									

Example for a read access with header 43_H:

SDR	header	rdadr							
SDX			rddata (rdadr)	rddata (rdadr)	rddata (rdadr)	rddata (rdadr)	rddata (rdadr)	rddata (rdadr)	rddata (rdadr)

Header 41_H: Non-interleaved A-D-D-D Sequence

This sequence allows in front of the A-D-D-D write access a non-interleaved A-D-A-D read access. This mode is useful for reading status information before writing to the HDLC XFIFO. The termination condition of the read access is the reception of the wradr. The sequence can have any length and is terminated by the rising edge of $\overline{CS}$.

Example for a read/write access with header 41_H:

SDR	header	rdadr		rdadr		wradr	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)	
SDX			rddata		rddata					

Header 49_H: Interleaved A-D-D-D Sequence

This sequence allows in front of the A-D-D-D write access an interleaved A-D-A-D read access. This mode is useful for reading status information before writing to the HDLC XFIFO. The termination condition of the read access is the reception of the wradr. The sequence can have any length and is terminated by the rising edge of the $\overline{CS}$ line.

Example for a read/write access with header 49_H:

SDR	header	rdadr	rdadr	wradr	wrdata (wradr)	wrdata (wradr)	wrdata (wradr)			
SDX			rddata	rddata						

3.2.3 Interrupt Structure

Special events in the device are indicated by means of a single interrupt output, which requests the host to read status information from the device or transfer data from/to the device.

Since only one interrupt request pin ($\overline{INT}$) is provided, the cause of an interrupt must be determined by the host reading the interrupt status registers of the device.

The structure of the interrupt status registers is shown in **Figure 8**.

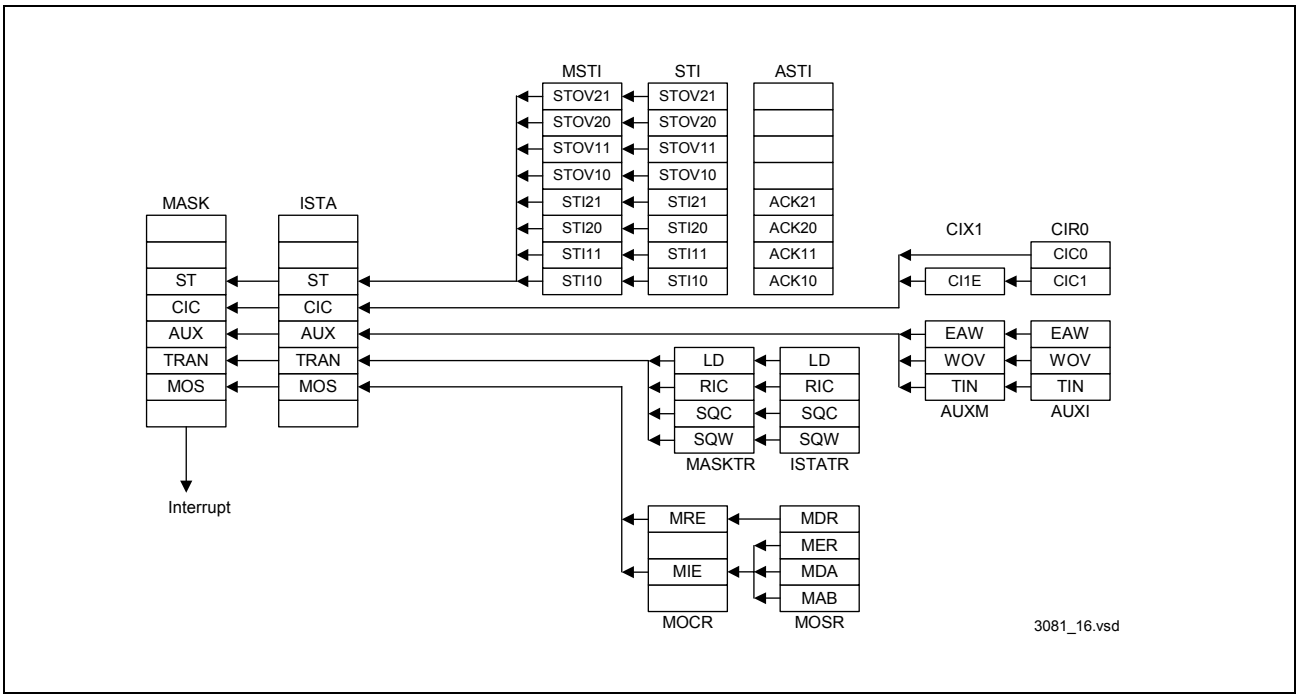


Figure 8 Interrupt Status and Mask Registers

All five interrupt bits in the ISTA register point at interrupt sources in the Monitor handler (MOS), C/I handler (CIC), the transceiver (TRAN), the synchronous transfer (ST) and the auxiliary interrupts (AUXI).

All these interrupt sources are described in the corresponding chapters. After the device has requested an interrupt activating the interrupt pin ($\overline{INT}$), the host must read first the device interrupt status register (ISTA) in the associated interrupt service routine. The interrupt pin of the device remains active until all interrupt sources are cleared by reading the corresponding interrupt register. Therefore it is possible that the interrupt pin is still active when the interrupt service routine is finished.
Each interrupt indication of the interrupt status registers can selectively be masked by setting the respective bit in the MASK register.

For some interrupt controllers or hosts it might be necessary to generate a new edge on the interrupt line to recognize pending interrupts. This can be done by masking all interrupts at the end of the interrupt service routine (writing FF_H into the MASK register) and write back the old mask to the MASK register.

3.2.4 Reset Generation

Figure 9 shows the organization of the reset generation of the device.

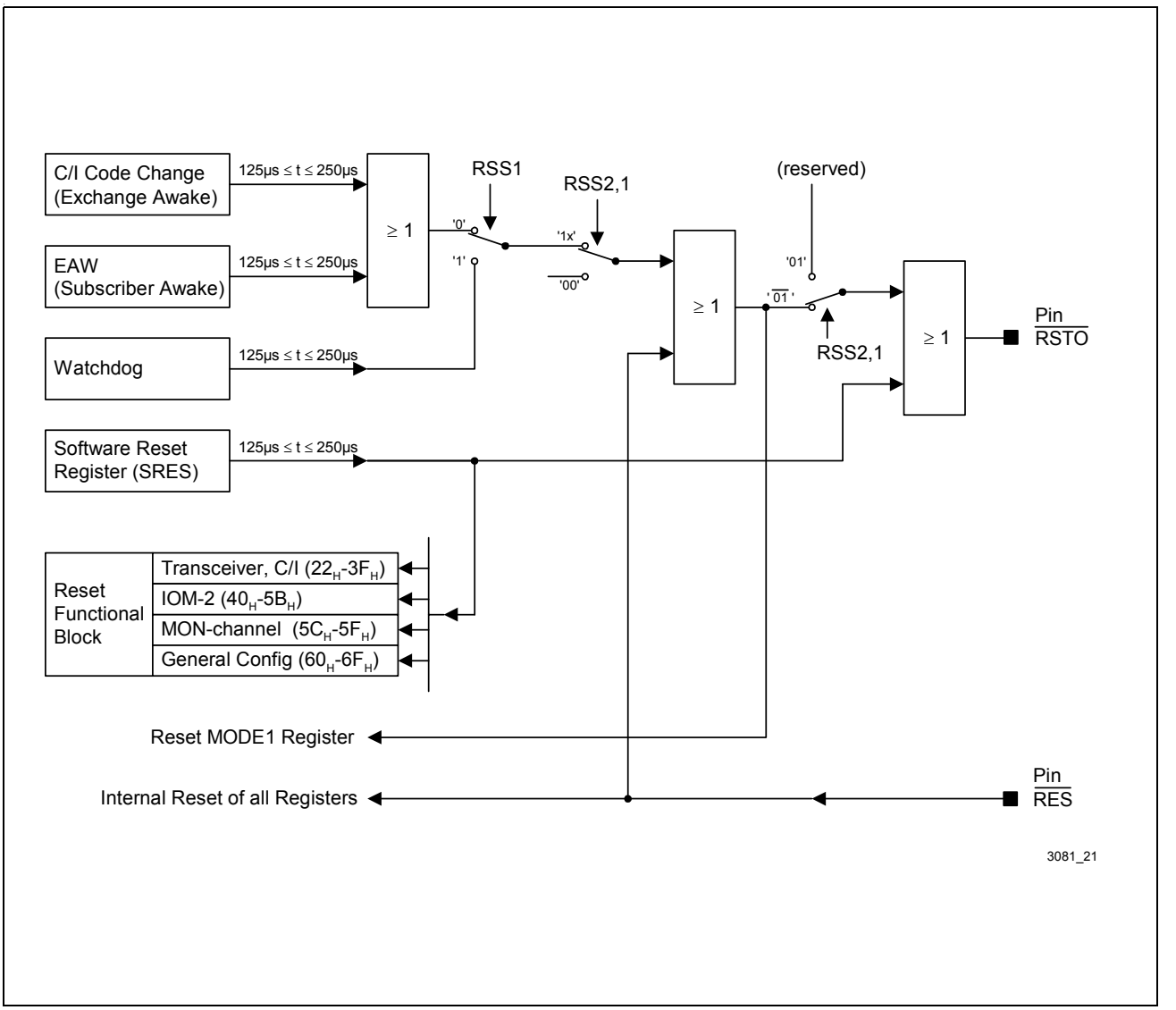


Figure 9 Reset Generation

Reset Source Selection

The internal reset sources C/I code change, $\overline{\text{EAW}}$ and Watchdog can be output at the low active reset pin $\overline{\text{RSTO}}$. The selection of these reset sources can be done with the RSS2,1 bits in the MODE1 register according **Table 5**.

The setting RSS2,1 = ’01’ is reserved for further use. In this case no reset except software reset (SRES.RSTO) is output on $\overline{\text{RSTO}}$. The internal reset sources set the MODE1 register to its reset value.

Table 5 Reset Source Selection

RSS2 Bit 1	RSS1 Bit 0	C/I Code Change	EAW	Watchdog Timer
0	0	--	--	--
0	1	reserved		
1	0	x	x	--
1	1	--	--	x

- **C/I Code Change (Exchange Awake)**
  A change in the downstream C/I channel (C/I0) generates an external reset pulse of 125 µs ≤ t ≤ 250 µs.
- **$\overline{\text{EAW}}$ (Subscriber Awake)**
  A low level on the $\overline{\text{EAW}}$ input starts the oscillator from the power down state and generates a reset pulse of 125 µs ≤ t ≤ 250 µs.
- **Watchdog Timer**

After the selection of the watchdog timer (RSS = ’11’) an internal timer is reset and started. During every time period of 128 ms the microcontroller has to program the WTC1- and WTC2 bits in the following sequence to reset and restart the watchdog timer:

	WTC1	WTC2
1.	1	0
2.	0	1

If not, the timer expires and a WOV-interrupt (ISTA Register) together with a reset pulse of 125 µs is generated.
Deactivation of the watchdog timer is only possible with a hardware reset.

External Reset Input

At the $\overline{\text{RES}}$ input an external reset can be applied forcing the device in the reset state. This external reset signal is additionally fed to the $\overline{\text{RSTO}}$ output. The length of the reset signal is specified in **Chapter 5.8**.

After an external reset from the $\overline{\text{RES}}$ pin all registers of the device are set to its reset values (see register description in **Chapter 4**).

Software Reset Register (SRES)

Every main functional block of the device can be reset separately by software setting the corresponding bit in the SRES register. A reset to external devices can also be controlled in this way. The reset state is activated by setting the corresponding bit to ’1’ and onchip

logic resets this bit again automatically after 4 BCL clock cycles. The address range of the registers which will be reset at each SRES bit is listed in **Figure 9**.

3.2.5 Timer Modes

The SBCX-X provides one timer which can be used for various purposes. It provides two modes (**Table 6**), a count down timer interrupt, i.e. an interrupt is generated only once after expiration of the selected period, and a periodic timer interrupt, which means an interrupt is generated continuously after every expiration of that period.

Table 6 SBCX-X Timer

Address	Register	Modes	Period
65_H	TIMR	Periodic	1 ... 63 ms
		Count Down	1 ... 63 ms

When the programmed period has expired an interrupt is generated and indicated in the auxiliary interrupt status ISTA.AUX. The source of the interrupt can be read from AUXI.TIN and masked in AUXM.

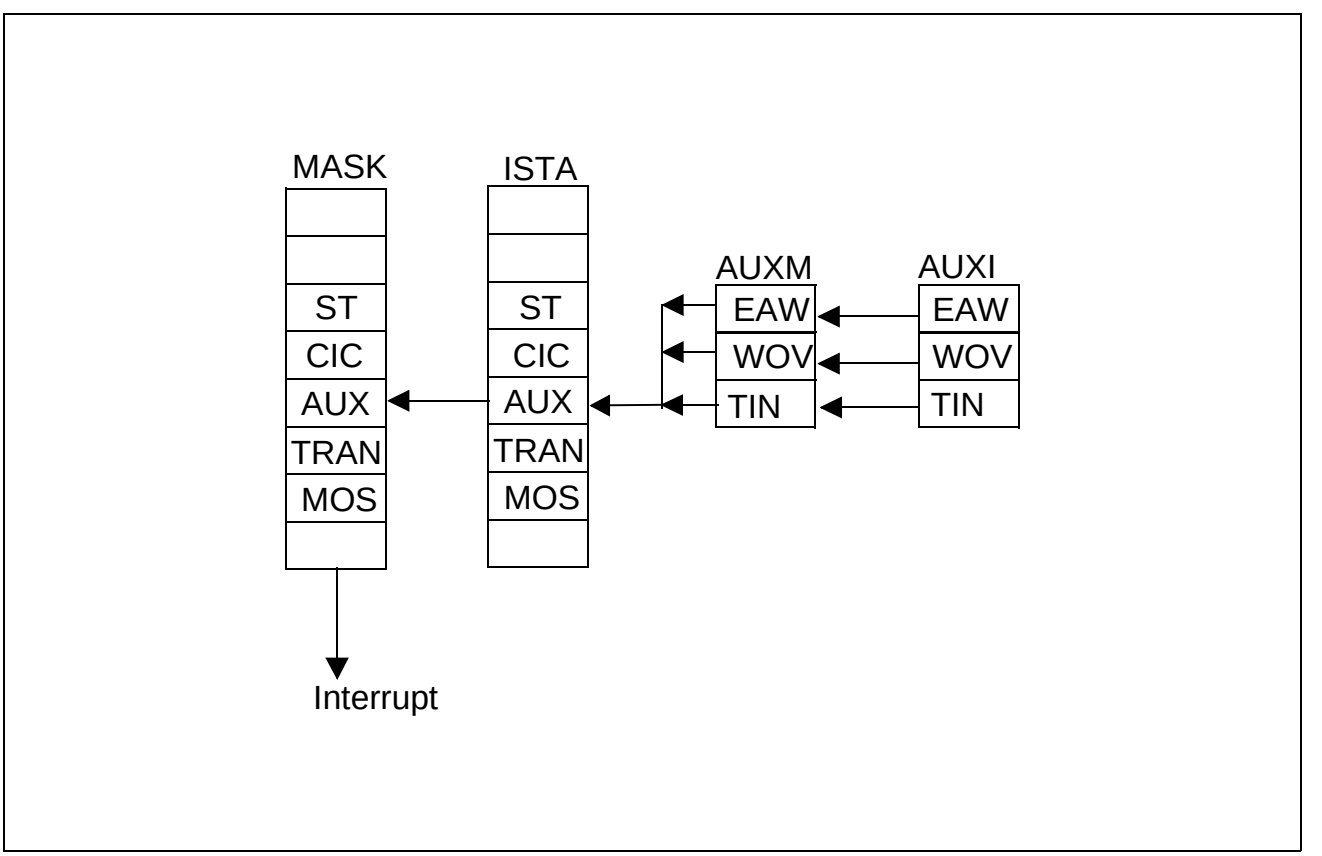


Figure 10 Timer Interrupt Status Registers

The host starts and stops the timer in TIMR.CNT (**Figure 11**). If TIMR.TMD=0 the timer is operating in count down mode, for TIMR.TMD=1 a periodic interrupt AUXI.TIN is generated. The timer length (for count down timer) or the timer period (for periodic timer), respectively, can be configured to a value between 1 - 63 ms (TIMR.CNT).

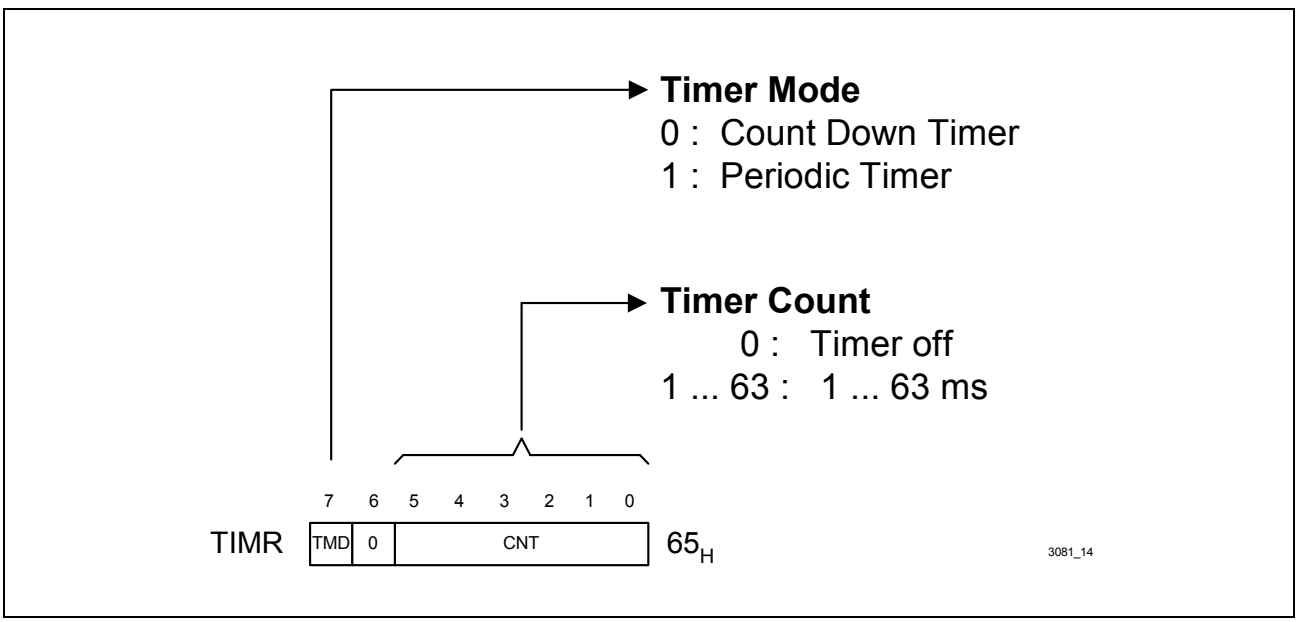


Figure 11 Timer Register

3.2.6 Activation Indication via Pin ACL

The activated state of the S-interface is directly indicated via pin $\overline{\text{ACL}}$ (Activation LED). An LED with pre-resistance may directly be connected to this pin and a low level is driven on $\overline{\text{ACL}}$ as soon as the layer 1 state machine reaches the activated state (see **Figure 12**).

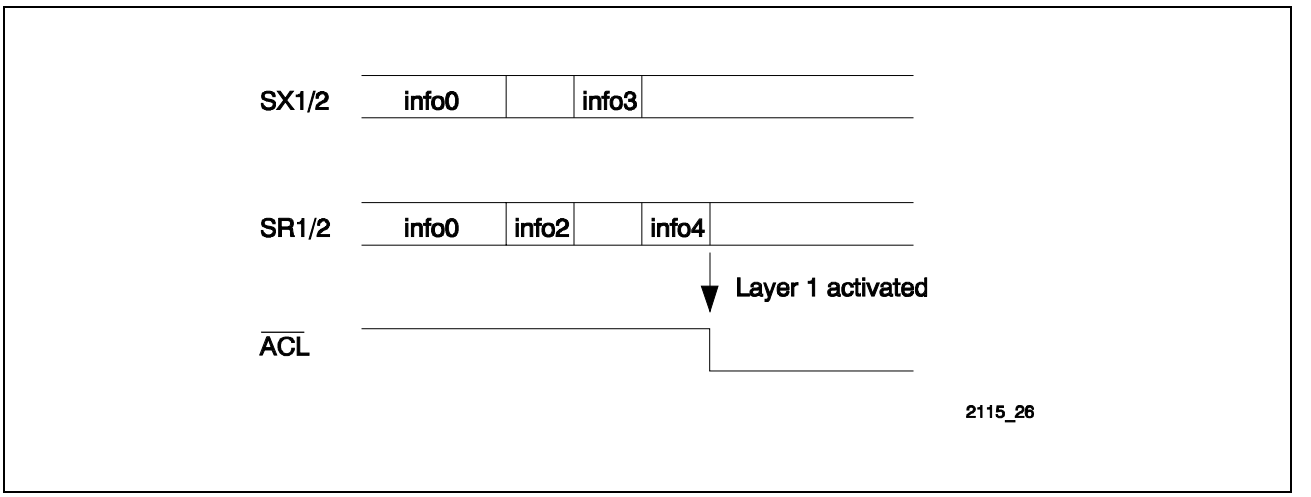


Figure 12 ACL Indication of Activated Layer 1 on TE Side

By default (ACFG2.ACL=0) the state of layer 1 is indicated at pin $\overline{\text{ACL}}$. If the automatic indication of the activated layer 1 is not required, the state on pin $\overline{\text{ACL}}$ can also be controlled by the host (see **Figure 13**).
If ACFG2.ACL=1 the LED on pin $\overline{\text{ACL}}$ can be switched on (ACFG2.LED=1) and off (ACFG2.LED=0) by the host.

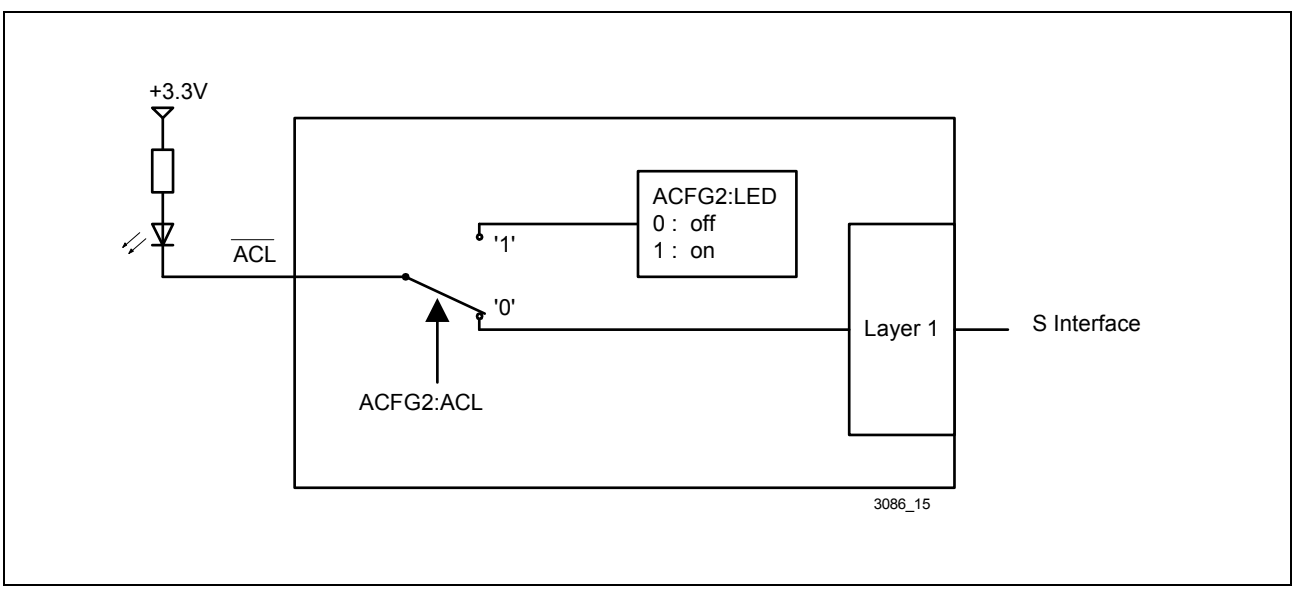


Figure 13 ACL Configuration

3.3 S/T-Interface

The layer-1 functions for the S/T interface of the SBCX-X are:

– line transceiver functions for the S/T interface according to the electrical specifications of ITU-T I.430;
– conversion of the frame structure between IOM-2 and S/T interface;
– conversion from/to binary to/from pseudo-ternary code;
– level detection;
– receive timing recovery for point-to-point, passive bus and extended passive bus configuration;
– S/T timing generation using IOM-2 timing synchronous to system, or vice versa;
– D-channel access control and priority handling;
– D-channel echo bit generation by handling of the global echo bit;
– activation/deactivation procedures, triggered by primitives received over the IOM-2 interface or by INFOs received from the line;
– execution of test loops.

The wiring configurations in user premises, in which the SBCX-X can be used, are illustrated in **Figure 14**.

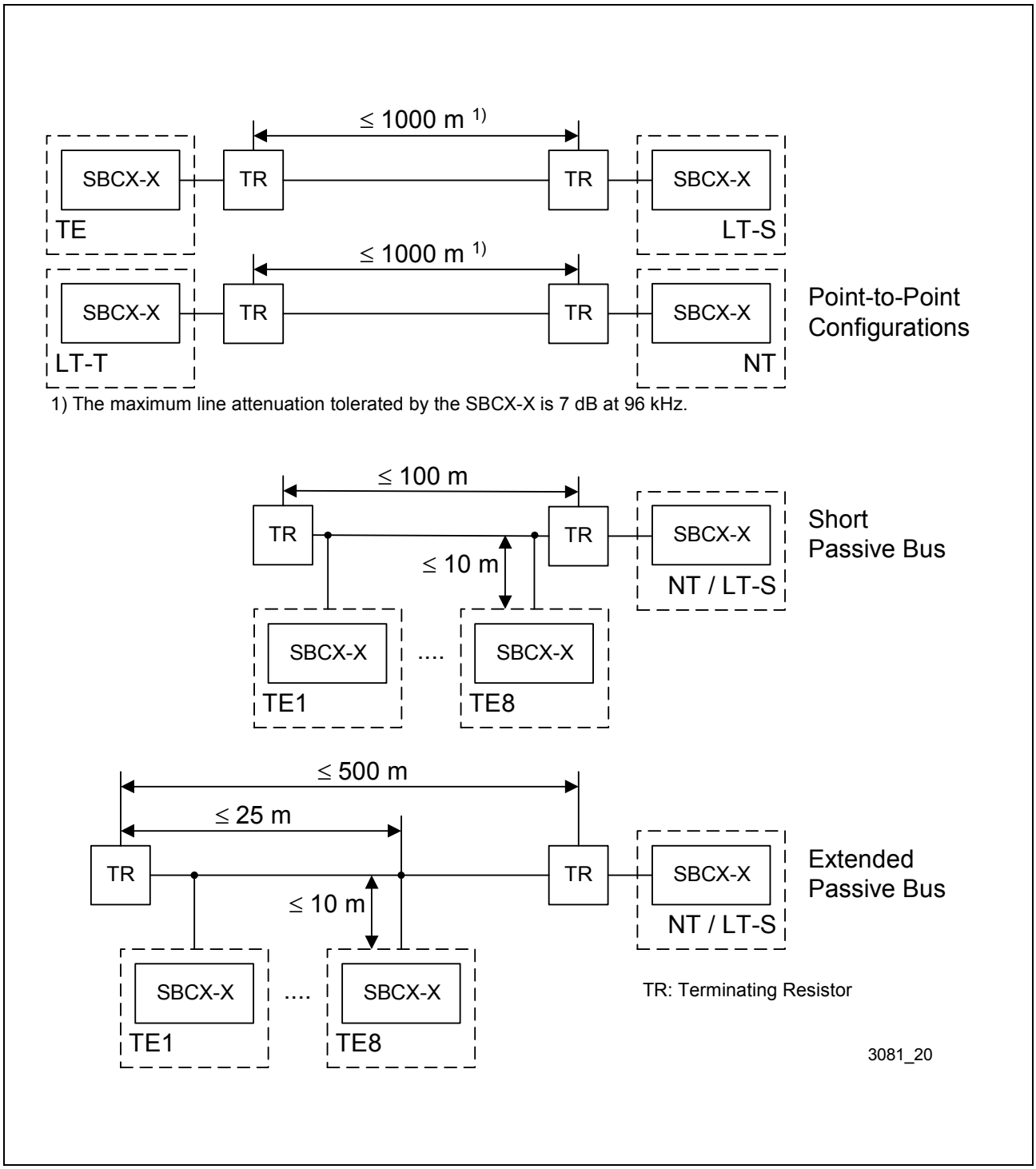


Figure 14 Wiring Configurations in User Premises

3.3.1 S/T-Interface Coding

Transmission over the S/T-interface is performed at a rate of 192 kbit/s. 144 kbit/s are used for user data (B1+B2+D), 48 kbit/s are used for framing and maintenance information.

Line Coding

The following figure illustrates the line code. A binary ONE is represented by no line signal. Binary ZEROs are coded with alternating positive and negative pulses with two exceptions:
For the required frame structure a code violation is indicated by two consecutive pulses of the same polarity. These two pulses can be adjacent or separated by binary ONEs.
In bus configurations a binary ZERO always overwrites a binary ONE.

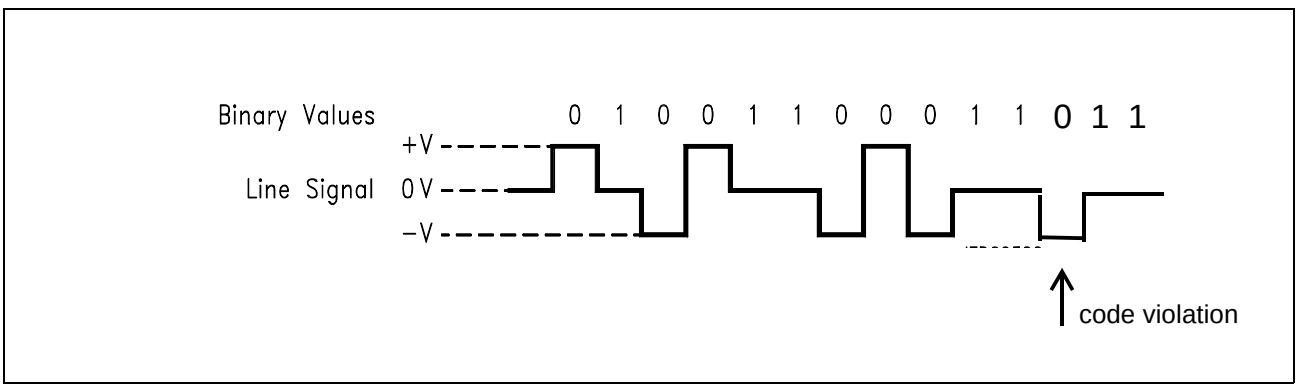


Figure 15 S/T-Interface Line Code

Frame Structure

Each S/T frame consists of 48 bits at a nominal bit rate of 192 kbit/s. For user data (B1+B2+D) the frame structure applies to a data rate of 144 kbit/s (see **Figure 16**).
In the direction TE → NT the frame is transmitted with a two bit offset. For details on the framing rules please refer to ITU I.430 section 6.3. The following figure illustrates the standard frame structure for both directions (NT → TE and TE → NT) with all framing and maintenance bits.

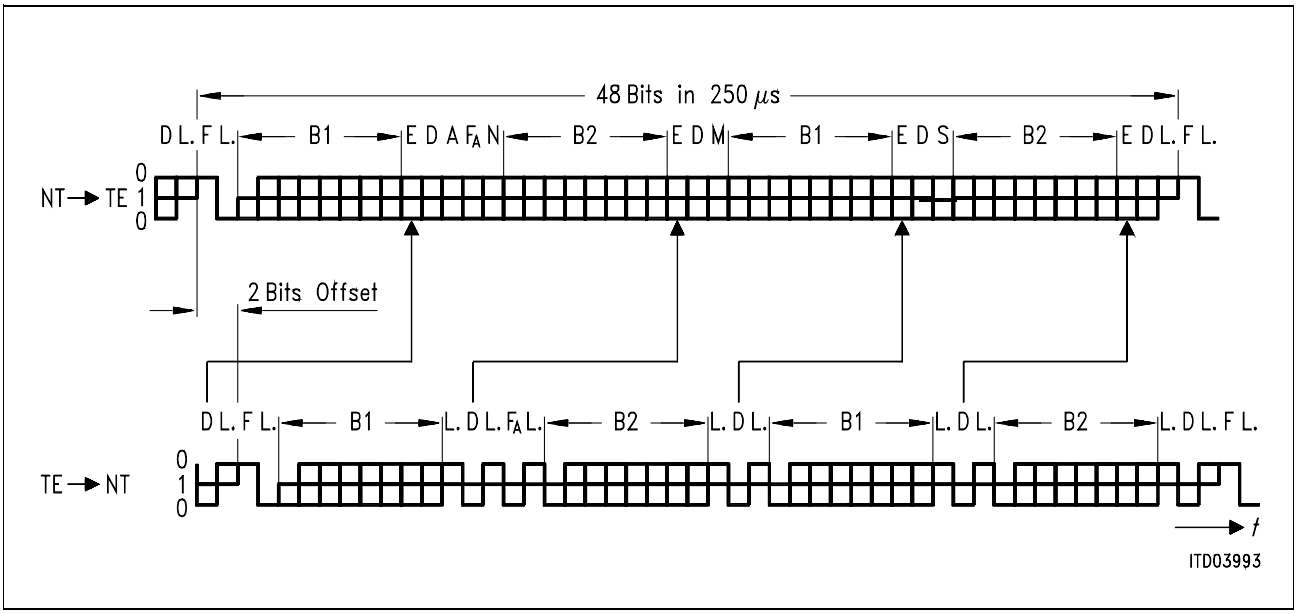


Figure 16 Frame Structure at Reference Points S and T (ITU I.430)

– F	Framing Bit	F = (0b) → identifies new frame (always positive pulse, always code violation)
– L.	D.C. Balancing Bit	L. = (0b) → number of binary ZEROs sent after the last L. bit was odd
– D	D-Channel Data Bit	Signaling data specified by user
– E	D-Channel Echo Bit	E = D → received E-bit is equal to transmitted D-bit
– F_A	Auxiliary Framing Bit	See section 6.3 in ITU I.430
– N		N = $\overline{F_A}$
– B1	B1-Channel Data Bit	User data
– B2	B2-Channel Data Bit	User data
– A	Activation Bit	A = (0b) → INFO 2 transmitted A = (1b) → INFO 4 transmitted
– S	S-Channel Data Bit	S_1 channel data (see note below)
– M	Multiframing Bit	M = (1b) → Start of new multiframe

Note: The ITU I.430 standard specifies S1 - S5 for optional use.

3.3.2 S/T-Interface Multiframing

According to ITU recommendation I.430 a multiframe provides extra layer 1 capacity in the TE-to-NT direction by using an extra channel between the TE and NT (Q-channel). The Q bits are defined to be the bits in the F_A bit position.

In the NT-to-TE direction the S-channel bits are used for information transmission. One S channel (S1) out of five possible S-channels can be accessed by the SBCX-X.

In the NT-to-TE direction the S-channel bits are used for information transmission.

The S and Q channels are accessed via the µC interface or the IOM-2 MONITOR channel, respectively, by reading/writing the SQR or SQX bits in the S/Q channel registers (SQRRx, SQXRx).

Table 7 shows the S and Q bit positions within the multiframe.

Table 7 S/Q-Bit Position Identification and Multiframe Structure

Frame Number	NT-to-TE F_A Bit Position	NT-to-TE M Bit	NT-to-TE S Bit	TE-to-NT F_A Bit Position
1	ONE	ONE	S11	Q1
2	ZERO	ZERO	S21	ZERO
3	ZERO	ZERO	S31	ZERO
4	ZERO	ZERO	S41	ZERO
5	ZERO	ZERO	S51	ZERO
6	ONE	ZERO	S12	Q2
7	ZERO	ZERO	S22	ZERO
8	ZERO	ZERO	S32	ZERO
9	ZERO	ZERO	S42	ZERO
10	ZERO	ZERO	S52	ZERO
11	ONE	ZERO	S13	Q3
12	ZERO	ZERO	S23	ZERO
13	ZERO	ZERO	S33	ZERO
14	ZERO	ZERO	S43	ZERO
15	ZERO	ZERO	S53	ZERO
16	ONE	ZERO	S14	Q4
17	ZERO	ZERO	S24	ZERO
18	ZERO	ZERO	S34	ZERO
19	ZERO	ZERO	S44	ZERO
20	ZERO	ZERO	S54	ZERO
1	ONE	ONE	S11	Q1
2	ZERO	ZERO	S21	ZERO

TE Mode

After multiframe synchronization has been established, the Q data will be inserted at the upstream (TE → NT) F_A bit position in each 5th S/T frame (see **Table 7**).
When synchronization is not achieved or lost, each received F_A bit is mirrored to the next transmitted F_A bit.
Multiframe synchronization is achieved after two complete multiframes have been detected with reference to F_A/N bit and M bit positions. Multiframe synchronization is lost if bit errors in F_A/N bit or M bit positions have been detected in two consecutive multiframes. The synchronization state is indicated by the MSYN bit in the S/Q-channel receive register (SQRR1).
The multiframe synchronization can be enabled or disabled by programming the MFEN bit in the S/Q-channel transmit register (SQXR1).

NT Mode

The transceiver in NT mode starts multiframing if SQXR1.MFEN is set.

After multiframe synchronization has been established in the TE, the Q data will be inserted at the upstream (TE → NT) F_A bit position by the TE in each 5th S/T frame, the S data will be inserted at the downstream (NT → TE) S bit position in each S/T frame (see **Table 7**).

Interrupt Handling for Multiframing

To trigger the microcontroller for a multiframe access an interrupt can be generated once per multiframe (SQW) or if the received S-channels (TE) or Q-channel (NT) have changed (SQC).
In both cases the microcontroller has access to the multiframe within the duration of one multiframe (5 ms).

3.3.3 Data Transfer and Delay between IOM-2 and S/T

TE mode

In the state F7 (Activated) or if the internal layer-1 statemachine is disabled and XINF of register TR_CMD is programmed to ’011’ the B1, B2, D and E bits are transferred transparently from the S/T to the IOM-2 interface. In all other states ’1’s are transmitted to the IOM-2 interface.

To transfer data transparently to the S/T interface any activation request C/I command (AR8, AR10 or ARL) is additionally necessary or if the internal layer-1 statemachine is disabled, bit TDDIS of register TR_CMD has additionally to be programmed to ’0’. **Figure 17** shows the data delay between the IOM-2 and the S/T interface and vice versa.

For the D channel the delay from the IOM-2 to the S/T interface is only valid if S/G evaluation is disabled (TR_MODE2.DIM0=0). If S/G evaluation is enabled (TR_MODE2.DIM2-0=0x1) the delay depends on the selected priority and the relation between the echo bits on S and the D channel bits on the IOM-2, e.g. for priority 8 the timing relation between the 8th D-bit on S bus and the D-channel on IOM-2.

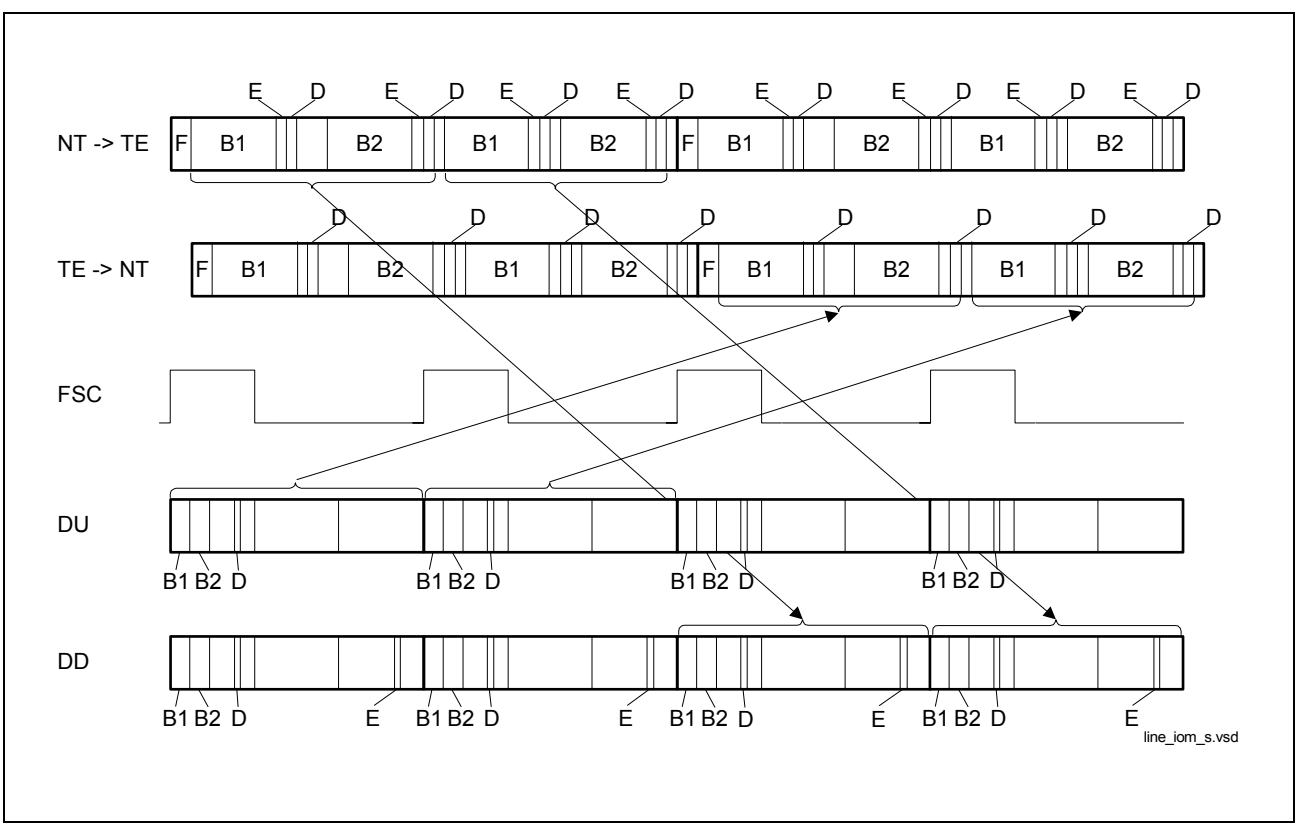


Figure 17 Data Delay between IOM-2 and S/T Interface (TE mode only)

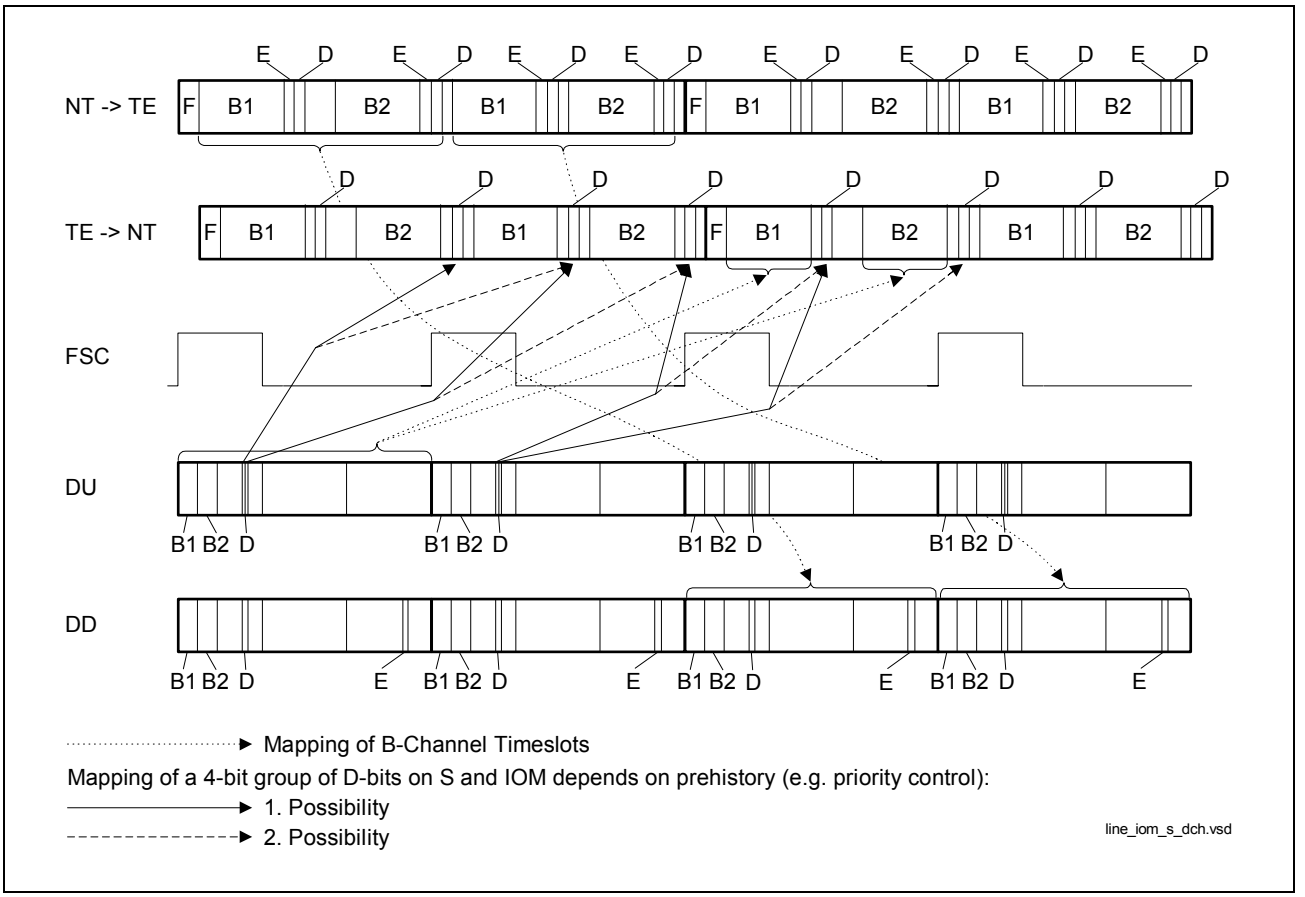


Figure 18 Data Delay between IOM-2 and S/T Interface with S/G Bit Evaluation (TE mode only)

LT-T mode

In this mode the frame relation between S/T interface and IOM-2 is flexible.

LT-S/NT mode

In the state F7 (Activated) or if the internal layer-1 statemachine is disabled and XINF of register TR_CMD is programmed to ’011’ the B1, B2 and D bits are transferred transparently from the S/T to the IOM-2 interface. In all other states ’1’s are transmitted to the IOM-2 interface.

Note: In intelligent NT the D-channel access can be blocked by the IOM-2 D-channel handler.

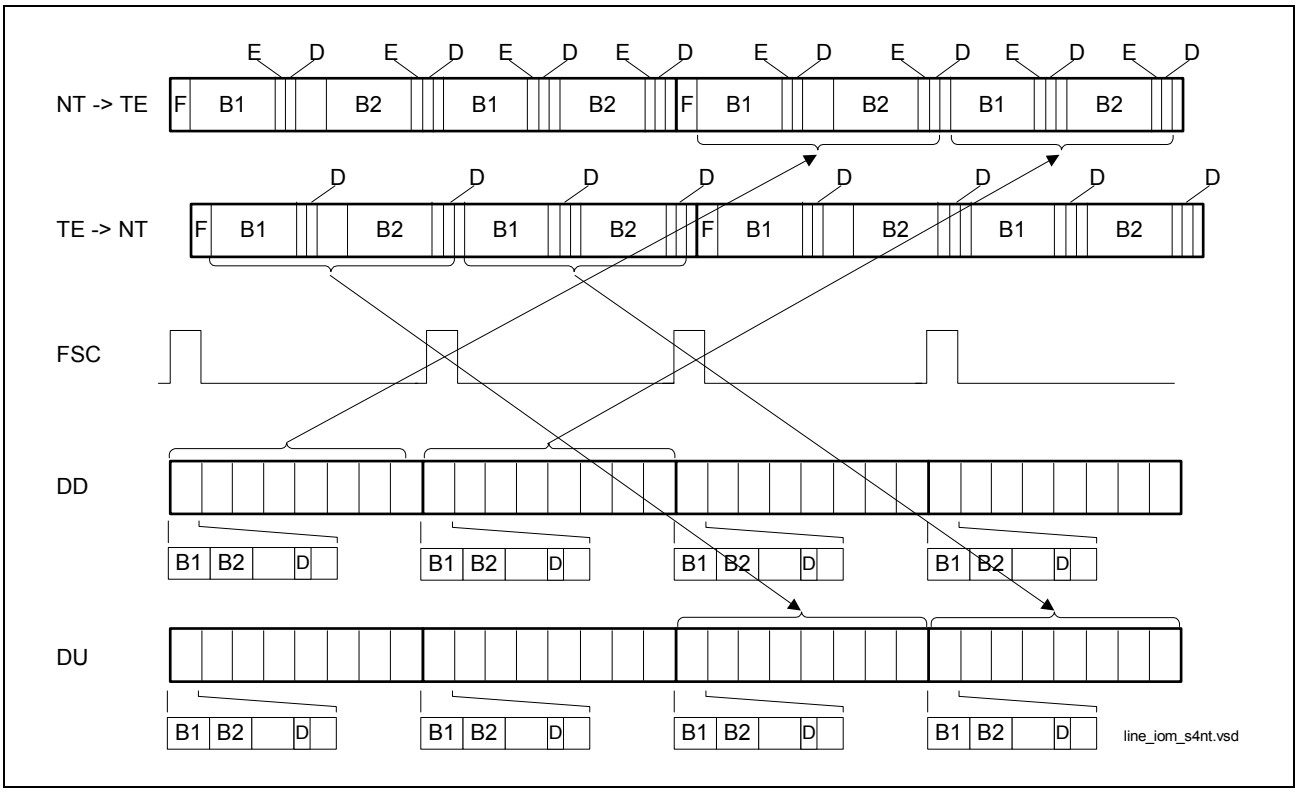


Figure 19 Data Delay between IOM-2 and S/T Interface with 8 IOM Channels (LT-S/NT mode only)

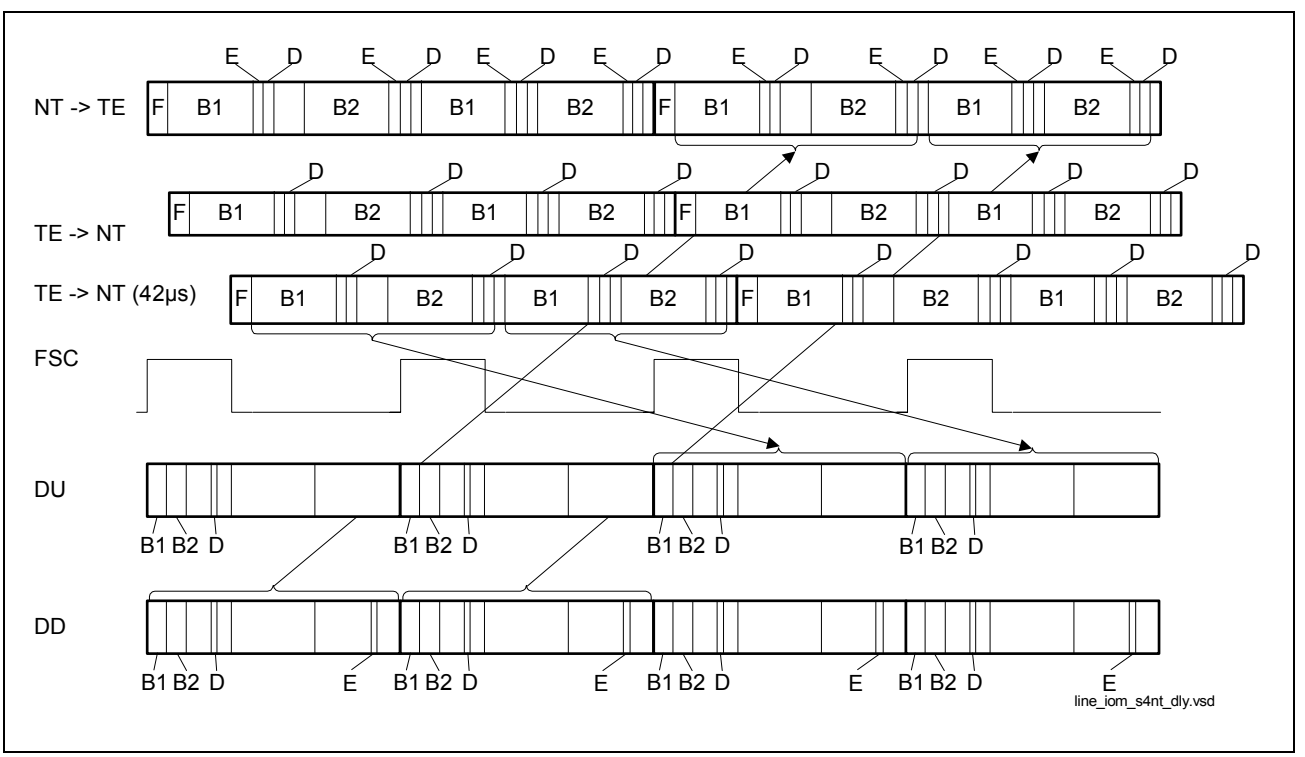


Figure 20 Data Delay between IOM-2 and S/T Interface with 3 IOM Channels and Maximum Receive Delay (LT-S/NT mode only)

3.3.4 Transmitter Characteristics

The full-bauded pseudo-ternary pulse shaping is achieved with the integrated transmitter which is realized as a symmetrical current limited voltage source ($V_{SX1/SX2}$ = +/-1.05 V; I_{max} = 26 mA). The equivalent circuit of the transmitter is shown in **Figure 21**.
The nominal pulse amplitude on the S-interface of 750 mV (zero-peak) is adjusted with external resistors (see **Chapter 3.3.6.1**).

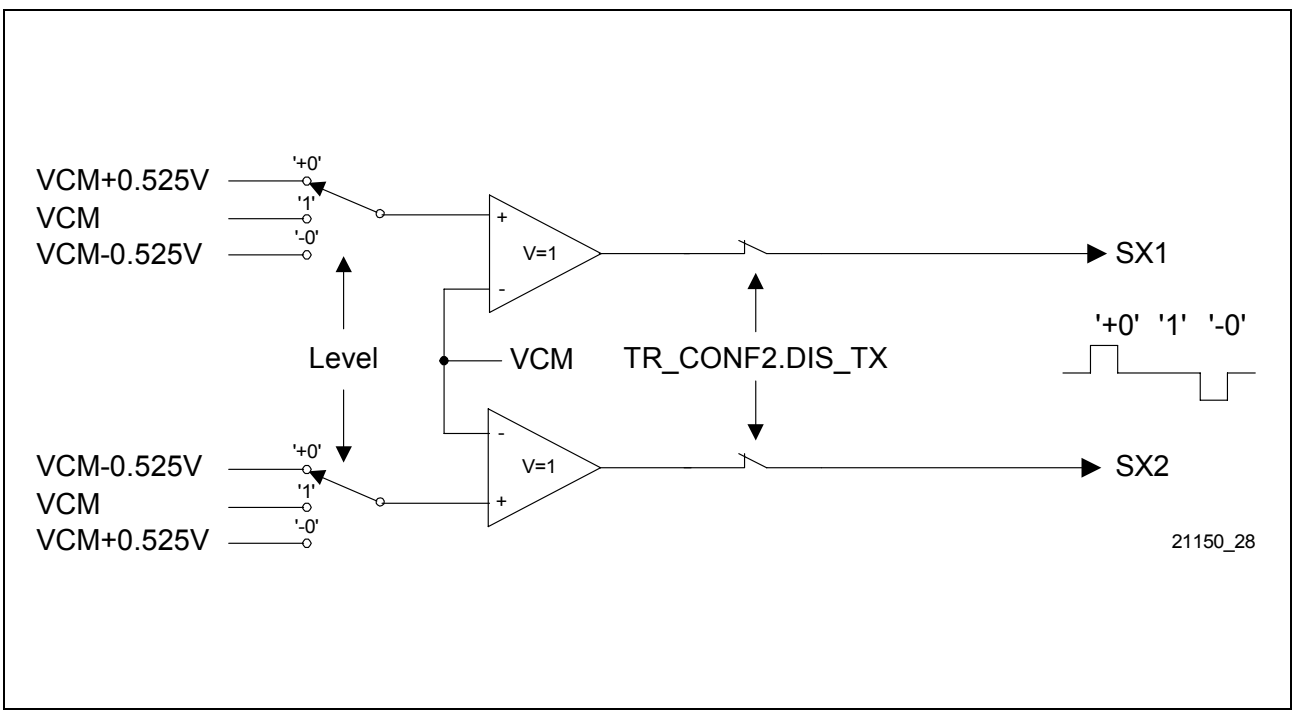


Figure 21 Equivalent Internal Circuit of the Transmitter Stage

3.3.5 Receiver Characteristics

The receiver consists of a differential input stage, a peak detector and a set of comparators. Additional noise immunity is achieved by digital oversampling after the comparators. A simplified equivalent circuit of the receiver is shown in **Figure 22**.

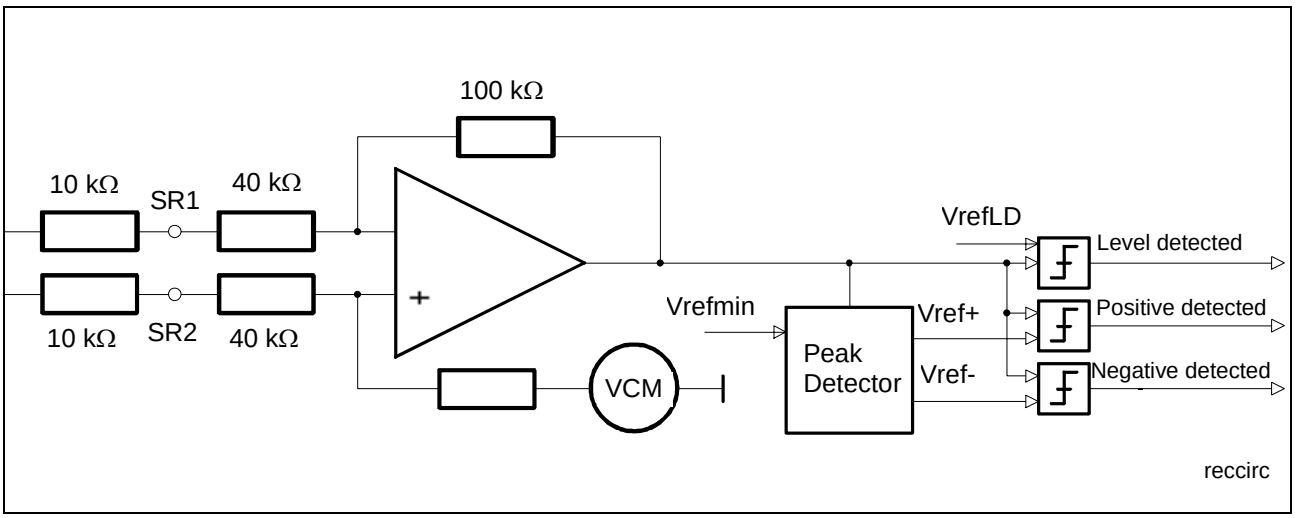


Figure 22 Equivalent Internal Circuit of the Receiver Stage

The input stage works together with external 10 kΩ resistors to match the input voltage to the internal thresholds. The data detection threshold Vref is continuously adapted between a maximal (Vrefmax) and a minimal (Vrefmin) reference level related to the line level. The peak detector requires maximum 2 µs to reach the peak value while storing the peak level for at least 250 µs (RC > 1 ms).

The additional level detector for power up/down control works with a fixed threshold VrefLD. The level detector monitors the line input signals to detect whether an INFO is present. When closing an analog loop it is therefore possible to indicate an incoming signal during activated loop.

3.3.6 S/T Interface Circuitry

For both, receive and transmit direction a 1:1 transformer is used to connect the SBCX-X transceiver to the 4 wire S/T interface. Typical transformer characteristics can be found in the chapter on electrical characteristics. The connections of the line transformers is shown in **Figure 23**.

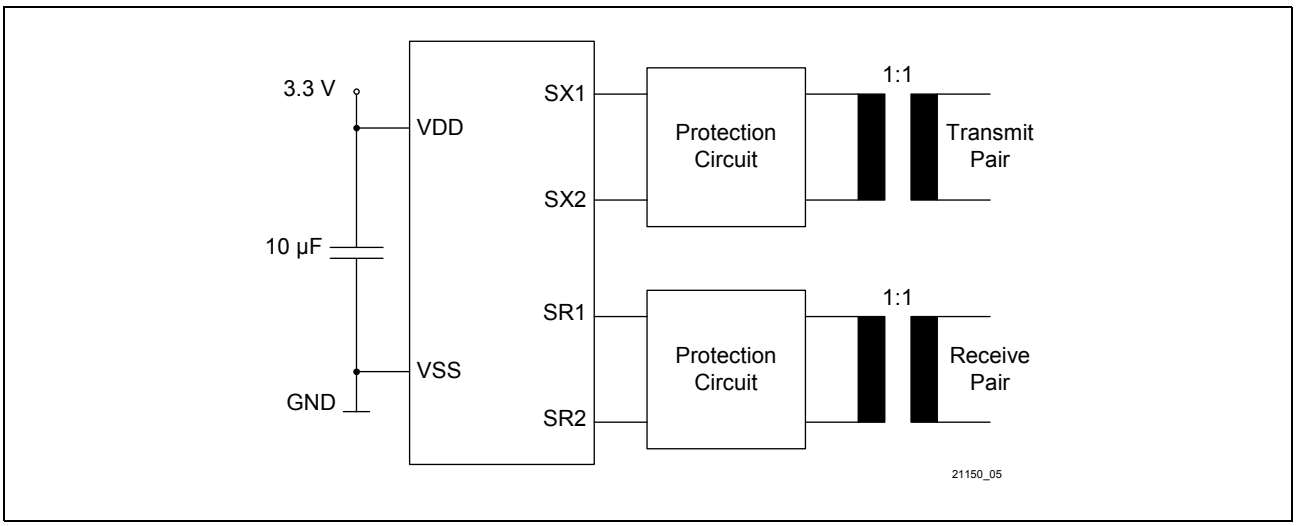


Figure 23 Connection of Line Transformers and Power Supply to the SBCX-X

For the transmit direction an external transformer is required to provide isolation and pulse shape according to the ITU-T recommendations.

3.3.6.1 External Protection Circuitry

The ITU-T I.430 specification for both transmitter and receiver impedances in TEs results in a conflict with respect to external S-protection circuitry requirements:

– To avoid destruction or malfunction of the S-device it is desirable to drain off even small overvoltages reliably.
– To meet the 96 kHz impedance test specified for transmitters and receivers (for TEs only, ITU-T I.430 sections 8.5.1.2a and 8.6.1.1) the protection circuit must be dimensioned such that voltages below 1.2 V (ITU-T I.430 amplitude) x transformer ratio are not affected.

This requirement results from the fact that this test is also to be performed with no supply voltage being connected to the TE. Therefore the second reference point for overvoltages V_{DD}, is tied to GND. Then, if the amplitude of the 96 kHz test signal is greater than the combined forward voltages of the diodes, a current exceeding the specified one may pass the protection circuit.

The following recommendations aim at achieving the highest possible device protection against overvoltages while still fulfilling the 96 kHz impedance tests.

Protection Circuit for Transmitter

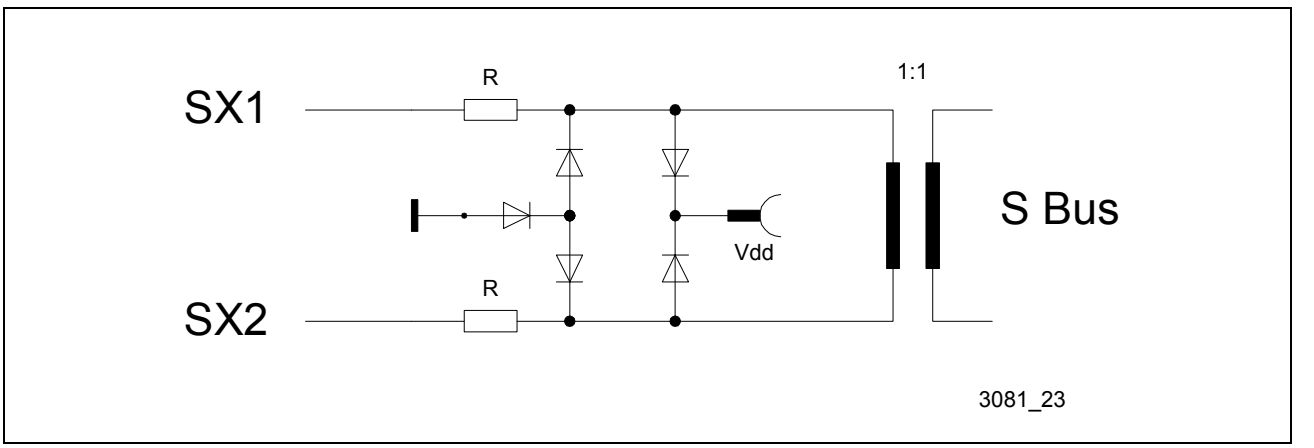


Figure 24 External Circuitry for Transmitter

Figure 24 illustrates the secondary protection circuit recommended for the transmitter.

The external resistors (R = 5 .... 10 Ω) are required in order to adjust the output voltage to the pulse mask on the one hand and in order to meet the output impedance of minimum 20 Ω (transmission of a binary zero according to ITU-T I.430) on the other hand.

Two mutually reversed diode paths protect the device against positive or negative overvoltages on both lines.

An ideal protection circuit should limit the voltage at the SX pins from – 0.4 V to V_{DD} + 0.4 V. With the circuit in **Figure 24** the pin voltage range is increased from – 1.4 V to V_{DD} + 0.7 V. The resulting forward voltage of 1.4 V will prevent the protection circuit from becoming active if the 96 kHz test signal is applied while no supply voltage is present.

Protection Circuit for Receiver

Figure 25 illustrates the external circuitry used in combination with a symmetrical receiver. Protection of symmetrical receivers is rather simple.

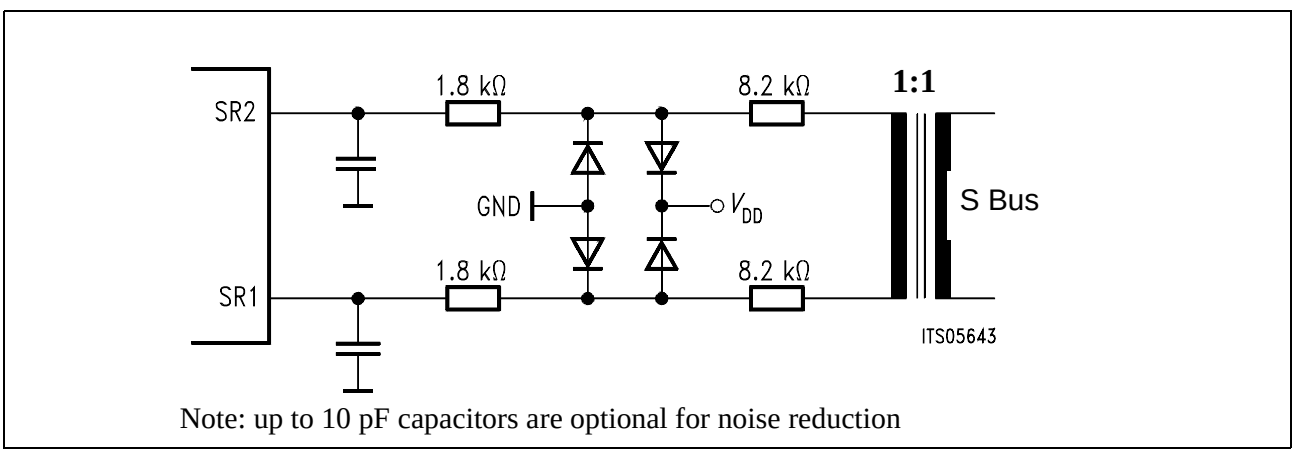


Figure 25 External Circuitry for Symmetrical Receivers

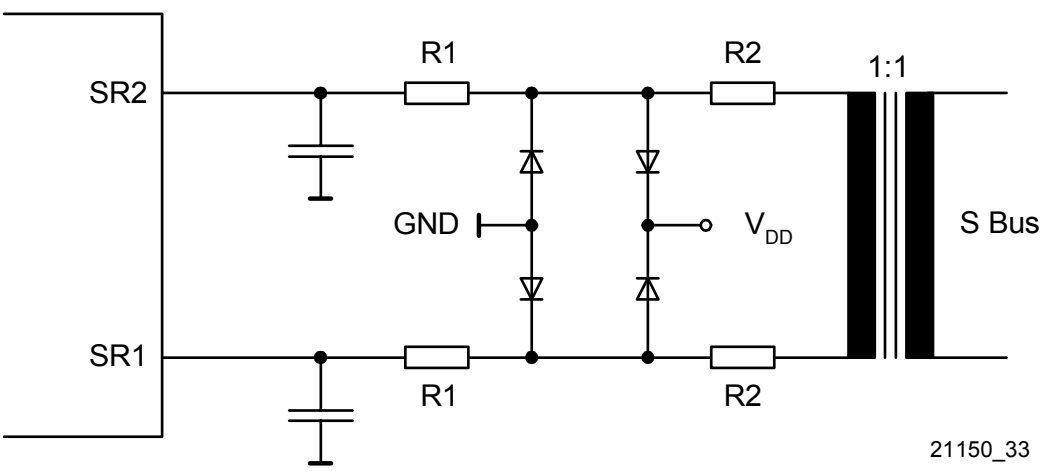
Between each receive line and the transformer a 10 kΩ resistor is used. This value is split into two resistors: one between transformer and protection diodes for current limiting during the 96 kHz test, and the second one between input pin and protection diodes to limit the maximum input current of the chip.

With symmetrical receivers no difficulties regarding LCL measurements are observed; compensation networks thus are obsolete.

In order to comply to the physical requirements of ITU-T recommendation I.430 and considering the national requirements concerning overvoltage protection and electromagnetic compatibility (EMC), the SBCX-X may need additional circuitry.

3.3.6.2 S-Transceiver Synchronization

Synchronization problems can occur on a S-Bus that is not terminated properly. Therefore, it is recommended to change the resistor values in the receive path. The sum of both resistors is increased from 10 kΩ (1.8 + 8.2) to e.g. 34 kΩ (6.8 + 27) for either receiver line. This change is possible but not necessary for a S-Bus that is terminated properly.



Note: Capacitors (up to 10 pF) are optional for noise reduction.

Figure 26 External Circuitry for Symmetrical Receivers

Note: Lower or higher values than 34 kΩ may be used as well, however for values above 34 kΩ the additional delay must be compensated by setting TR_CONF2.PDS=1 (compensates 260 ns) so the allowed input phase delay is not violated.

3.3.7 S/T Interface Delay Compensation (TE/LT-T Mode)

The S/T transmitter is shifted by two S/T bits minus 7 oscillator periods (plus analog delay plus delay of the external circuitry) with respect to the received frame. To compensate additional delay introduced into the receive and transmit path by the external circuit the delay of the transmit data can be reduced by another two oscillator periods (2 x 130 ns). Therefore PDS of the TR_CONF2 register must be programmed to ’1’. This delay compensation might be necessary in order to comply with the "total phase deviation input to output" requirement of ITU-T recommendation I.430 which specifies a phase deviation in the range of – 7% to + 15% of a bit period.

3.3.8 Level Detection Power Down

If MODE1.CFS is set to ’0’, the clocks are also provided in power down state, whereas if CFS is set to ’1’ only the analog level detector is active in power down state. All clocks, including the IOM-2 interface, are stopped (DD, DU are ’high’, DCL and BCL are ’low’).

An activation initiated from the exchange side will have the consequence that a clock signal is provided automatically if TR_CONF0.LDD is set to ’0’. If TR_CONF0.LDD is set to ’1’ the microcontroller has to take care of an interrupt caused by the level detect circuit (ISTATR.LD)

From the terminal side an activation must be started by setting and resetting the SPU-bit in the IOM_CR register and writing TIM to the CIX0 register or by resetting MODE1.CFS=0.

3.3.9 Transceiver Enable/Disable

The layer-1 part of the SBCX-X can be enabled/disabled by configuration (see **Figure 27**) with the two bits TR_CONF0.DIS_TR and TR_CONF2.DIS_TX .
By default all layer-1 functions with the exception of the transmitter buffer is enabled (DIS_TR = ’0’, DIS_TX = ’1’). With several terminals connected to the S/T interface, another terminal may keep the interface activated although the SBCX-X does not establish a connection. The receiver will monitor for incoming calls in this configuration. If the transceiver is disabled (DIS_TR = ’1’) all layer-1 functions are disabled including the level detection circuit of the receiver. In this case the power consumption of the Layer-1 is reduced to a minimum. The DCL and FSC pins become input.

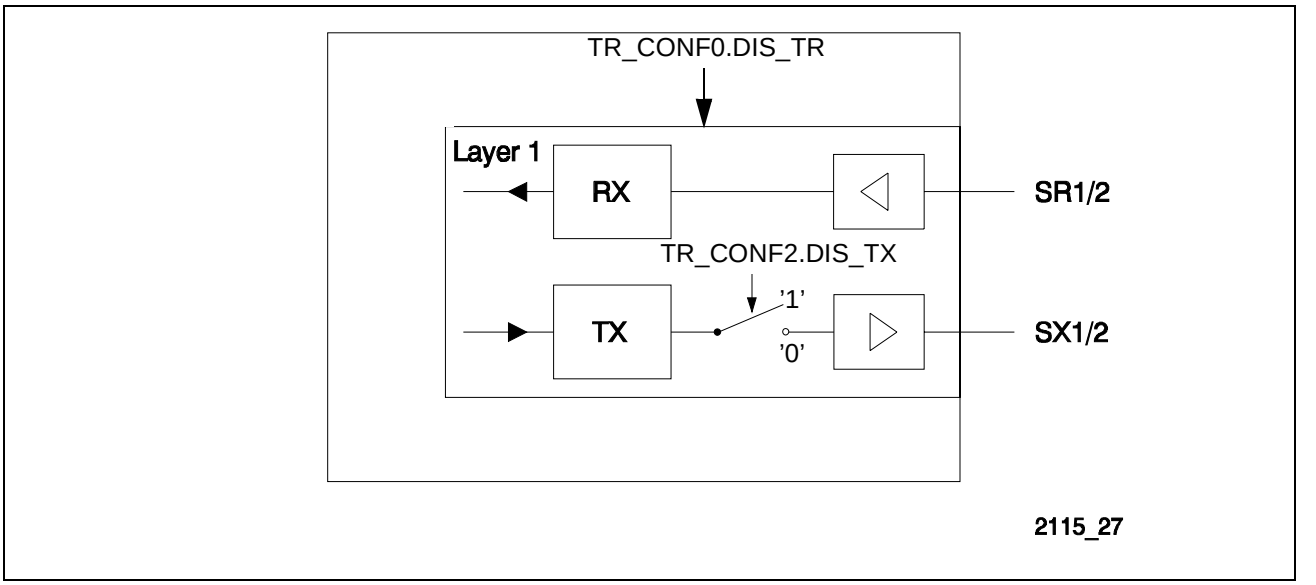


Figure 27 Disabling of S/T Transmitter

3.3.10 Test Functions

The SBCX-X provides test and diagnostic functions for the S/T interface:

Note: For more details please refer to the application note "Test Function of new S-Transceiver family"

– The **internal local loop** (internal Loop A) is activated by a C/I command ARL or by setting the bit LP_A (Loop Analog) in the TR_CMD register if the layer-1 statemachine is disabled.
The transmit data of the transmitter is looped back internally to the receiver. The data of the IOM-2 input B- and D-channels are looped back to the output B- and D-channels.
The S/T interface level detector is enabled, i.e. if a level is detected this will be reported by the Resynchronization Indication (RSY) but the loop function is not affected.
Depending on the DIS_TX bit in the TR_CONF2 register the internal local loop can be transparent or non transparent to the S/T line.
– The **external local loop** (external Loop A) is activated in the same way as the internal local loop described above. Additionally the EXLP bit in the TR_CONF0 register has to be programmed and the loop has to be closed externally as described in **Figure 28**.
The S/T interface level detector is disabled.
This allows complete system diagnostics.
– In **remote line loop** (RLP) received data is looped back to the S/T interface. The D-channel information received from the line card is transparently forwarded to the output IOM-2 D-channel. The output B-channel information on IOM-2 is fixed to 'FF'$_H$ while this test loop is active. The remote loop is programmable in TR_CONF2.RLP.

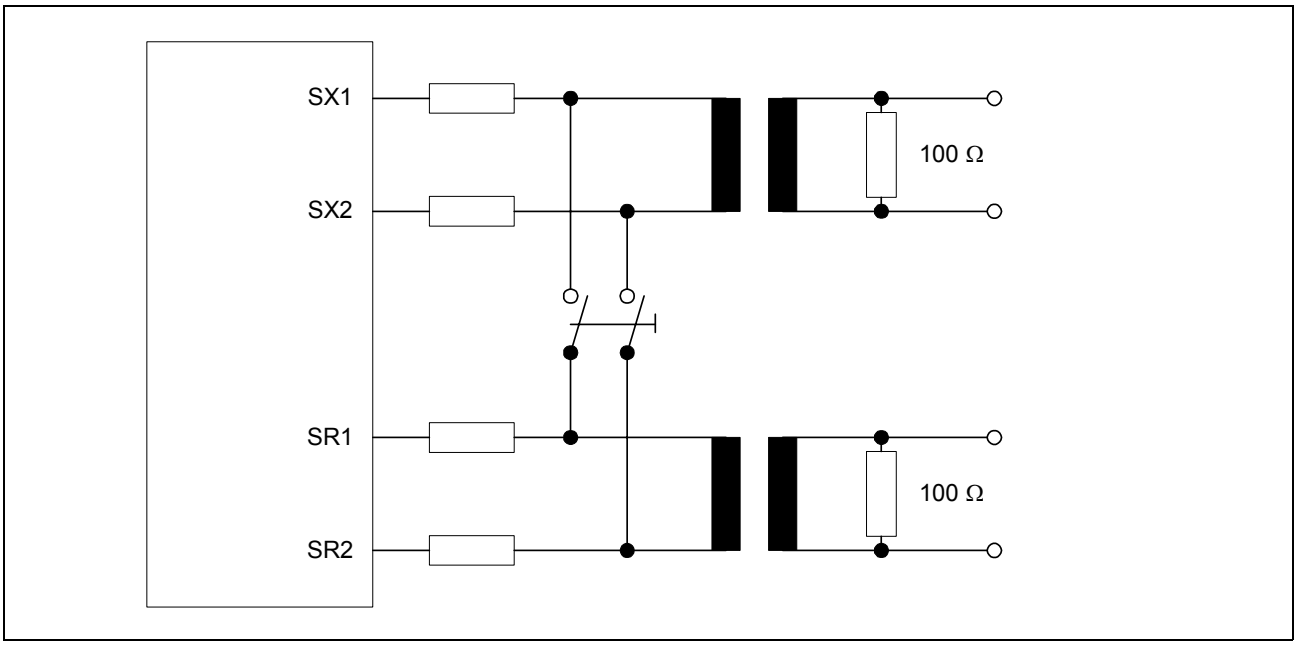


Figure 28 External Loop at the S/T-Interface

– transmission of special test signals on the S/T interface according to the modified AMI code are initiated via a C/I command written in CIX0 register (see **Chapter 3.5.4**)

Two kinds of test signals may be transmitted by the SBCX-X:

– The single pulses are of alternating polarity. One pulse is transmitted in each frame resulting in a frequency of the fundamental mode of 2 kHz. The corresponding C/I command is SSP (Send Single Pulses).
– The continuous pulses are of alternating polarity. 48 pulses are transmitted in each frame resulting in a frequency of the fundamental mode of 96 kHz. The corresponding C/I command is SCP (Send Continuous Pulses).

3.4 Clock Generation

Figure 29 shows the clock system of the SBCX-X. The oscillator is used to generate a 7.68 MHz clock signal (f_{XTAL}). In TE mode the DPLL generates the IOM-2 clocks FSC (8 kHz), DCL (1536 kHz) and BCL (768 kHz) synchronous to the received S/T frames. In LT modes these pins are input and in LT-T mode an 1536 kHz clock synchronous to S is output at SCLK which can be used for DCL input.

The FSC signal is used to generate the pulse lengths of the different reset sources C/I Code, $\overline{\text{EAW}}$ pin and Watchdog (see **Chapter 3.2.4**).

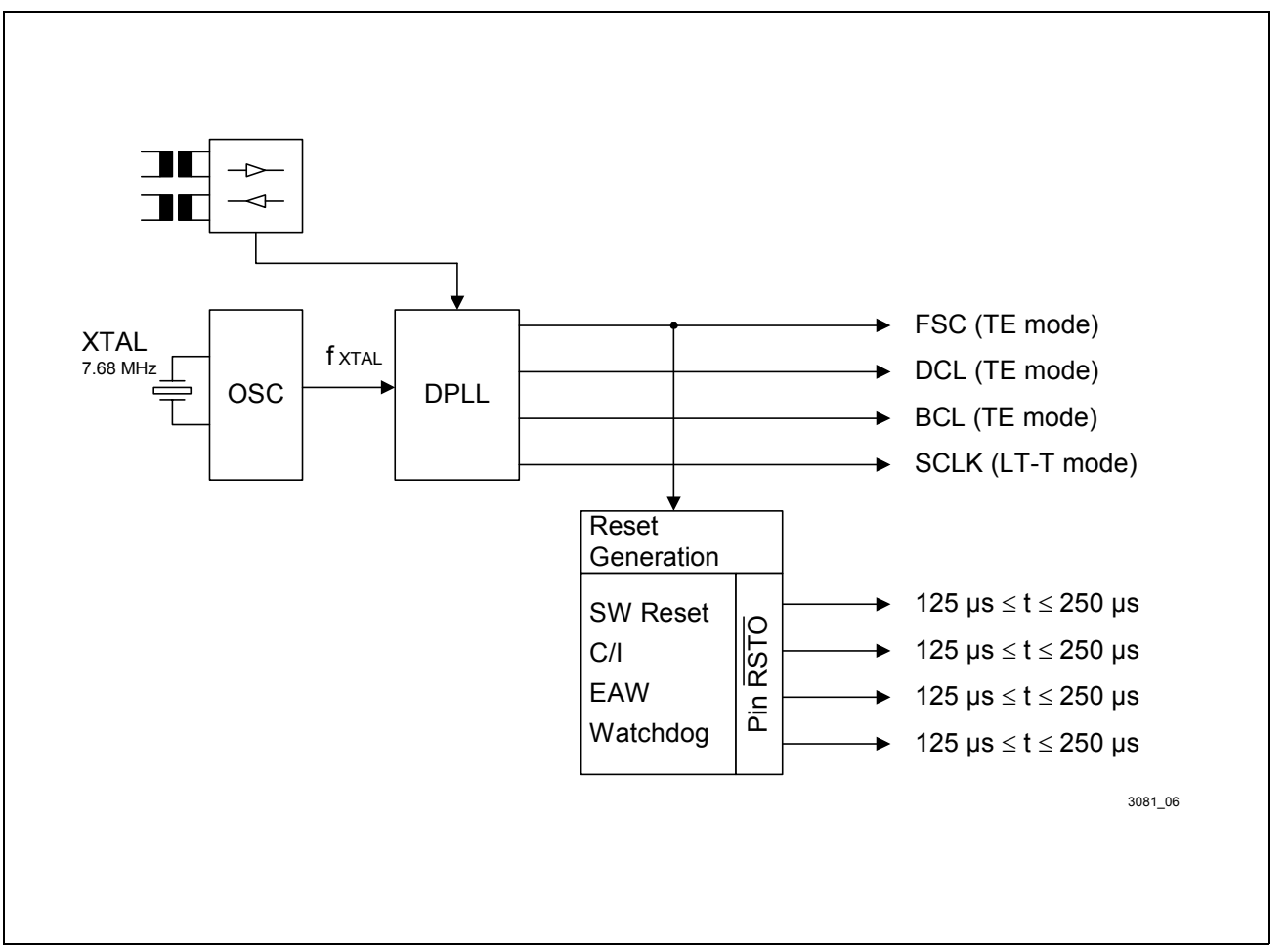


Figure 29 Clock System of the SBCX-X

Table 8 Clock Modes

	TE	LT-T	LT-S	NT	Int. NT
Selected via	pin: MODE0=0	pin:MODE1=0 MODE0=1	pin:MODE1=1 MODE0=1	bit:MODE2=0 MODE1=1 MODE0=0	bit:MODE2=1 MODE1=1 MODE0=1 or MODE0=0 *1)
FSC	o:8 kHz	i:8 kHz	i:8 kHz	i:8 kHz	i:8 kHz
DCL	o:1536 kHz	i:1536 kHz (from SCLK) or 4096 kHz (from ext. PLL)	i:512 kHz or 1536 kHz or 4096 kHz	i:512 kHz or 1536 kHz or 4096 kHz	i:1536 kHz
BCL/SCLK	o:768 kHz (BCL)	o:1536 kHz (SCLK) *3)	o:256 kHz or 768 kHz or 2048 kHz (derived from DCL/2)	o:256 kHz or 768 kHz or 2048 kHz (derived from DCL/2)	o:768 kHz (derived from DCL/2)
DU *4)	i	i	o	o	o
DD	o	o	i	i	i
AUX0-2	general purpose I/O pins	CH0-2: strap pins for IOM channel select *2)	CH0-2: strap pins for IOM channel select *2)	CH0-2: strap pins for IOM channel select *2)	general purpose I/O pins

Note: ***The IOM-2 interface is adaptive. This means in LT-S/NT and LT-T mode other frequencies for BCL and DCL are possible in the range of 512-4096 kHz (DCL) and 256-2048 kHz (BCL). For details please refer to the application note "Reconfigurable PBX".***

Note: *i = input; o = output;*
For all input clocks typical values are given although other clock frequencies may be used, too.
1) The modes TE, LT-T and LT-S can directly be selected by strapping the pins MODE1 and MODE0. The mode can be reprogrammed in TR_MODE.MODE2-0 where NT and intelligent NT can be selected additionally. In int. NT mode MODE0 selects between NT state machine (0) and LT-S state machine (1).
2) The number of IOM channels depends on the DCL clock, e.g. with DCL=1536 kHz 3 IOM channels and with DCL=4096 kHz 8 channels are available.
3) In LT-T mode the 1536 kHz output clock on SCLK is synchronous to the S interface and can be used as input for the DCL clock.
4) The direction input/output refers to the direction of the B- and D-channel data stream across the S-transceiver. Due to the capabilites of the IOM-2 handler the direction of some other timeslots may be different if this is programmed by the host (e.g. for data exchange between different devices connected to IOM-2).

3.4.1 Description of the Receive PLL (DPLL)

The receive PLL performs phase tracking between the F/L transition of the receive signal and the recovered clock. Phase adjustment is done by adding or subtracting 0.5 or 1 XTAL period to or from a 1.536-MHz clock cycle. The 1.536-MHz clock is than used to generate any other clock synchronized to the line.

During (re)synchronization an internal reset condition may effect the 1.536-MHz clock to have high or low times as short as 130 ns. After the S/T interface frame has achieved the synchronized state (after three consecutive valid pairs of code violations) the FSC output in TE mode is set to a specific phase relationship, thus causing once an irregular FSC timing.

The phase relationships of the clocks are shown in **Figure 30.**

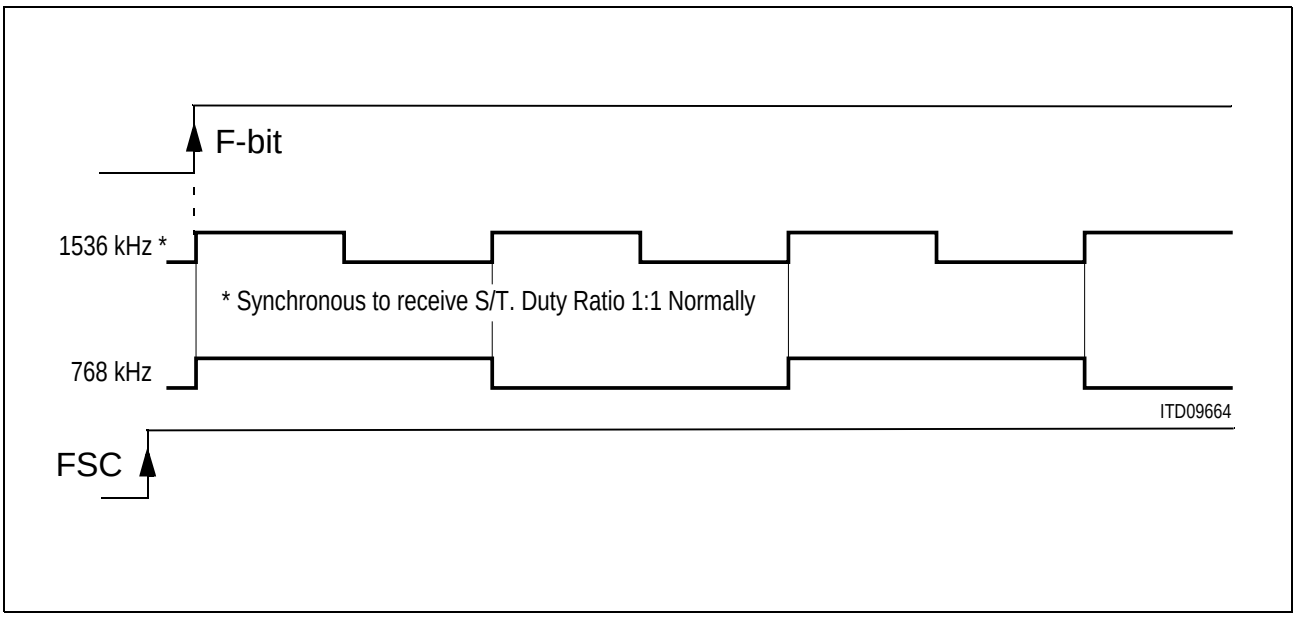


Figure 30 Phase Relationships of SBCX-X Clock Signals

3.4.2 Jitter

The timing extraction jitter of the SBCX-X conforms to ITU-T Recommendation I.430 (– 7% to + 7% of the S-interface bit period).

3.4.3 Oscillator Clock Output C768

The SBCX-X derives its system clocks from an external clock connected to XTAL1 (while XTAL2 is not connected) or from a 7.68 MHz crystal connected across XTAL1 and XTAL2.

At pin C768 a buffered 7.68 MHz output clock is provided to drive further devices, which is suitable in multiline applications for example (see **Figure 31**). This clock is not synchronized to the S-interface.

In power down mode the C768 output is disabled (low signal).

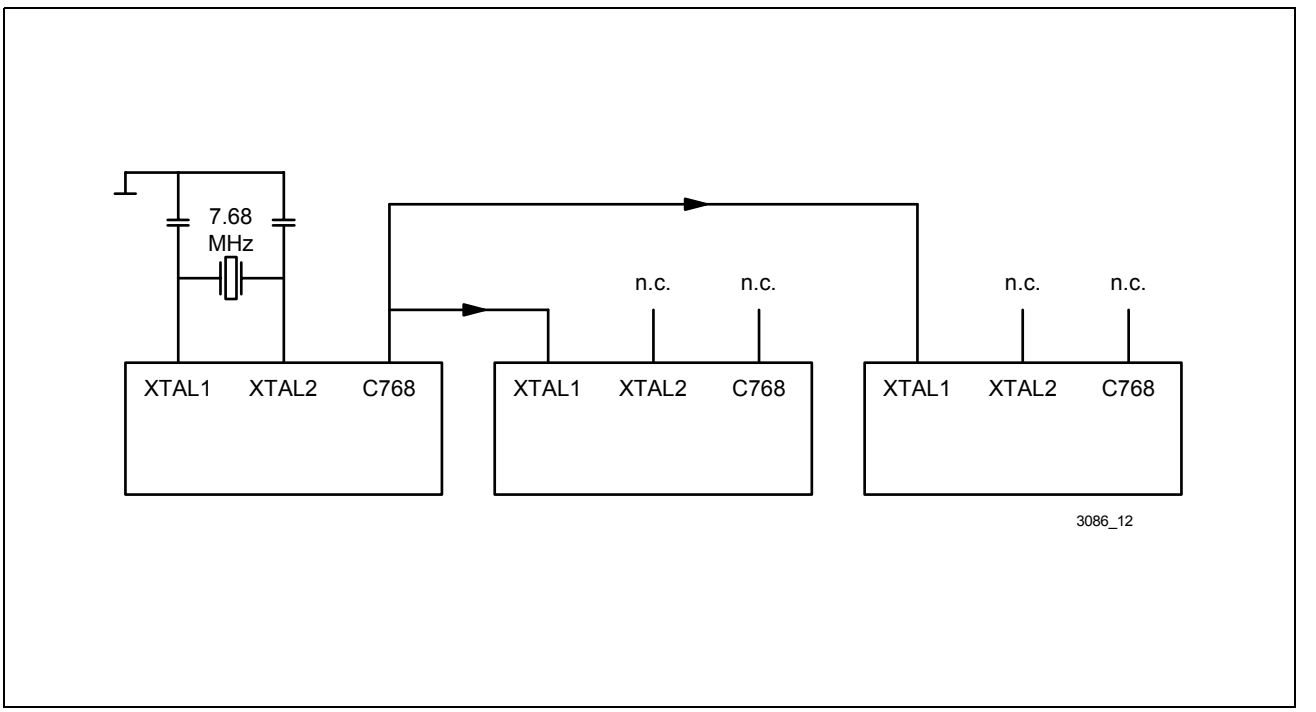


Figure 31 Buffered Oscillator Clock Output

3.5 Control of Layer-1

The layer-1 activation / deactivation can be controlled by an internal state machine via the IOM-2 C/I0 channel or by software via the microcontroller interface directly. In the default state the internal layer-1 state machine of the SBCX-X is used.

By setting the L1SW bit in the TR_CONF0 register the internal state machine can be disabled and the layer-1 commands, which are normally generated by the internal state machine are written directly in the TR_CMD register or indications read from the TR_STA register respectively.The SBCX-X layer-1 control flow is shown in **Figure 32**.

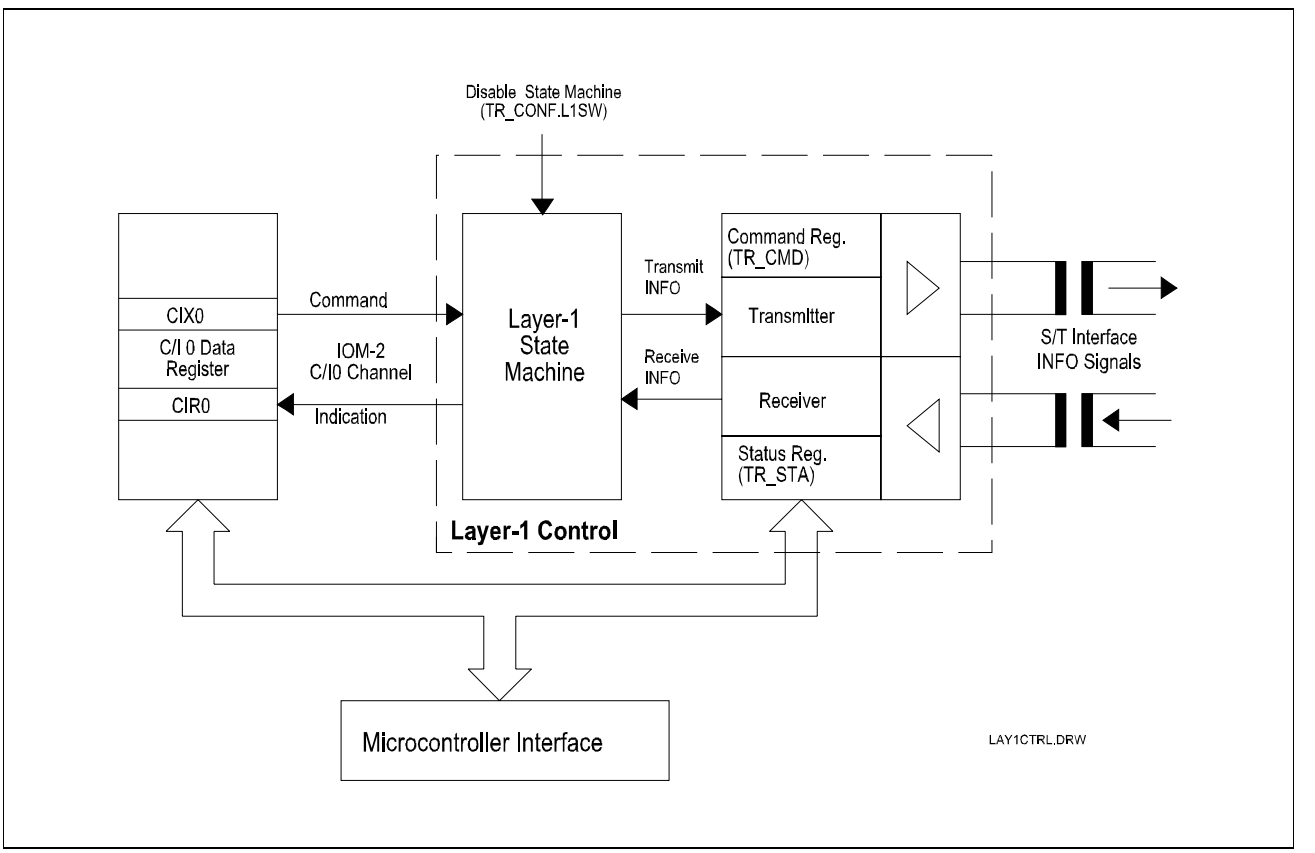


Figure 32 Layer-1 Control

In the following sections the layer-1 control by the SBCX-X state machine will be described. For the description of the IOM-2 C/I0 channel see also **Chapter 3.7.4**.

The layer-1 functions are controlled by commands issued via the CIX0 register. These commands, sent over the IOM-2 C/I channel 0 to layer-1, trigger certain procedures, such as activation/deactivation, switching of test loops and transmission of special pulse patterns. These procedures are governed by layer-1 state diagrams. Responses from layer 1 are obtained by reading the CIR0 register after a CIC interrupt (ISTA).

The state diagrams of the SBCX-X are shown in **Figure 34** and **Figure 35**. The activation/deactivation implemented by the SBCX-X agrees with the requirements set forth in ITU recommendations. State identifiers F1-F8 are in accordance with ITU I.430.

State machines are the key to understanding the transceiver part of the SBCX-X. They include all information relevant to the user and enable him to understand and predict the behaviour of the SBCX-X. The state diagram notation is given in **Figure 33**. The informations contained in the state diagrams are:

– state name (based on ITU I.430)
– S/T signal received (INFO)
– S/T signal transmitted (INFO)
– C/I code received
– C/I code transmitted
– transition criteria

The coding of the C/I commands and indications are described in detail in **Chapter 3.5.4**.

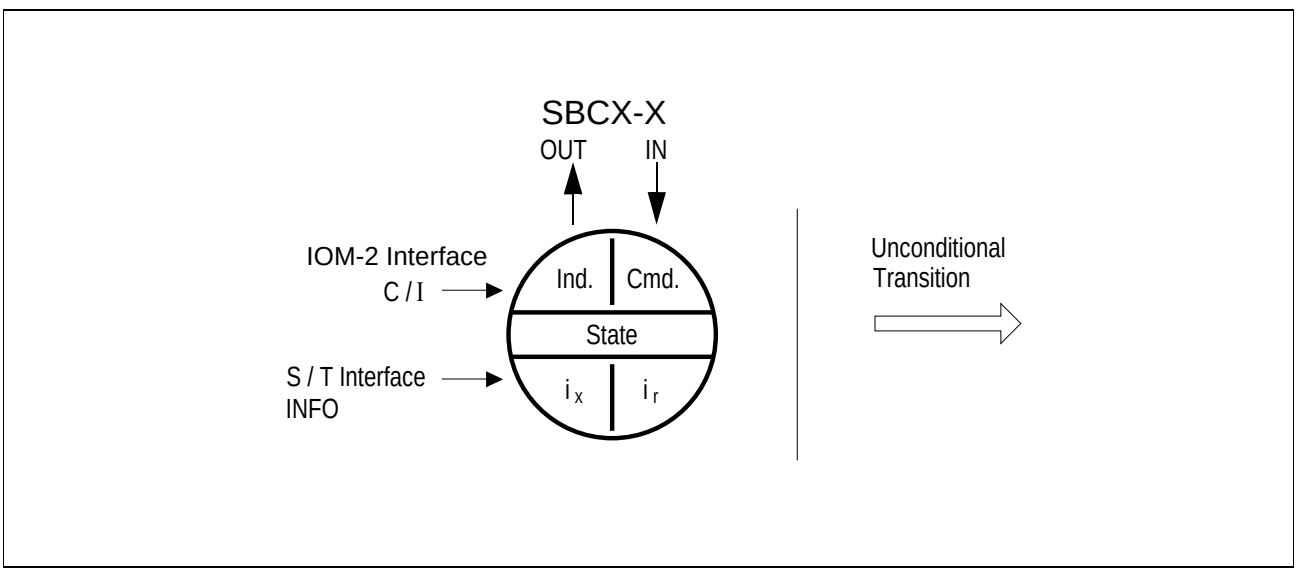


Figure 33 State Diagram Notation

The following example illustrates the use of a state diagram with an extract of the TE state diagram. The state explained is “F3 deactivated”.

The state may be entered:

– from the unconditional states (ARL, RES, TM)
– from state “F3 pending deactivation”, “F3 power up”, “F4 pending activation” or “F5 unsynchronized” after the C/I command “DI” has been received.

The following informations are transmitted:

– INFO 0 (no signal) is sent on the S/T-interface.
– C/I message “DC” is issued on the IOM-2 interface.

The state may be left by either of the following methods:

– Leave for the state “F3 power up” in case C/I = “TIM” code is received.
– Leave for state “F4 pending activation” in case C/I = AR8 or AR10 is received.
– Leave for the state “F6 synchronized” after INFO 2 has been recognized on the S/T-interface.
– Leave for the state “F7 activated” after INFO 4 has been recognized on the S/T-interface.
– Leave for any unconditional state if any unconditional C/I command is received.

As can be seen from the transition criteria, combinations of multiple conditions are possible as well. A “∗” stands for a logical AND combination. And a “+” indicates a logical OR combination.

The sections following the state diagram contain detailed information on all states and signals used.

3.5.1 State Machine TE and LT-T Mode

3.5.1.1 State Transition Diagram (TE, LT-T)

Figure 34 shows the state transition diagram of the SBCX-X state machine. **Figure 35** shows this for the unconditional transitions (Reset, Loop, Test Mode i).

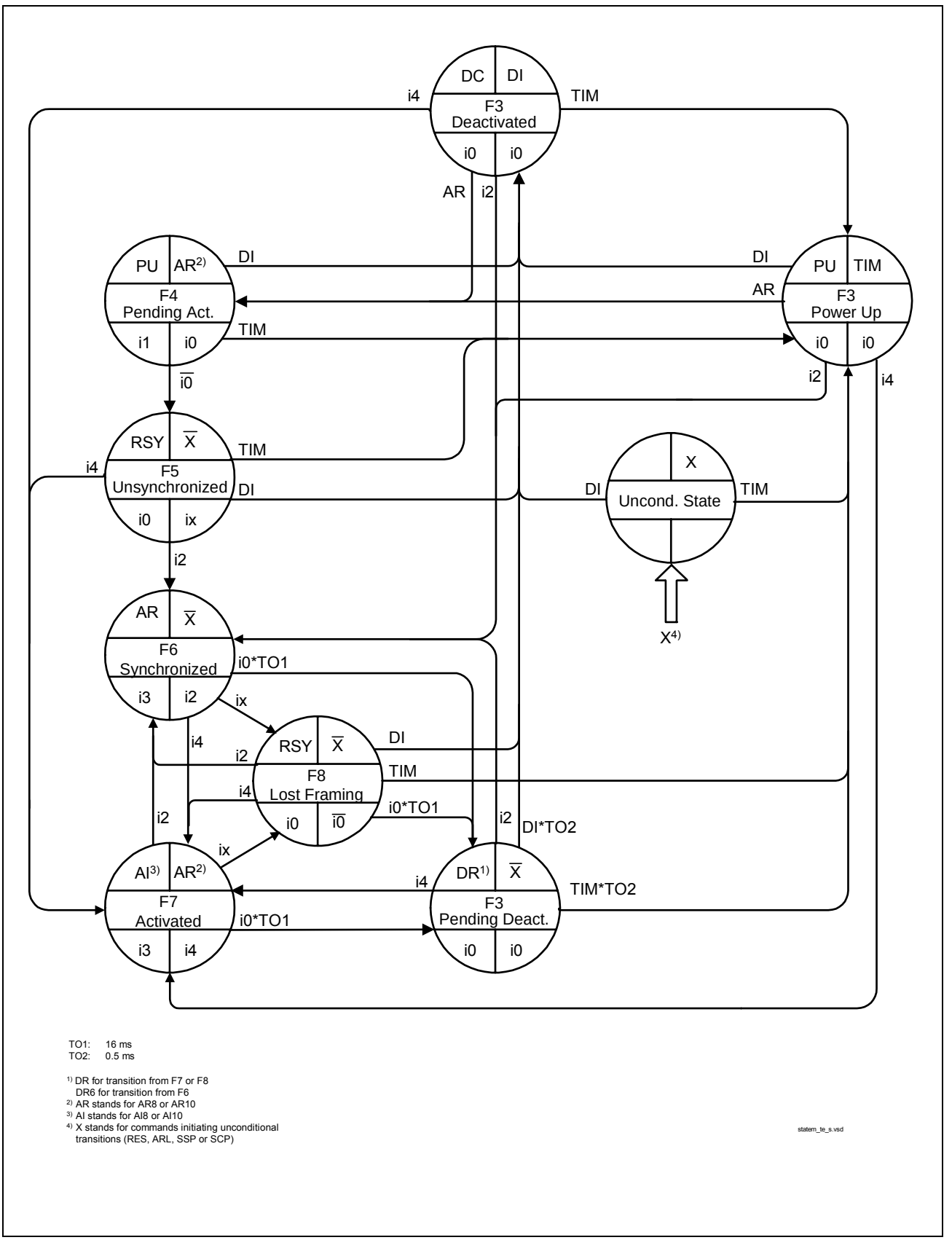


Figure 34 State Transition Diagram (TE, LT-T)

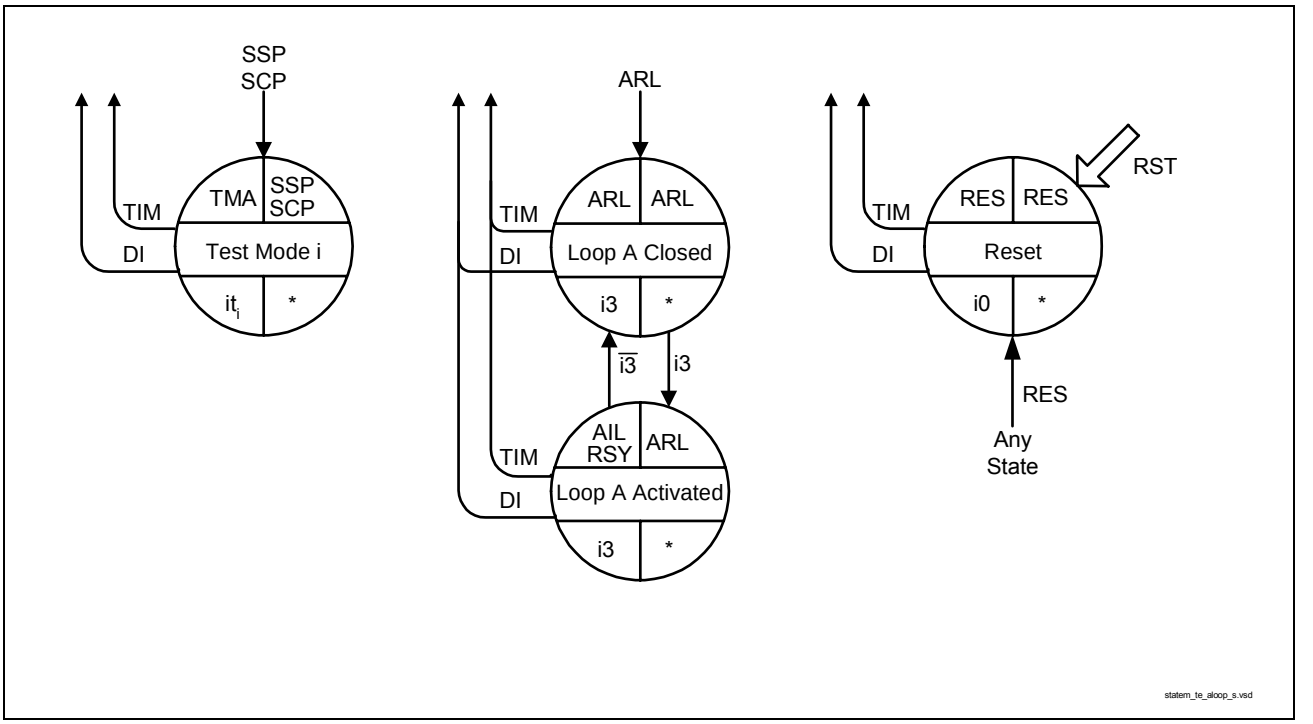


Figure 35 State Transition Diagram of Unconditional Transitions (TE, LT-T)

3.5.1.2 States (TE, LT-T)

F3 Pending Deactivation

State after deactivation from the S/T interface by INFO 0. Note that no activation from the terminal side is possible starting from this state. A ’DI’ command has to be issued to enter the state ’Deactivated State’.

F3 Deactivated State

The S/T interface is deactivated and the clocks are deactivated 500 µs after entering this state and receiving INFO 0 if the CFS bit of the SBCX-X Configuration Register is set to “0“. Activation is possible from the S/T interface and from the IOM-2 interface. The bit TR_CMD.PD is set and the analog part is powered down.

F3 Power Up

The S/T interface is deactivated (INFO 0 on the line) and the clocks are running.

F4 Pending Activation

The SBCX-X transmits INFO 1 towards the network, waiting for INFO 2.

F5 Unsynchronized

Any signal except INFO 2 or 4 detected on the S/T interface.

F6 Synchronized

The receiver has synchronized and detects INFO 2. INFO 3 is transmitted to synchronize the NT.

F7 Activated

The receiver has synchronized and detects INFO 4. All user channels are now conveyed transparently to the IOM-2 interface.
To transfer user channels transparently to the S/T interface either the command AR8 or AR10 has to be issued and TR_STA.FSYN must be “1” (signal from remote side must be synchronous).

F8 Lost Framing

The receiver has lost synchronization in the states F6 or F7 respectively.

Unconditional States

Loop A Closed (internal or external)

The SBCX-X loops back the transmitter to the receiver and activates by transmission of INFO 3. The receiver has not yet synchronized.
For a non transparent internal loop the DIS_TX bit of register TR_CONF2 has to be set to ’1’.

Loop A Activated (internal or external)

The receiver has synchronized to INFO 3. Data may be sent. The indication “AIL” is output to indicate the activated state. If the loop is closed internally and the S/T line awake detector detects any signal on the S/T interface, this is indicated by “RSY”.

Test Mode - SSP

Single alternating pulses are transmitted to the S/T-interface resulting in a frequency of the fundamental mode of 2 kHz.

Test Mode - SCP

Continuous alternating pulses are transmitted to the S/T-interface resulting in a frequency of the fundamental mode of 96 kHz.

3.5.1.3 C/I Codes (TE, LT-T)

Command	Abbr.	Code	Remark
Activation Request with priority class 8	AR8	1000	Activation requested by the SBCX-X, D-channel priority set to 8 (**see note**)
Activation Request with priority class 10	AR10	1001	Activation requested by the SBCX-X, D-channel priority set to 10 (**see note**)
Activation Request Loop	ARL	1010	Activation requested for the internal or external Loop A (**see note**). For a non transparent internal loop bit DIS_TX of register TR_CONF2 has to be set to ’1’ additionally.
Deactivation Indication	DI	1111	Deactivation Indication
Reset	RES	0001	Reset of the layer-1 statemachine
Timing	TIM	0000	Layer-2 device requires clocks to be activated
Test mode SSP	SSP	0010	One AMI-coded pulse transmitted in each frame, resulting in a frequency of the fundamental mode of 2 kHz
Test mode SCP	SCP	0011	AMI-coded pulses transmitted continuously, resulting in a frequency of the fundamental mode of 96 kHz

Note: In the activated states (AI8, AI10 or AIL indication) the 2B+D channels are only transferred transparently to the S/T interface if one of the three “Activation Request” commands is permanently issued.

Indication	Abbr.	Code	Remark
Deactivation Request	DR	0000	Deactivation request via S/T-interface if left from F7/F8
Reset	RES	0001	Reset acknowledge
Test Mode Acknowledge	TMA	0010	Acknowledge for both SSP and SCP
Slip Detected	SLD	0011	
Resynchronization during level detect	RSY	0100	Signal received, receiver not synchronous
Deactivation Request from F6	DR6	0101	Deactivation Request from state F6
Power up	PU	0111	IOM-2 interface clocking is provided
Activation request	AR	1000	INFO 2 received
Activation request loop	ARL	1010	Internal or external loop A closed
Illegal Code Violation	CVR	1011	Illegal code violation received. This function has to be enabled by setting the EN_ICV bit of register TR_CONF0.
Activation indication loop	AIL	1110	Internal or external loop A activated
Activation indication with priority class 8	AI8	1100	INFO 4 received, D-channel priority is 8 or 9.
Activation indication with priority class 10	AI10	1101	INFO 4 received, D-channel priority is 10 or 11.
Deactivation confirmation	DC	1111	Clocks are disabled if CFS bit of register MODE1 is set to ’1’, quiescent state

3.5.1.4 Infos on S/T (TE, LT-T)

Receive Infos on S/T (Downstream)

Name	Abbr.	Description
INFO 0	i0	No signal on S/T
INFO 2	i2	4 kHz frame A=’0’
INFO 4	i4	4 kHz frame A=’1’
INFO X	ix	Any signal except INFO 2 or INFO 4

Transmit Infos on S/T (Upstream)

Name	Abbr.	Description
INFO 0	i0	No signal on S/T
INFO 1	i1	Continuous bit sequence of the form ’00111111’
INFO 3	i3	4 kHz frame
Test INFO 1	it_1	SSP - Send Single Pulses
Test INFO 2	it_2	SCP - Send Continuous Pulses

3.5.2 State Machine LT-S Mode

3.5.2.1 State Transition Diagram (LT-S)

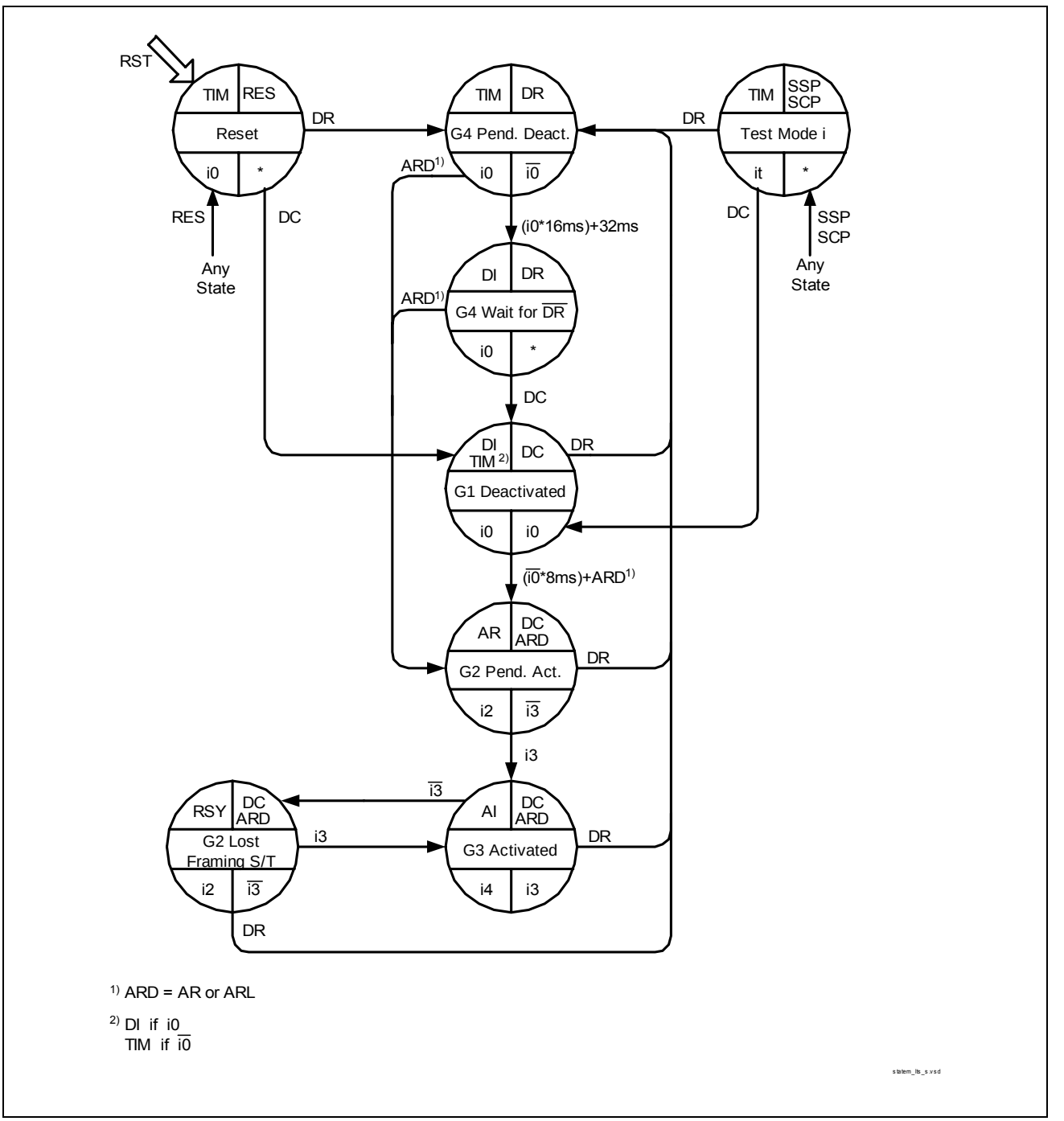


Figure 36 State Transition Diagram (LT-S)

Note: State 'Test Mode' can be entered from any state except from state 'Test Mode' itself , i.e. C/I-code 'SSP/SCP' must not be followed by C/I-code 'SCP/SSP' directly.

3.5.2.2 States (LT-S)

G1 Deactivated

The transceiver is not transmitting. There is no signal detected on the S/T interface, and no activation command is received in the C/I channel. The clocks are deactivated if MODE1.CFS is set to 1. Activation is possible from the S/T interface and from the IOM-2 interface.

G2 Pending Activation

As a result of an $\overline{\text{INFO 0}}$ detected on the S/T line or an ARD command, the transceiver begins transmitting INFO 2 and waits for reception of INFO 3. The timer to supervise reception of INFO 3 is to be implemented in software. In case of an ARL command, loop 2 is closed.

G3 Activated

Normal state where INFO 4 is transmitted to the S/T-interface. The transceiver remains in this state as long as neither a deactivation nor a test mode is requested, nor the receiver looses synchronism.

When receiver synchronism is lost, INFO 2 is sent automatically. After reception of INFO 3, the transmitter keeps on sending INFO 4.

G2 Lost Framing

This state is reached when the transceiver has lost synchronism in the state G3 activated.

G4 Pending Deactivation

This state is triggered by a deactivation request DR. It is an unstable state: indication DI (state “G4 Wait for DR.”) is issued by the transceiver when:

either INFO 0 is received for a duration of 16 ms,

or an internal timer of 32 ms expires.

G4 Wait for $\overline{\text{DR}}$

Final state after a deactivation request. The transceiver remains in this state until DC is issued.

Unconditional States

Test mode - SSP

Single alternating pulses are sent on the S/T-interface.

Test mode - SCP

Continuous alternating pulses are sent on the S/T-interface.

3.5.2.3 C/I Codes (LT-S)

Command	Abbr.	Code	Remark
Deactivation Request	DR	0000	DR - Deactivation Request. Initiates a complete deactivation from the exchange side by transmitting INFO 0.
Reset	RES	0001	Reset of state machine. Transmission of INFO 0. No reaction to incoming infos. RES is an unconditional command.
Send Single Pulses	SSP	0010	Send Single Pulses.
Send Continuous Pulses	SCP	0011	Send Continuous Pulses.
Activation Request	AR	1000	Activation Request. This command is used to start an exchange initiated activation.
Activation Request Loop	ARL	1010	Activation request loop. The transceiver is requested to operate an analog loop-back close to the S/T-interface.
Deactivation Confirmation	DC	1111	Deactivation Confirmation. Transfers the transceiver into a deactivated state in which it can be activated from a terminal (detection of $\overline{\text{INFO 0}}$ enabled).

Indication	Abbr.	Code	Remark
Timing	TIM	0000	Interim indication during activation procedure in G1.
Receiver not Synchronous	RSY	0100	Receiver is not synchronous
Activation Request	AR	1000	$\overline{\text{INFO 0}}$ received from terminal. Activation proceeds.
Illegal Code Violation	CVR	1011	Illegal code violation received. This function has to be enabled in TR_CONF0.EN_ICV.

Indication	Abbr.	Code	Remark
Activation Indication	AI	1100	Synchronous receiver, i.e. activation completed.
Deactivation Indication	DI	1111	Timer (32 ms) expired or INFO 0 received for a duration of 16 ms after deactivation request

3.5.2.4 Infos on S/T (LT-S)

Receive Infos on S/T (Downstream)

I0 INFO 0 detected

$\overline{I0}$ Level detected (signal different to I0)

I3 INFO 3 detected

$\overline{I3}$ Any INFO other than INFO 3

Transmit Infos on S/T (Upstream)

I0 INFO 0

I2 INFO 2

I4 INFO 4

It Send Single Pulses (SSP).
Send Continuous Pulses (SCP).

3.5.3 State Machine NT Mode

3.5.3.1 State Transition Diagram (NT)

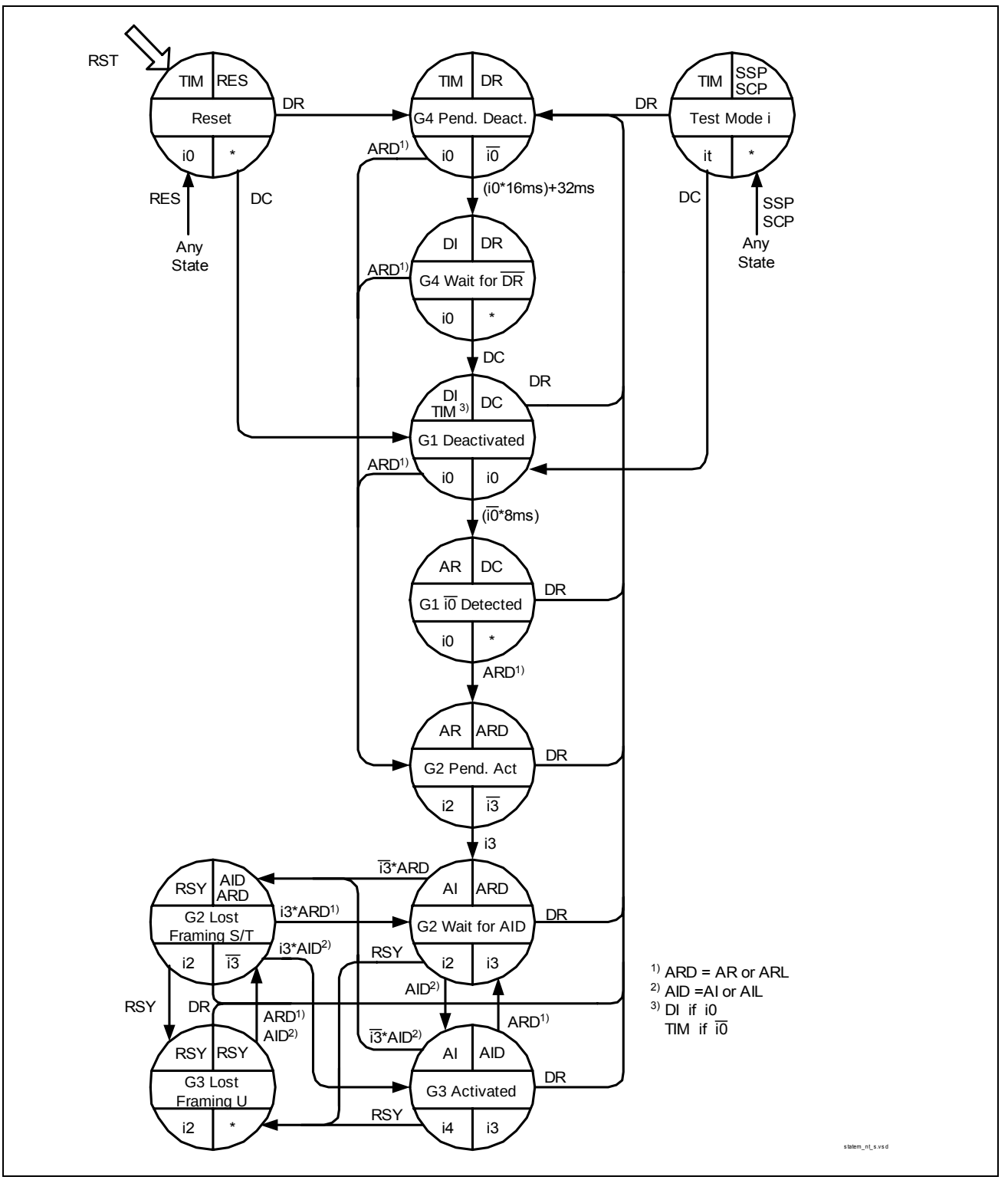


Figure 37 State Transition Diagram (NT)

Note: State 'Test Mode' can be entered from any state except from state 'Test Mode' itself , i.e. C/I-code 'SSP/SCP' must not be followed by C/I-code 'SCP/SSP' directly.

3.5.3.2 States (NT)

G1 Deactivated

The transceiver is not transmitting. There is no signal detected on the S/T-interface, and no activation command is received in the C/I channel. The clocks are deactivated if the bit MODE1.CFS is set to 1. Activation is possible from the S/T interface and from the IOM-2 interface.

G1 $\overline{\text{I0}}$ Detected

An $\overline{\text{INFO 0}}$ is detected on the S/T-interface, translated to an "Activation Request" indication in the C/I channel. The transceiver is waiting for an AR command, which normally indicates that the transmission line upstream (usually a two-wire U interface) is synchronized.

G2 Pending Activation

As a result of the ARD command, an INFO 2 is sent on the S/T-interface. INFO 3 is not yet received. In case of ARL command, loop 2 is closed.

G2 wait for AID

INFO 3 was received, INFO 2 continues to be transmitted while the transceiver waits for a "switch-through" command AID from the device upstream.

G3 Activated

INFO 4 is sent on the S/T-interface as a result of the "switch through" command AID: the B and D-channels are transparent. On the command AIL, loop 2 is closed.

G2 Lost Framing S/T

This state is reached when the transceiver has lost synchronism in the state G3 activated.

G3 Lost Framing U

On receiving an RSY command which usually indicates that synchronization has been lost on the two-wire U interface, the transceiver transmits INFO 2.

G4 Pending Deactivation

This state is triggered by a deactivation request DR, and is an unstable state. Indication DI (state “G4 wait for DR”) is issued by the transceiver when:

either INFO 0 is received for a duration of 16 ms

or an internal timer of 32 ms expires.

G4 wait for $\overline{\text{DR}}$

Final state after a deactivation request. The transceiver remains in this state until DC is issued.

Unconditional States

Test Mode SSP

Send Single Pulses

Test Mode SCP

Send Continuous Pulses

3.5.3.3 C/I Codes (NT)

Command	Abbr.	Code	Remark
Deactivation Request	DR	0000	DR - Deactivation Request. Initiates a complete deactivation from the exchange side by transmitting INFO 0. Unconditional command.
Reset	RES	0001	Reset of state machine. Transmission of INFO 0. No reaction to incoming infos. RES is an unconditional command.
Send Single Pulses	SSP	0010	Send Single Pulses.
Send Continuous Pulses	SCP	0011	Send Continuous Pulses.
Receiver not Synchronous	RSY	0100	Receiver is not synchronous
Activation Request	AR	1000	Activation Request. This command is used to start an exchange initiated activation.
Activation Request Loop	ARL	1010	Activation request loop. The transceiver is requested to operate an analog loop-back close to the S/T-interface.

Command	Abbr.	Code	Remark
Activation Indication	AI	1100	Synchronous receiver, i.e. activation completed.
Activation Indication Loop	AIL	1110	Activation Indication Loop
Deactivation Confirmation	DC	1111	Deactivation Confirmation. Transfers the transceiver into a deactivated state in which it can be activated from a terminal (detection of $\overline{\text{INFO 0}}$ enabled).

Indication	Abbr.	Code	Remark
Timing	TIM	0000	Interim indication during deactivation procedure
Receiver not Synchronous	RSY	0100	Receiver is not synchronous
Activation Request	AR	1000	$\overline{\text{INFO 0}}$ received from terminal. Activation proceeds.
Illegal Code Violation	CVR	1011	Illegal code violation received. This function has to be enabled in TR_CONF0.EN_ICV.
Activation Indication	AI	1100	Synchronous receiver, i.e. activation completed.
Deactivation Indication	DI	1111	Timer (32 ms) expired or INFO 0 received for a duration of 16 ms after deactivation request

3.5.4 Command / Indicate Channel Codes (C/I0) - Overview

The table below presents all defined C/I0 codes. A command needs to be applied continuously until the desired action has been initiated. Indications are strictly state orientated. Refer to the state diagrams in the previous sections for commands and indications applicable in various states.

Code				TE/LT-T		LT-S		NT	
				Cmd	**Ind**	**Cmd**	**Ind**	**Cmd**	**Ind**
0	0	0	0	TIM	DR	DR	TIM	DR	TIM
0	0	0	1	RES	RES	RES	–	RES	–
0	0	1	0	SSP	TMA	SSP	–	SSP	–
0	0	1	1	SCP	SLD	SCP	–	SCP	–
0	1	0	0	–	RSY	–	RSY	RSY	RSY
0	1	0	1	–	DR6	–	–	–	–
0	1	1	0	–	–	–	–	–	–
0	1	1	1	–	PU	–	–	–	–
1	0	0	0	AR8	AR	AR	AR	AR	AR
1	0	0	1	AR10	–	–	–	–	–
1	0	1	0	ARL	ARL	ARL	–	ARL	–
1	0	1	1	–	CVR	–	CVR	–	CVR
1	1	0	0	–	AI8	–	AI	AI	AI
1	1	0	1	–	AI10	–	–	–	–
1	1	1	0	–	AIL	–	–	AIL	–
1	1	1	1	DI	DC	DC	DI	DC	DI

3.6 Control Procedures

3.6.1 Example of Activation/Deactivation

An example of an activation/deactivation of the S/T interface initiated by the terminal with the time relationships mentioned in the previous chapters is shown in **Figure 38**.

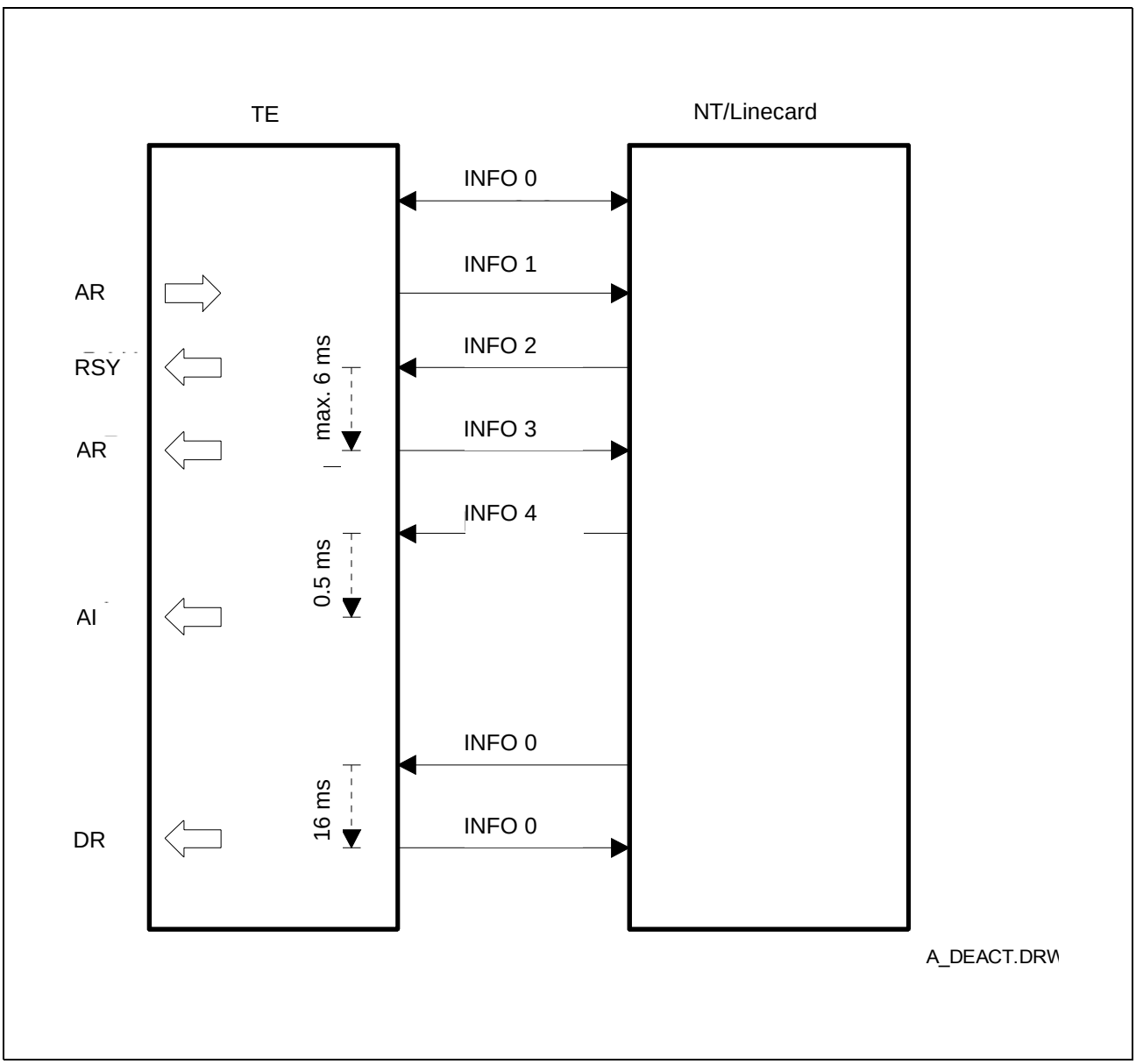


Figure 38 Example of Activation/Deactivation Initiated by the Terminal

3.6.2 Activation initiated by the Terminal

INFO 1 has to be transmitted as long as INFO 0 is received.
INFO 0 has to be transmitted thereafter as long as no valid INFO (INFO 2 or INFO 4) is received.
After reception of INFO 2 or INFO 4 transmission of INFO 3 has to be started.
Data can be transmitted if INFO 4 has been received.

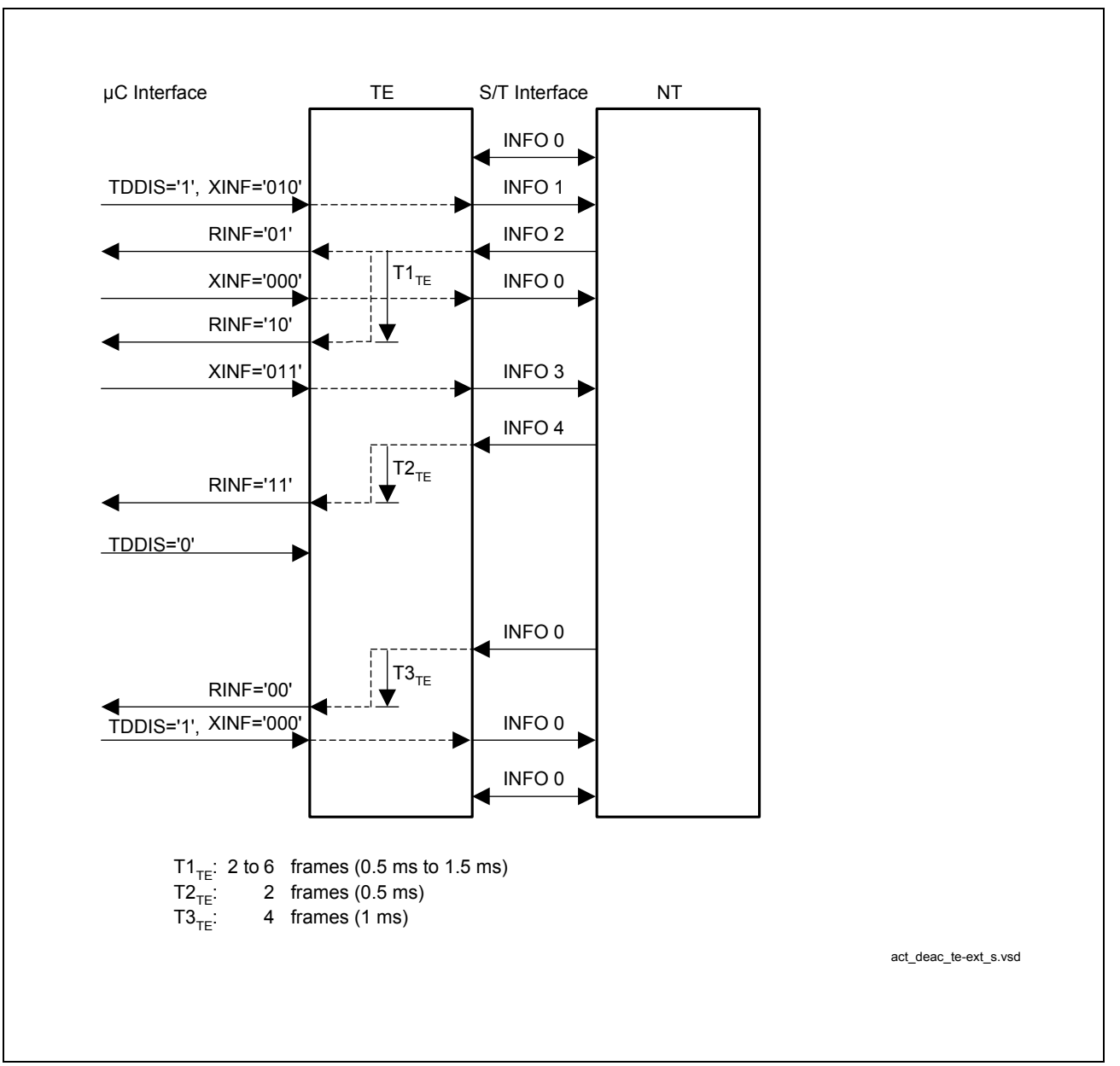


Figure 39 Example of Activation/Deactivation initiated by the Terminal (TE). Activation/Deactivation completely under Software Control

Note: RINF and XINF are Receive- and Transmit-INFOs of the registers TR_STA TR_CMD.

3.6.3 Activation initiated by the Network Termination NT

INFO 0 has to be transmitted as long as no valid INFO (INFO 2 or INFO 4) is received. After reception of INFO 2 or INFO 4 transmission of INFO 3 has to be started. Data can be transmitted if INFO 4 has been received.

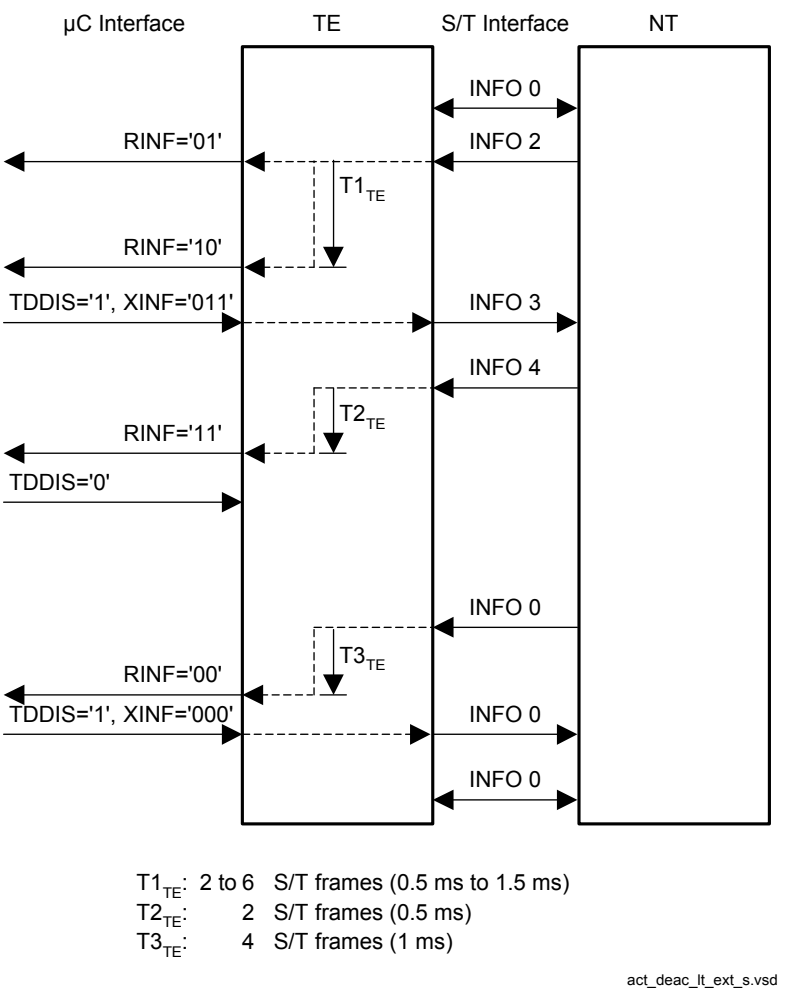


Figure 40 Example of Activation/Deactivation initiated by the Network Termination (NT). Activation/Deactivation completely under Software Control

Note: RINF and XINF are Receive- and Transmit-INFOs of the registers TR_STA TR_CMD.

3.7 IOM-2 Interface

The SBCX-X supports the IOM-2 interface in linecard mode and in terminal mode with single clock and double clock. The IOM-2 interface consists of four lines: FSC, DCL, DD and DU. The rising edge of FSC indicates the start of an IOM-2 frame. The DCL and the BCL clock signals synchronize the data transfer on both data lines DU and DD. The DCL is twice the bit rate, the BCL rate is equal to the bit rate. The bits are shifted out with the rising edge of the first DCL clock cycle and sampled at the falling edge of the second clock cycle.

The IOM-2 interface can be enabled/disabled with the DIS_IOM bit in the IOM_CR register.

TE Mode

A DCL signal and BCL signal (pin BCL/SCLK) output is provided and the FSC signal is generated by the receive DPLL which synchronizes it to the received S/T frame.

The BCL clock together with the two serial data strobe signals (SDS1, SDS2) can be used to connect time slot oriented standard devices to the IOM-2 interface. If the transceiver is disabled (TR_CON.DIS_TR) the DCL and FSC pins become input. In this case the clock mode bit (IOM_CR.CLKM) selects between a double clock and a single clock input for DCL.

The clock rate/frequency of the IOM-2 signals in TE mode are:
DD, DU: 768 kbit/s
FSC (o): 8 kHz
DCL (o): 1536 kHz (double clock rate)
BCL (o): 768 kHz (single clock rate)
Option - Transceiver disabled (DIS_TR = ’1’):
FSC (i): 8 kHz
DCL (i): 1536 ... 4096 kHz, in steps of 512 kHz (double clock rate)

LT-S, LT-T, NT, iNT Mode

The IOM-2 clock signals FSC and BCL are input.
In LT-T mode a 1536 kHz output clock synchronous to S is provided at pin SCLK which can directly be connected to the DCL input.

DD, DU: data rate = DCL/2 kbit/s (LT-T mode)
FSC (i): 8 kHz
DCL (i): 512 ... 4096 kHz, in steps of 512 kHz (double clock rate)
SCLK (o): 1536 kHz (LT-T mode), BCL derived via DCL/2 (LT-S/NT mode)

Note: In all modes the direction of the data lines DU and DD is not fix but depending on the timeslot which can be seen in the figures below.

IOM-2 Frame Structure (TE Mode)

The frame structure on the IOM-2 data ports (DU, DD) of a master device in IOM-2 terminal mode is shown in **Figure 41.**

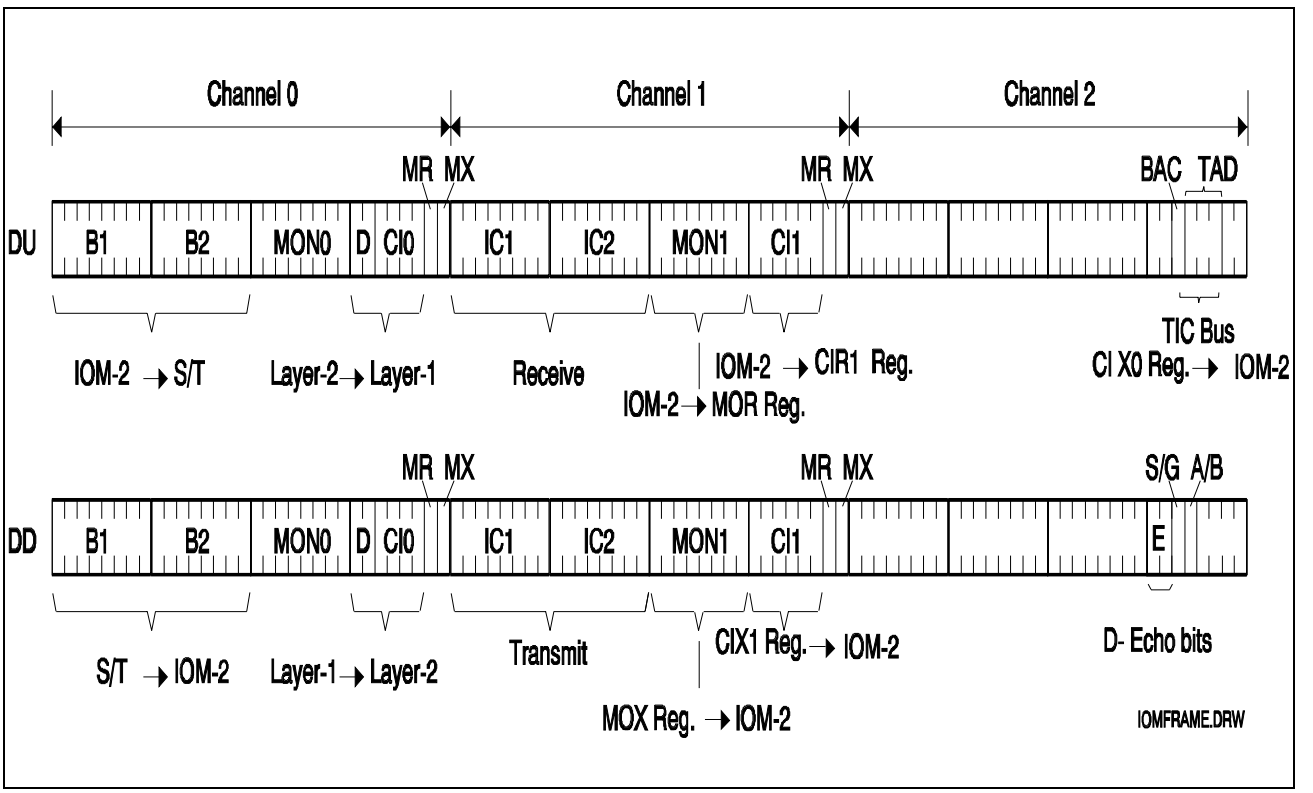


Figure 41 IOM®-2 Frame Structure in Terminal Mode

The frame is composed of three channels

- Channel 0 contains 144-kbit/s of user and signaling data (2B + D), a MONITOR programming channel (MON0) and a command/indication channel (CI0) for control and programming of the layer-1 transceiver.
- Channel 1 contains two 64-kbit/s intercommunication channels (IC) plus a MONITOR and command/indicate channel (MON1, CI1) to program or transfer data to other IOM-2 devices.
- Channel 2 is used for the TIC-bus access. Only the command/indicate bits are specified in this channel.

IOM-2 Frame Structure (LT-S, LT-T Modes)

This mode is used in LT-S and LT-T applications. The frame is a multiplex of up to eight IOM-2 channels (DCL = 4096 kHz, see **Figure 42**), each of which has the structure described above.

The reset value for assignment to one of the eight channels (0 to 7) is done via pin strapping (CH0-2), however the host can reprogram the selected timeslot in DCH_TSDP.TSS.

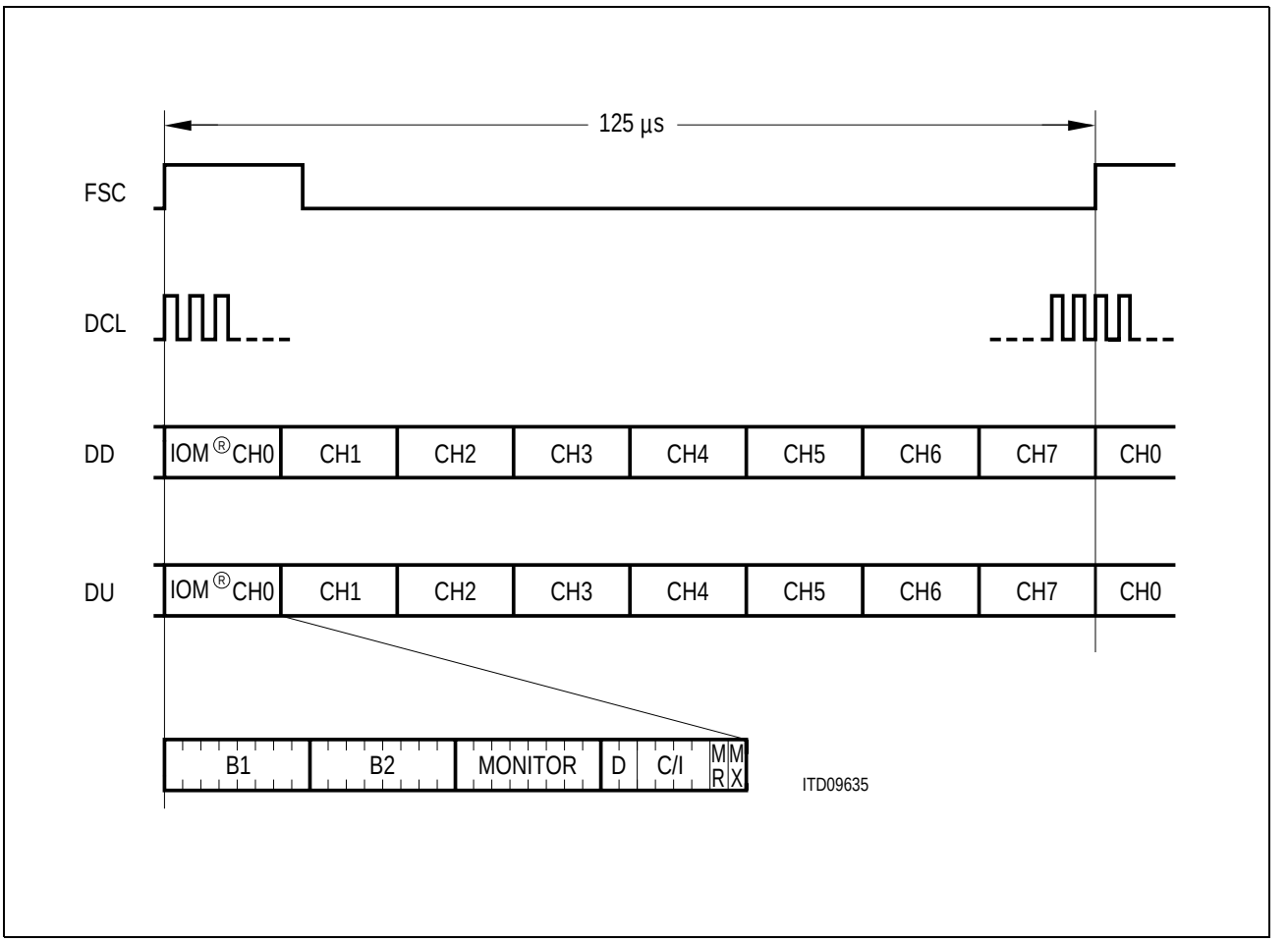


Figure 42 Multiplexed Frame Structure of the IOM-2 Interface in Non-TE Timing Mode

IOM-2 Frame Structure (NT Mode)

In NT mode one IOM-2 channel is used (DCL=512 kHz). The channel structure is the same as described above.

3.7.1 IOM-2 Handler

The IOM-2 handler offers a great flexibility for handling the data transfer between the different functional units of the SBCX-X and voice/data devices connected to the IOM-2 interface. Additionally it provides a microcontroller access to all timeslots of the IOM-2 interface via the four controller data access registers (CDA). **Figure 43** shows the architecture of the IOM-2 handler. For illustrating the functional description it contains all configuration and control registers of the IOM-2 handler. A detailed register description can be found in **Chapter 4.3.**

The PCM data of the functional units

- Transceiver (TR) and the
- Controller data access (CDA)

can be configured by programming the time slot and data port selection registers (TSDP). With the TSS bits (Time Slot Selection) the PCM data of the functional units can be assigned to each of the 32 PCM time slots of the IOM-2 frame. With the DPS bit (Data Port Selection) the output of each functional unit is assigned to DU or DD respectively. The input is assigned vice versa. With the data control registers (xxx_CR) the access to the data of the functional units can be controlled by setting the corresponding control bits (EN, SWAP).

The IOM-2 handler also provides access to the

- MONITOR channel (MON)
- C/I channels (C/I0, C/I1) and
- TIC bus (TIC)

The access to these channels is controlled by the register MON_CR and DCI_CR.
The IOM-2 interface with the two Serial Data Strobes (SDS1,2) is controlled by the control registers IOM_CR, SDS1_CR and SDS2_CR.

The reset configuration of the SBCX-X IOM-2 handler corresponds to the defined frame structure and data ports of a master device in IOM-2 terminal mode (see **Figure 41**).

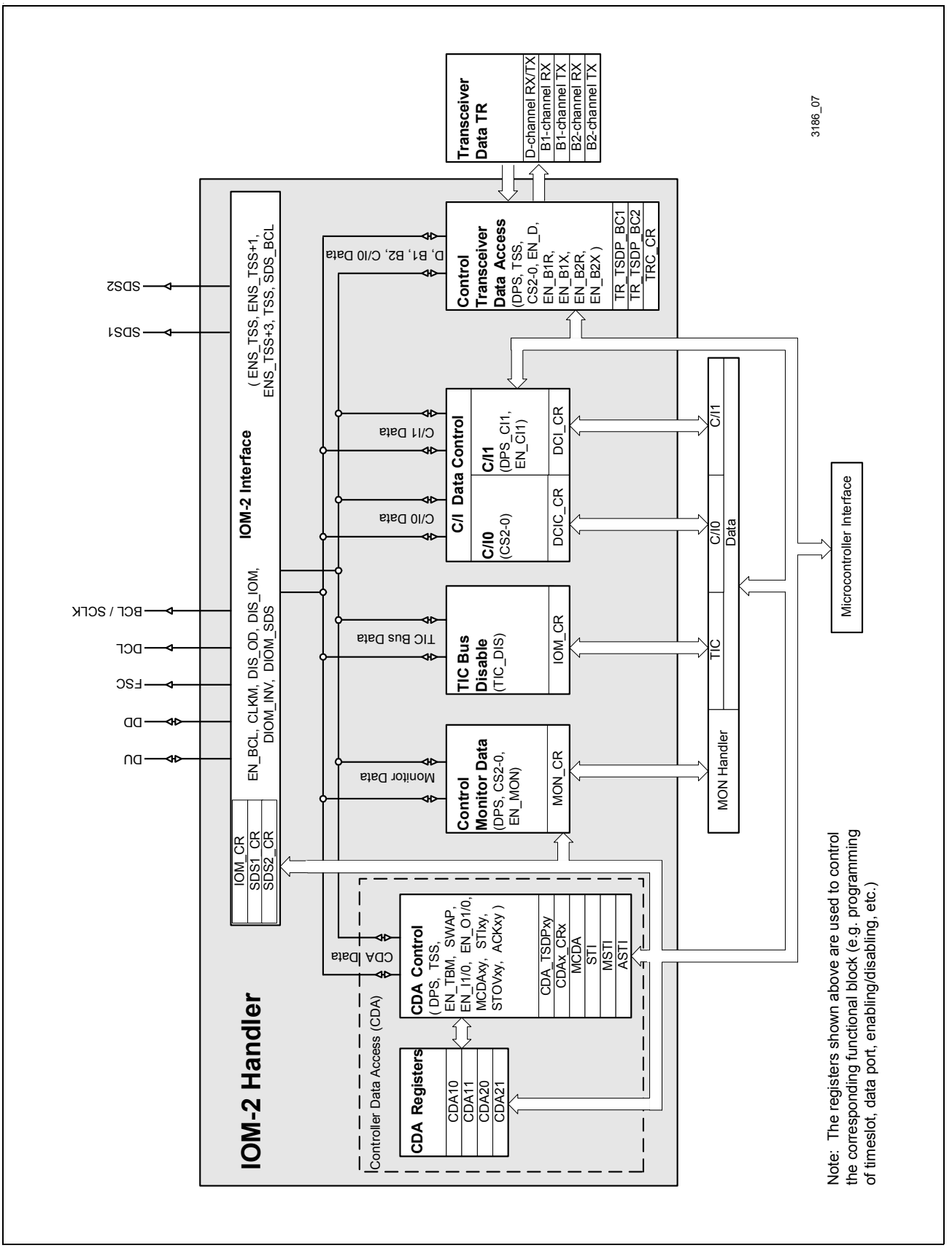


Figure 43 Architecture of the IOM Handler (Example Configuration)

3.7.1.1 Controller Data Access (CDA)

With its four controller data access registers (CDA10, CDA11, CDA20, CDA21) the SBCX-X IOM-2 handler provides a very flexible solution for the host access to up to 32 IOM-2 time slots.

The functional unit CDA (controller data access) allows with its control and configuration registers

- looping of up to four independent PCM channels from DU to DD or vice versa over the four CDA registers
- shifting of two independent PCM channels to another two independent PCM channels on both data ports (DU, DD). Between reading and writing the data can be manipulated (processed with an algorithm) by the microcontroller. If this is not the case a switching function is performed
- monitoring of up to four time slots on the IOM-2 interface simultaneously
- microcontroller read and write access to each PCM timeslot

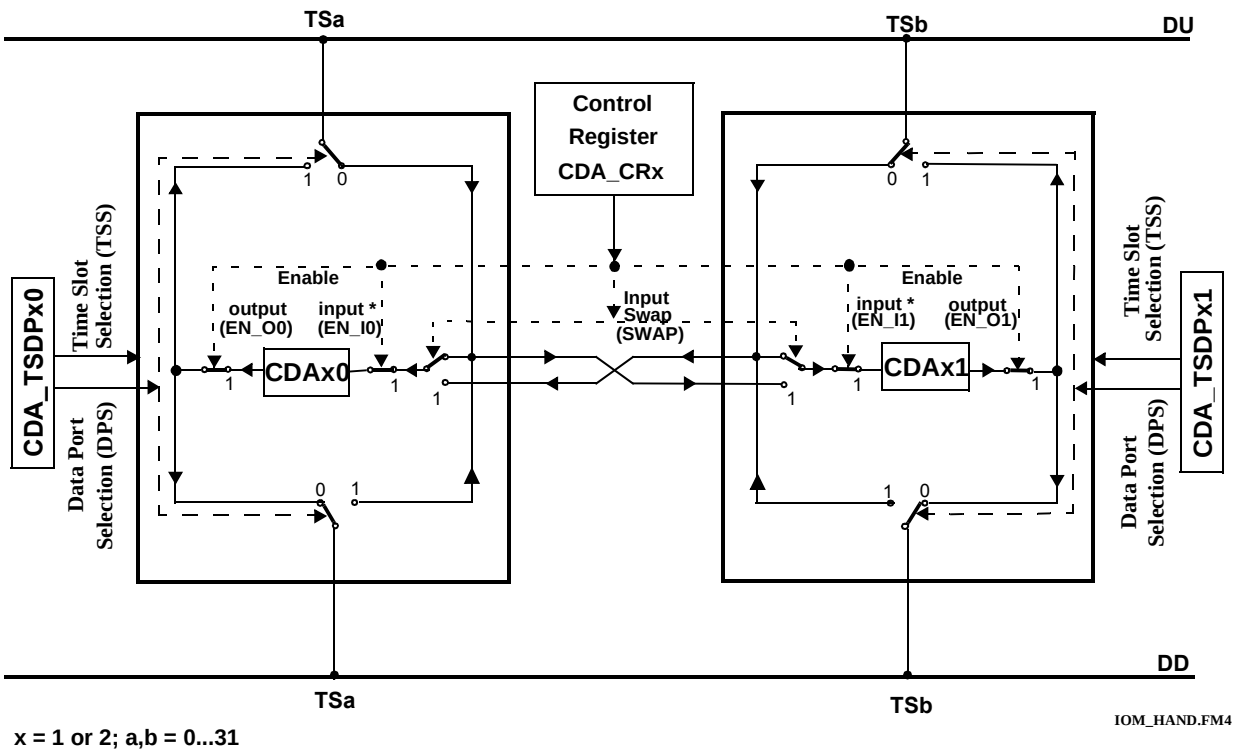
The access principle which is identical for the two channel register pairs CDA10/11 and CDA20/21 is illustrated in **Figure 44**. Each of the index variables x,y used in the following description can be 1 or 2 for x and 0 or 1 for y. The prefix ’CDA_’ from the register names has been omitted for simplification.

To each of the four CDAxy data registers a TSDPxy register is assigned by which the time slot and the data port can be determined. With the TSS (Time Slot Selection) bits a time slot from 0...31 can be selected. With the DPS (Data Port Selection) bit the output of the CDAxy register can be assigned to DU or DD respectively. The time slot and data port for the output of CDAxy is always defined by its own TSDPxy register. The input of CDAxy depends on the SWAP bit in the control registers CRx.

- If the SWAP bit = ’0’ (swap is disabled) the time slot and data port for the input and output of the CDAxy register is defined by its own TSDPxy register.
- If the SWAP bit = ’1’ (swap is enabled) the input port and timeslot of the CDAx0 is defined by the TSDP register of CDAx1 and the input port and timeslot of CDAx1 is defined by the TSDP register of CDAx0. The input definition for timeslot and data port CDAx0 are thus swapped to CDAx1 and for CDAx1 swapped to CDAx0. The output timeslots are not affected by SWAP.

The input and output of every CDAxy register can be enabled or disabled by setting the corresponding EN (-able) bit in the control register CDAx_CR. If the input of a register is disabled the output value in the register is retained.

Usually one input and one output of a functional unit (transceiver, HDLC controller, CDA register) is programmed to a timeslot on IOM-2 (e.g. for B-channel transmission in upstream direction the HDLC controller writes data onto IOM and the transceiver reads data from IOM). For monitoring data in such cases a CDA register is programmed as described below under “Monitoring Data”. Besides that none of the IOM timeslots must be assigned more than one input and output of any functional unit.



*) In the normal mode (SWAP=0) the input of CDAx0 and CDAx1 is enabled via EN_I0 and EN_I1, respectively. If SWAP=1 EN_I0 controls the input of CDAx1 and EN_I1 controls the input of CDAx0. The output control (EN_O0 and EN_O1) is not affected by SWAP.

Figure 44 Data Access via CDAx1 and CDAx2 Register Pairs

Looping and Shifting Data

Figure 45 gives examples for typical configurations with the above explained control and configuration possibilities with the bits TSS, DPS, EN and SWAP in the registers TSDPxy or CDAx_CR:

a) looping IOM-2 time slot data from DU to DD or vice versa (SWAP = 0)

b) shifting data from TSa to TSb and TSc to TSd in both transmission directions (SWAP = 1)

c) switching data from TSa to TSb and looping from DU to DD or TSc to TSd and looping from DD to DU respectively

TSa is programmed in TSDP10, TSb in TSDP11, TSc in TSDP20 and TSd in TSDP21. It should also be noted that the input control of CDA registers is swapped if SWAP=1 while the output control is not affected (e.g. for CDA11 in example a: EN_I1=1 and EN_O1=1, whereas for CDA11 in example b: EN_I0=1 and EN_O1=1).

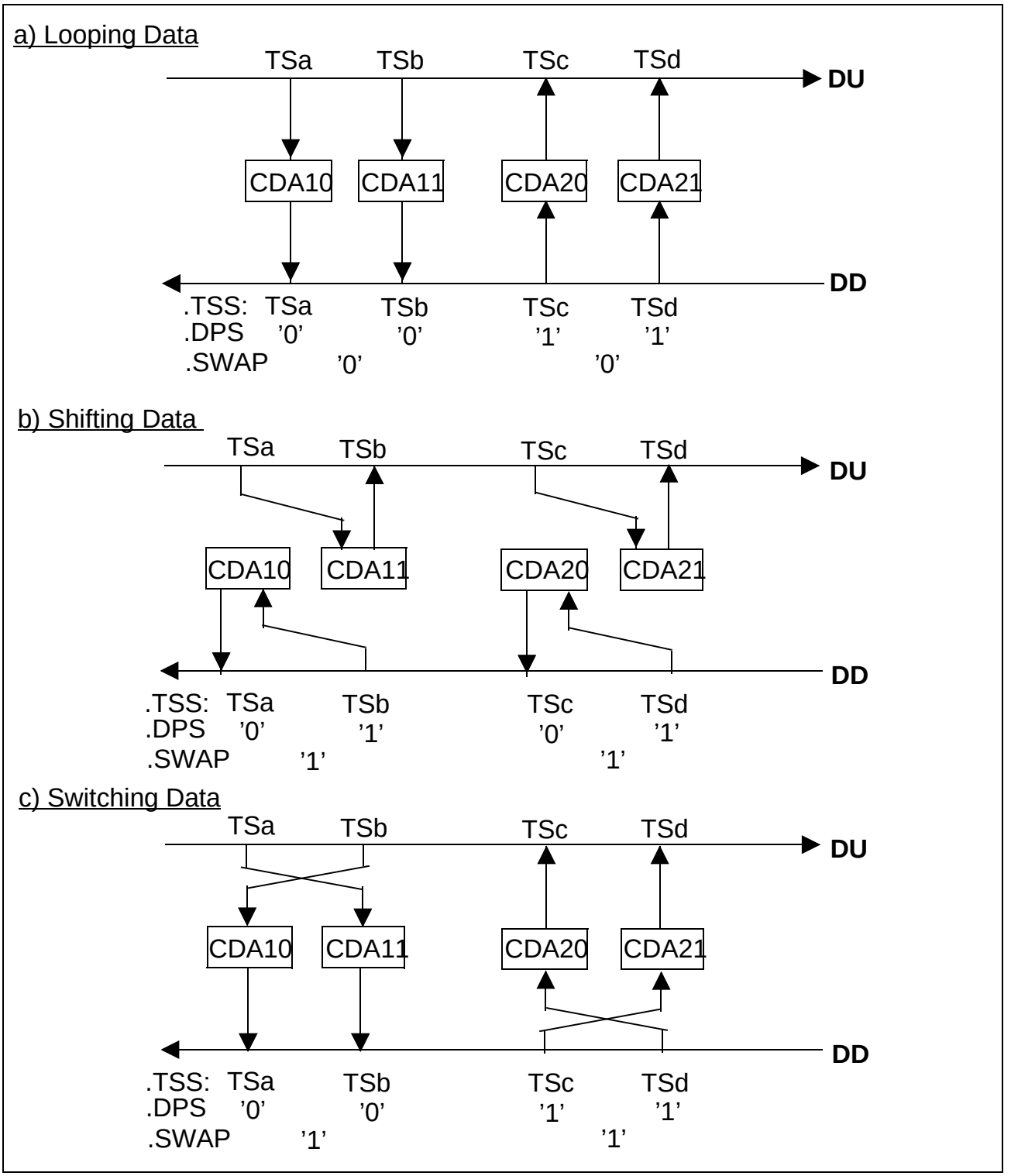


Figure 45 Examples for Data Access via CDAxy Registers

a) Looping Data
b) Shifting (Switching) Data
c) Switching and Looping Data

Figure 46 shows the timing of looping TSa from DU to DD (a = 0...31) via CDAxy register. TSa is read in the CDAxy register from DU and is written one frame later on DD.

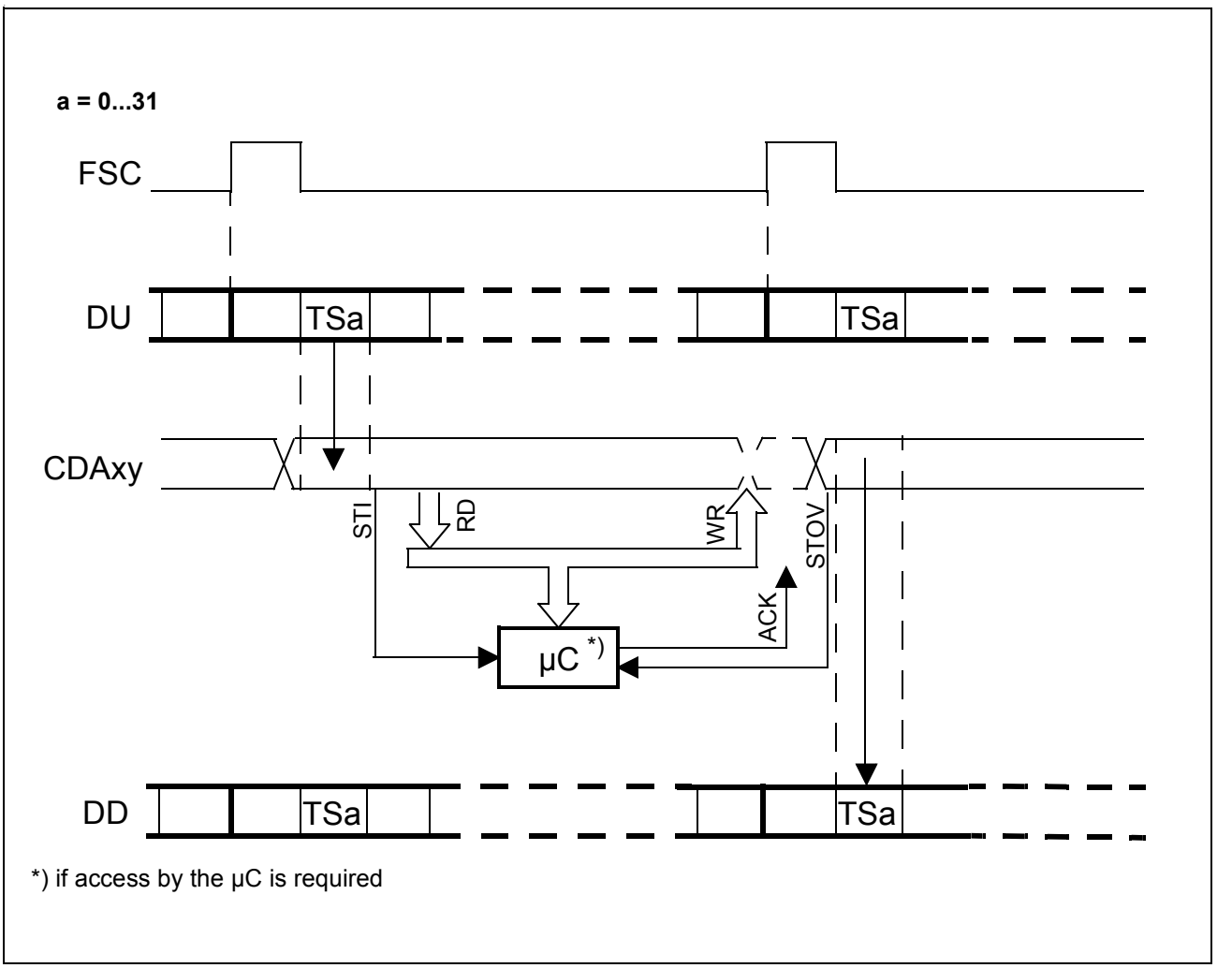


Figure 46 Data Access when Looping TSa from DU to DD

Figure 47 shows the timing of shifting data from TSa to TSb on DU (DD). In **Figure 47a)** shifting is done in one frame because TSa and TSb didn't succeed direct one another (a, b = 0...29 and b ≥ a+2. In **Figure 47b)** shifting is done from one frame to the following frame. This is the case when the time slots succeed one other (b = a+1) or b is smaller than a (b < a).

At looping and shifting the data can be accessed by the controller between the synchronous transfer interrupt (STI) and the status overflow interrupt (STOV). STI and STOV are explained in the section 'Synchronous Transfer'. If there is no controller intervention the looping and shifting is done autonomous.

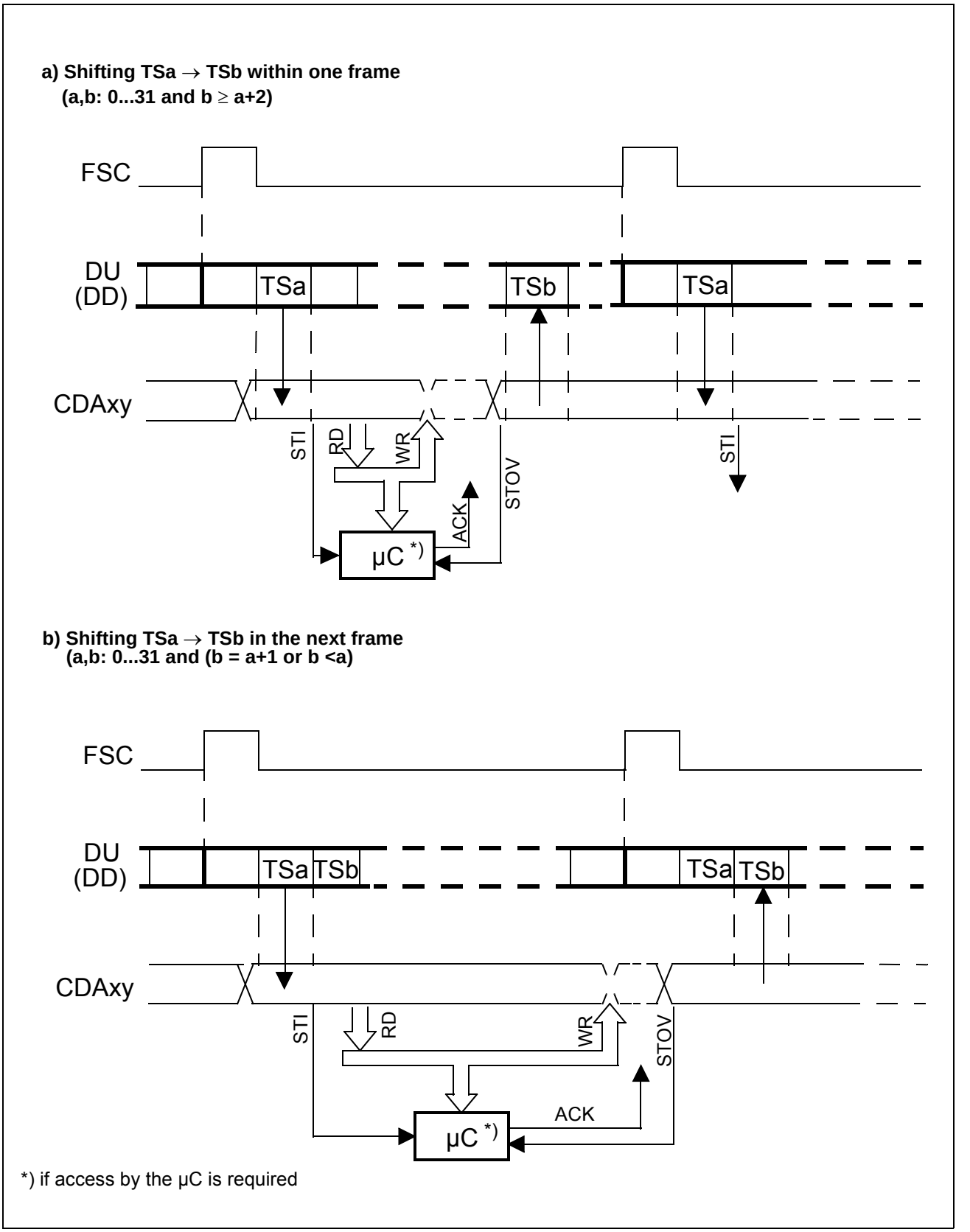


Figure 47 Data Access when Shifting TSa to TSb on DU (DD)

Monitoring Data

Figure 48 gives an example for monitoring of two IOM-2 time slots each on DU or DD simultaneously. For monitoring on DU and/or DD the channel registers with even numbers (CDA10, CDA20) are assigned to time slots with even numbers TS(2n) and the channel registers with odd numbers (CDA11, CDA21) are assigned to time slots with odd numbers TS(2n+1). The user has to take care of this restriction by programming the appropriate time slots.

However, this rule is only valid if two blocks (e.g. transceiver and HDLC controller) are programmed to these timeslots and are communicating via IOM-2. If only one block is programmed to this timeslot, the timeslots for CDAx0 and CDAx1 can programmed completely independently.

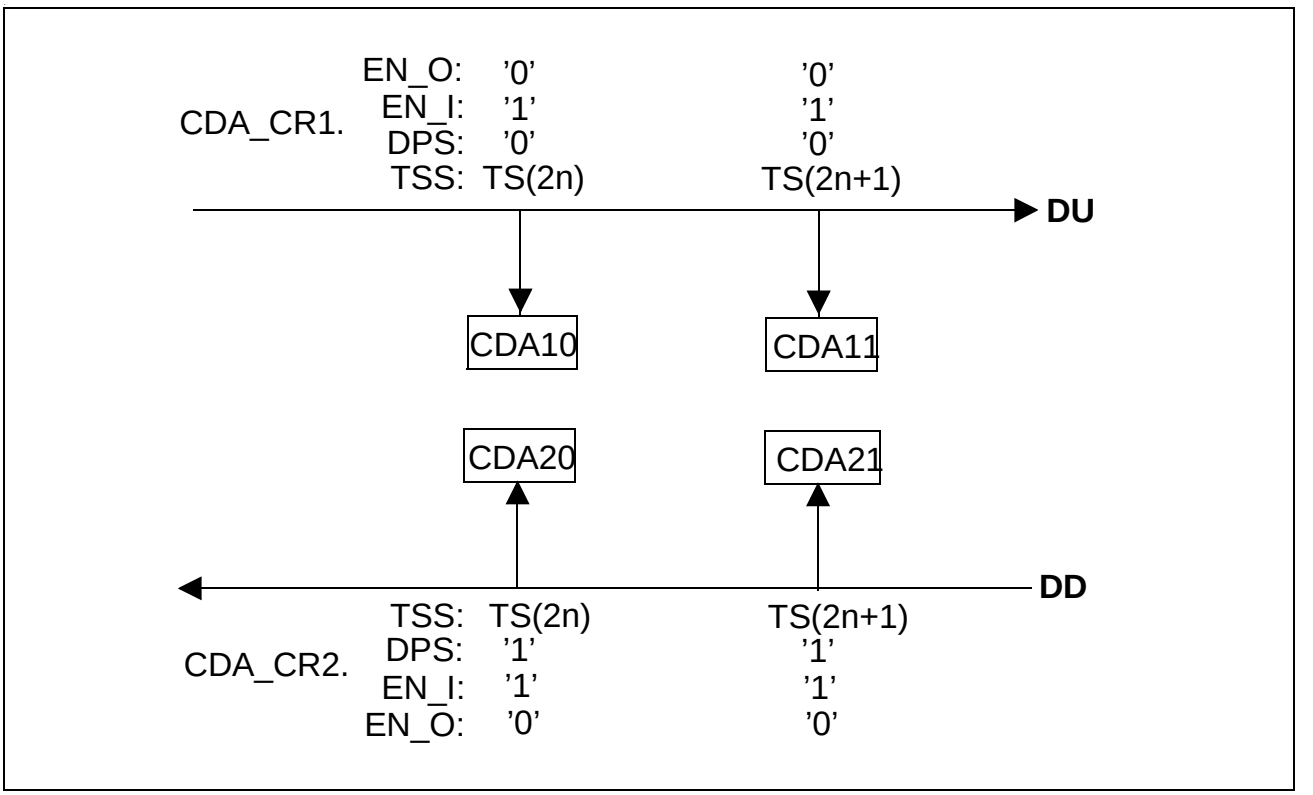


Figure 48 Example for Monitoring Data

Monitoring TIC Bus (TE mode)

Monitoring the TIC bus (TS11) is handled as a special case. The TIC bus can be monitored with the registers CDAx0 by setting the EN_TBM (Enable TIC Bus Monitoring) bit in the control registers CRx. In this special case the TSDPx0 must be set to 08_h for monitoring from DU or 88_h for monitoring from DD respectively. By this it is possible to monitor the TIC bus (TS11) and the odd numbered D-channel (TS3) simultaneously on DU and DD.

Synchronous Transfer

While looping, shifting and switching the data can be accessed by the controller between the synchronous transfer interrupt (STI) and the status overflow interrupt (STOV).

The microcontroller access to the CDAxy registers can be synchronized by means of four programmable synchronous transfer interrupts (STIxy)[1] and synchronous transfer overflow interrupts (STOVxy) [2] in the STI register.

Depending on the DPS bit in the corresponding CDA_TSDPxy register the STIxy is generated two (for DPS='0') or one (for DPS='1') BCL clock after the selected time slot (CDA_TSDPxy.TSS). One BCL clock is equivalent to two DCL clocks.

In the following description the index xy_0 and xy_1 are used to refer to two different interrupt pairs (STI/STOV) out of the four CDA interrupt pairs (STI10/STOV10, STI11/ STOV11, STI20/STOV20, STI21/STOV21).

An $STOVxy_0$ is related to its $STIxy_0$ and is only generated if $STIxy_0$ is enabled and not acknowledged. However, if $STIxy_0$ is masked, the $STOVxy_0$ is generated for any other $STIxy_1$ which is enabled and not acknowledged.

Table 9 gives some examples for that. It is assumed that an STOV interrupt is only generated because an STI interrupt was not acknowledged before.

In example 1 only the $STIxy_0$ is enabled and thus $STIxy_0$ is only generated. If no STI is enabled, no interrupt will be generated even if STOV is enabled (example 2).
In example 3 $STIxy_0$ is enabled and generated and the corresponding $STOVxy_0$ is disabled. $STIxy_1$ is disabled but its $STOVxy_1$ is enabled, and therefore $STOVxy_1$ is generated due to $STIxy_0$. In example 4 additionally the corresponding $STOVxy_0$ is enabled, so $STOVxy_0$ and $STOVxy_1$ are both generated due to $STIxy_0$.
In example 5 additionally the $STIxy_1$ is enabled with the result that $STOVxy_0$ is only generated due to $STIxy_0$ and $STOVxy_1$ is only generated due to $STIxy_1$.

Compared to the previous example $STOVxy_0$ is disabled in example 6, so $STOVxy_0$ is not generated and $STOVxy_1$ is only generated for $STIxy_1$ but not for $STIxy_0$.

Compared to example 5 in example 7 a third $STOVxy_2$ is enabled and thus STOVxy2 is generated additionally for both $STIxy_0$ and $STIxy_1$.

1) In order to enable the STI interrupts the input of the corresponding CDA register has to be enabled. This is also valid if only a synchronous write access is wanted. The enabling of the output alone does not effect an STI interrupt.
2) In order to enable the STOV interrupts the output of the corresponding CDA register has to be enabled. This is also valid if only a synchronous read access is wanted. The enabling of the input alone does not effect an interrupt.

Table 9 Examples for Synchronous Transfer Interrupts

Enabled Interrupts (Register MSTI)		Generated Interrupts (Register STI)		
STI	**STOV**	**STI**	**STOV**	
xy_0	-	xy_0	-	Example 1
-	xy_0	-	-	Example 2
xy_0	xy_1	xy_0	xy_1	Example 3
xy_0	xy_0 ; xy_1	xy_0	xy_0 ; xy_1	Example 4
xy_0 ; xy_1	xy_0 ; xy_1	xy_0 xy_1	xy_0 xy_1	Example 5
xy_0 ; xy_1	xy_1	xy_0 xy_1	- xy_1	Example 6
xy_0 ; xy_1	xy_0 ; xy_1 ; xy_2	xy_0 xy_1	xy_0 ; xy_2 xy_1 ; xy_2	Example 7

An STOV interrupt is not generated if all stimulating STI interrupts are acknowledged.

An STIxy must be acknowledged by setting the ACKxy bit in the ASTI register until two BCL clocks (for DPS='0') or one BCL clocks (for DPS='1') before the time slot which is selected for the appropriate STIxy.

The interrupt structure of the synchronous transfer is shown in **Figure 49**.

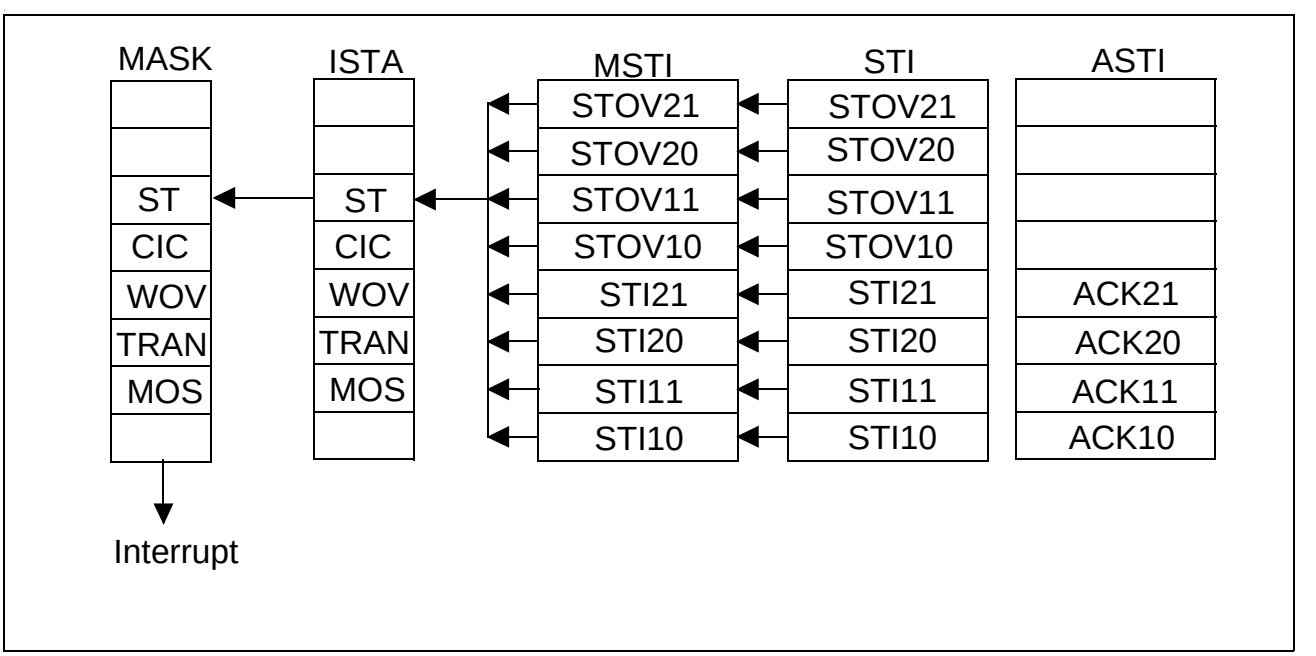


Figure 49 Interrupt Structure of the Synchronous Data Transfer

Figure 50 shows some examples based on the timeslot structure. Figure a) shows at which point in time an STI and STOV interrrupt is generated for a specific timeslot. Figure b) is identical to example 3 above, figure c) corresponds to example 5 and figure d) shows example 4.

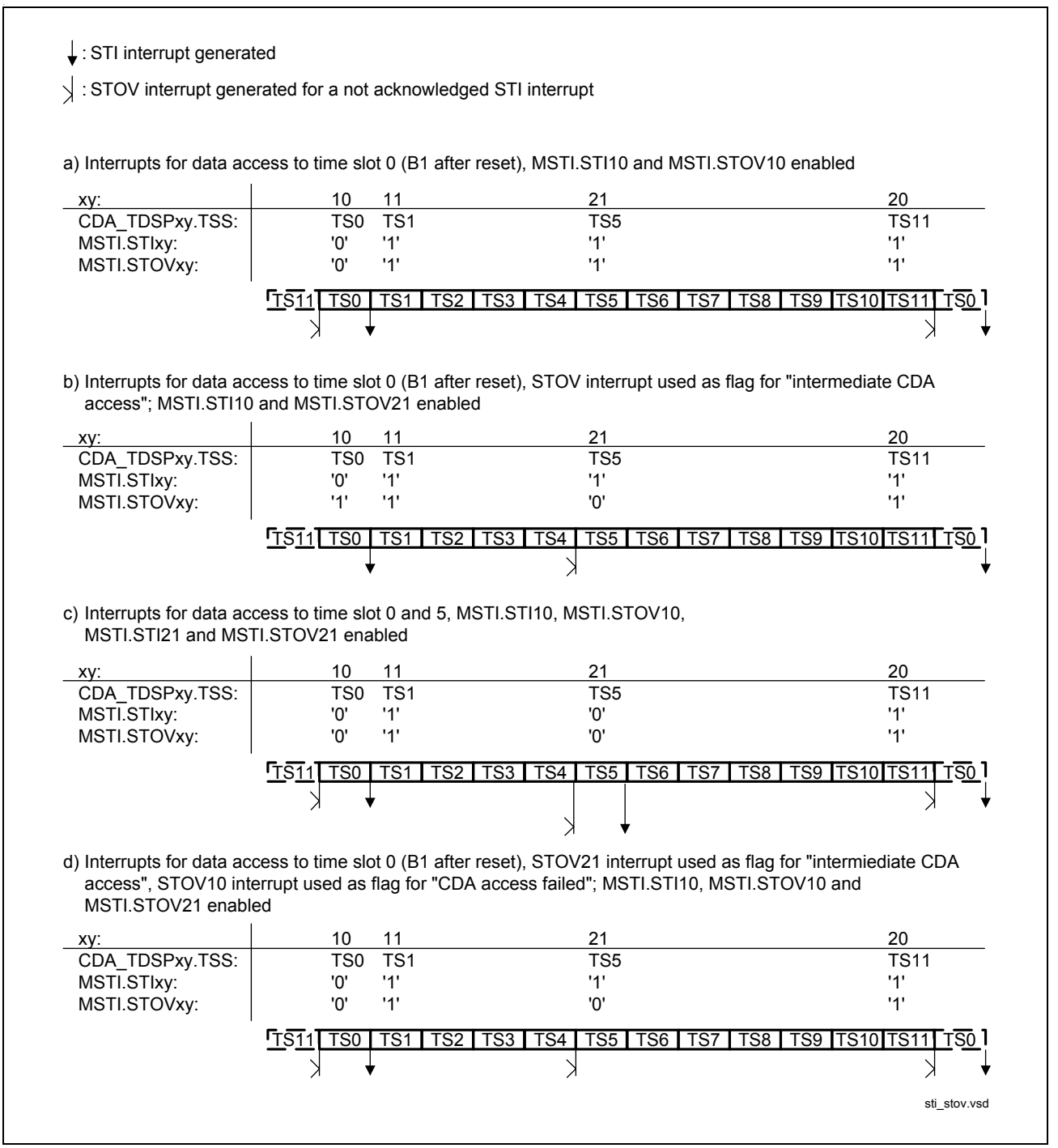


Figure 50 Examples for the Synchronous Transfer Interrupt Control with one Enabled STIxy

Restrictions Concerning Monitoring and Shifting Data

Due to the hardware design, there are some restrictions for the CDA shifting data function and for the CDA monitoring data function. The selection of the CDA registers is restricted if other functional blocks of the SBCX-X (transceiver cores, CI handler, Monitor handler, TIC bus etc.) access the corresponding timeslot.

If no functional block is assigned to a certain timeslot, any CDA register can be used for monitoring or shifting it.

If a timeslot is already occupied by a functional block in a certain transmission direction, only CDA registers with odd numbers (CDA11/21) can be assigned to odd timeslots and CDA registers with even numbers (CDA10/20) can be assigned to even timeslots in the same transmission direction. For the other transmission direction every CDA register can be used. (Example: If TS 5 is already occupied in DD direction, only CDA11 and 21 can be used for monitoring it. For monitoring TS 5 in DU direction, also CDA10 or CDA20 could be used.)

If above guideline is not considered, data can be overwritten in corresponding timeslots. In this context no general rules can be derived in which way the data are overwritten.

The usage of the looping data and switching data functions are unrestricted.

Restrictions Concerning Read/Write Access

If data shall be read out from a certain transmission direction and other data shall be written in the opposite transmission direction in the same timeslot, only special CDA register combinations can be used. The correct behavior can be achieved with the following CDA register combinations:

Table 10 CDA Register Combinations with Correct Read/Write Access

CDA Register Combination	1	2	3	4
Data of the downstream timeslot is read by	CDA10	CDA11	CDA20	CDA21
Data is written to the upstream timeslot from	CDA20	CDA21	CDA10	CDA11

With other register combinations unintended loops or erroneous monitorings can occur or wrong data is written to the IOM interface.

Unexpected Write/Read Behavior of CDA Registers

If inputs and outputs are disabled, the programmed values of CDA10/11/20/21 registers cannot be read back. Instead of the expected value the content of the previous programming can be read out. The programmed value ($5A_H$ in the following example) will be fetched if the output is enabled.

Example:

w CDA1_CR = 00_H (inputs and outputs are disabled)
w CDA10 = $5A_H$ (example)
r CDA10 = FF_H (old value of previous programming)
w CDA1_CR = 02_H (output of CDA10 is enabled)
r CDA10 = $5A_H$ (the programmed value can be read back)

3.7.2 Serial Data Strobe Signal and Strobed Data Clock

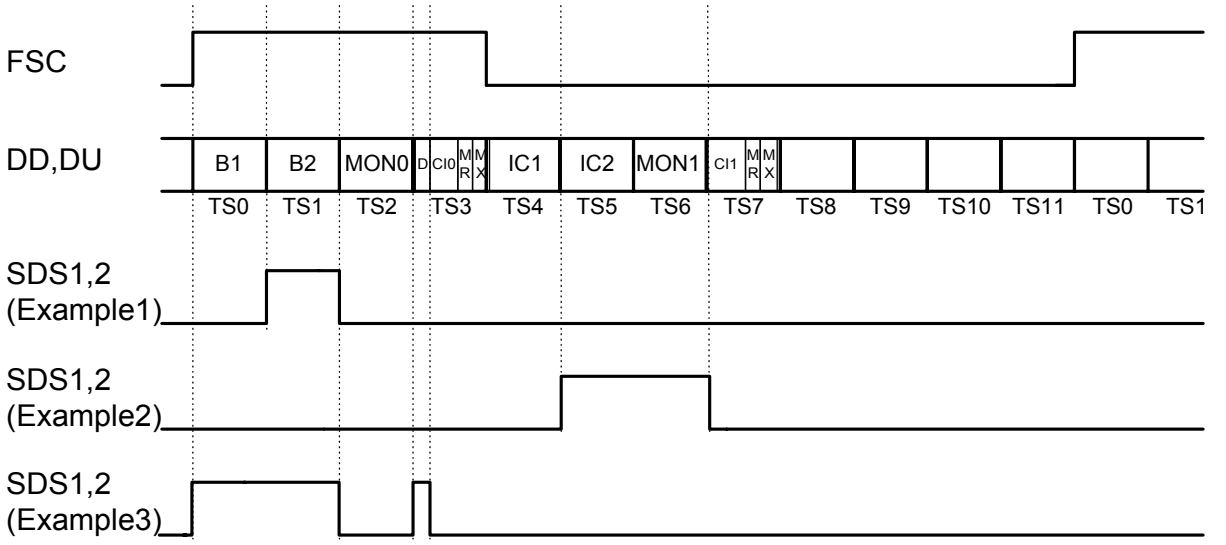
For time slot oriented standard devices connected to the IOM-2 interface the SBCX-X provides two independent data strobe signals SDS1 and SDS2. Instead of a data strobe signal a strobed IOM-2 bit clock can be provided on pin SDS1 and SDS2.

3.7.2.1 Serial Data Strobe Signal

The two strobe signals can be generated with every 8-kHz frame and are controlled by the registers SDS1/2_CR. By programming the TSS bits and three enable bits (ENS_TSS, ENS_TSS+1, ENS_TSS+3) a data strobe can be generated for the IOM-2 time slots TS, TS+1 and TS+3 and any combination of them.

The data strobes for TS and TS+1 are always 8 bits long (bit7 to bit0) whereas the data strobe for TS+3 is always 2 bits long (bit7, bit6).

Figure 51 shows three examples for the generation of a strobe signal. In example 1 the SDS is active during channel B2 on IOM-2 whereas in the second example during IC2 and MON1. The third example shows a strobe signal for 2B+D channels which can be used e.g. for an IDSL (144kbit/s) transmission.



Example 1: TSS = '0_H'
ENS_TSS = '0'
ENS_TSS+1 = '1'
ENS_TSS+3 = '0'

Example 2: TSS = '5_H'
ENS_TSS = '1'
ENS_TSS+1 = '1'
ENS_TSS+3 = '0'

Example 3: TSS = '0_H'
ENS_TSS = '1'
ENS_TSS+1 = '1'
ENS_TSS+3 = '1'

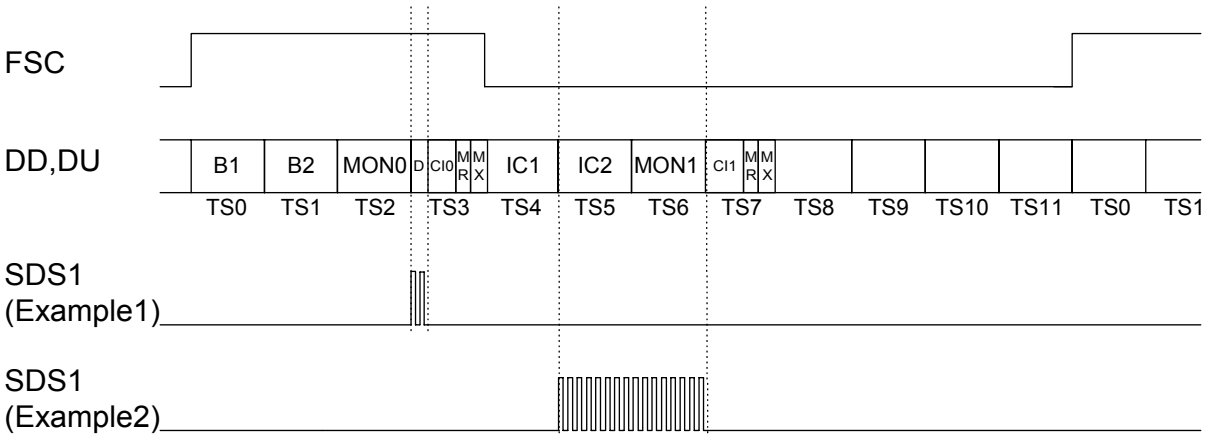
strobe.vsd

For all examples SDS_CONF.SDS1/2_BCL must be set to “0”.

Figure 51 Data Strobe Signal

3.7.2.2 Strobed IOM-2 Bit Clock

The strobed IOM-2 bit clock is active during the programmed window. Outside the programmed window a ’0’ is driven. Two examples are shown in **Figure 52**.



Setting of SDS1_CR:

Example 1:
TSS = '0_H'
ENS_TSS = '0'
ENS_TSS+1 = '0'
ENS_TSS+3 = '1'

Example 2:
TSS = '5_H'
ENS_TSS = '1'
ENS_TSS+1 = '1'
ENS_TSS+3 = '0'

bcl_strobed.vsd

For all examples SDS_CONF.SDS1_BCL must be set to “1”.

Figure 52 Strobed IOM-2 Bit Clock. Register SDS_CONF Programmed to 01_H

The strobed bit clock can be enabled in SDS_CONF.SDS1/2_BCL.

3.7.3 IOM-2 Monitor Channel

The IOM-2 MONITOR channel (see **Figure 53**) is utilized for information exchange in the MONITOR channel between a master mode device and a slave mode device.

The MONTIOR channel data can be controlled by the bits in the MONITOR control register (MON_CR). For the transmission of the MONITOR data one of the IOM-2 channels (3 IOM-2 channels in TE mode, 8 channels in non TE mode) can be selected by setting the MONITOR channel selection bits (MCS) in the MONITOR control register (MON_CR).

The DPS bit in the same register selects between an output on DU or DD respectively and with EN_MON the MONITOR data can be enabled/disabled. The default value is MONITOR channel 0 (MON0) enabled and transmission on DD.

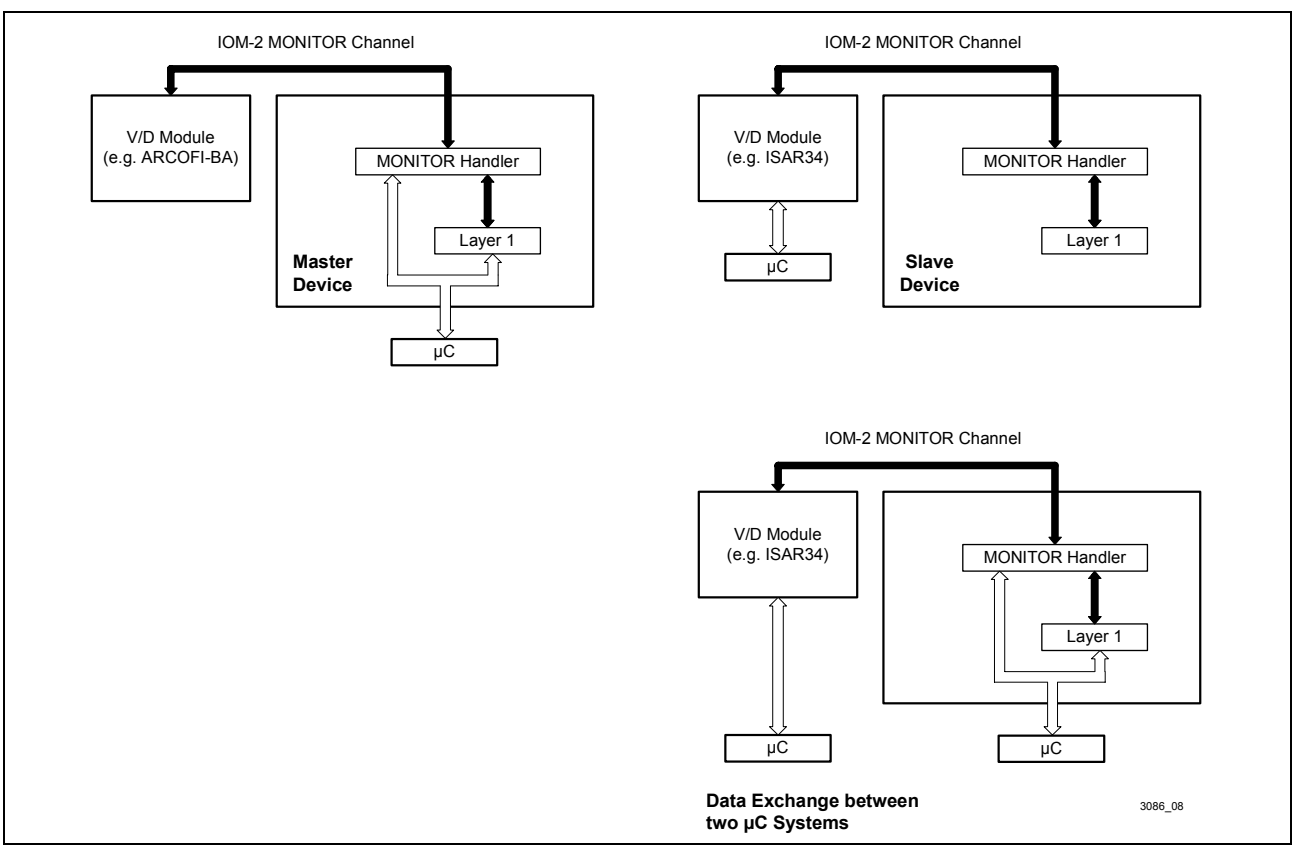


Figure 53 Examples of MONITOR Channel Applications in IOM-2 TE Mode

The MONITOR channel of the SBCX-X can be used in following applications which are illustrated in **Figure 53**:

- As a **master device** the SBCX-X can program and control other devices attached to the IOM-2 which do not need a parallel microcontroller interface e.g. ARCOFI-BA PSB 2161. This facilitates redesigning existing terminal designs in which e.g. an interface of an expansion slot is realized with IOM-2 interface and monitor programming.

- As a **slave device** the transceiver part of the SBCX-X is programmed and controlled from a master device on IOM-2 (e.g. ISAR 34 PSB 7115). This is used in applications where no microcontroller is connected directly to the SBCX-X in order to simplify host interface connection. The HDLC controlling is processed by the master device therefore the HDLC data is transferred via IOM-2 interface directly to the master device.
- For **data exchange** between two microcontroller systems attached to two different devices on one IOM-2 backplane. Use of the MONITOR channel avoids the necessity of a dedicated serial communication path between the two systems. This simplifies the system design of terminal equipment.

3.7.3.1 Handshake Procedure

The MONITOR channel operates on an asynchronous basis. While data transfers on the bus take place synchronized to frame sync (FSC), the flow of data is controlled by a handshake procedure using the MONITOR Channel Receive (MR) and MONITOR Channel Transmit (MX) bits. Data is placed onto the MONITOR channel and the MX bit is activated. This data will be transmitted once per 8-kHz frame until the transfer is acknowledged via the MR bit.

The MONITOR channel protocol is described in the following section and **Figure 54** illustrates this. The relevant control and status bits for transmission and reception are listed in **Table 11** and **Table 12**.

Table 11 Transmit Direction

Control/ Status Bit	Register	Bit	Function
Control	MOCR	MXC	MX Bit Control
		MIE	Transmit Interrupt Enable
Status	MOSR	MDA	Data Acknowledged
		MAB	Data Abort
	MSTA	MAC	Transmission Active

Table 12 Receive Direction

Control/ Status Bit	Register	Bit	Function
Control	MOCR	MRC	MR Bit Control
		MRE	Receive Interrupt Enable
Status	MOSR	MDR	Data Received
		MER	End of Reception

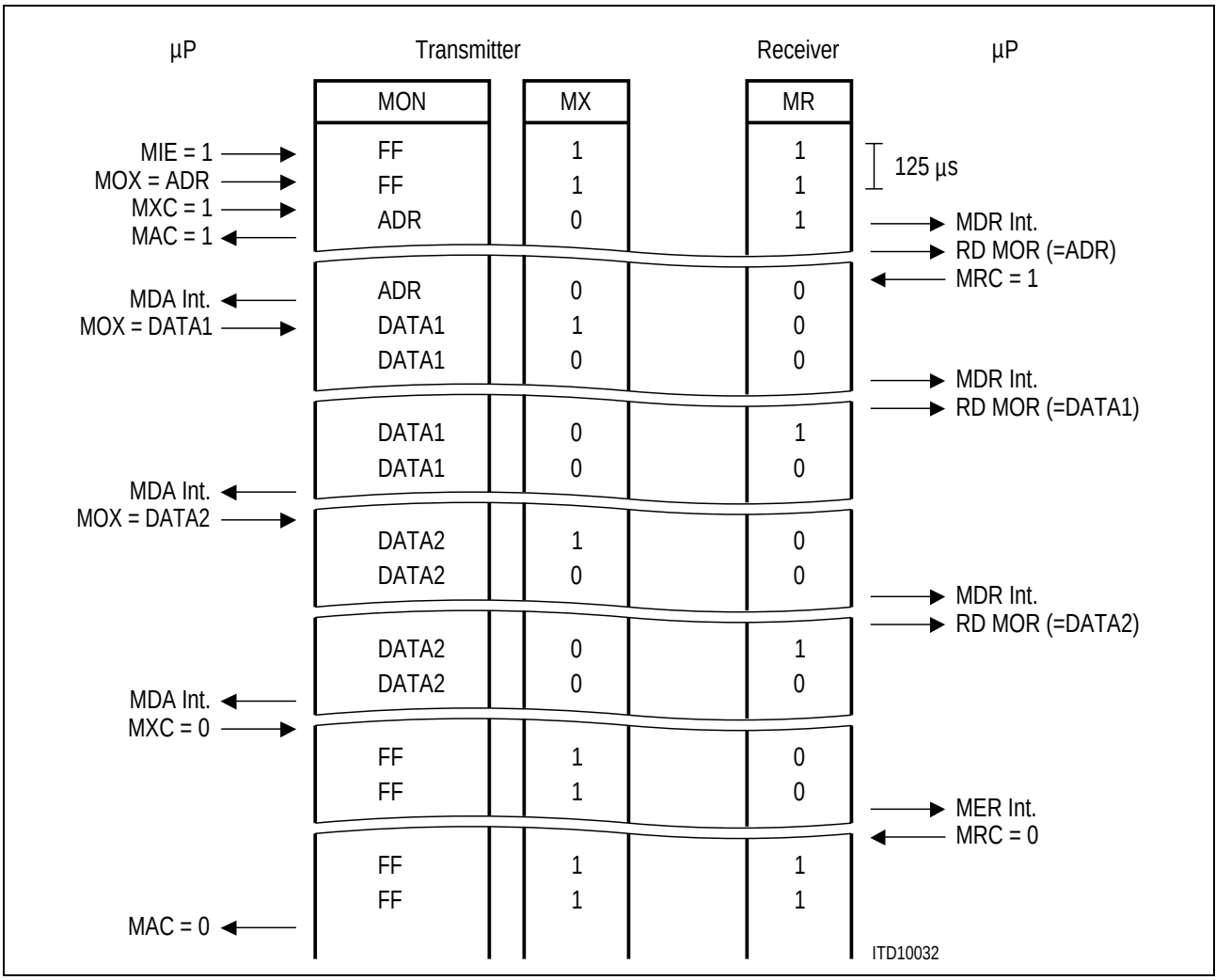


Figure 54 MONITOR Channel Protocol (IOM-2)

Before starting a transmission, the microprocessor should verify that the transmitter is inactive, i.e. that a possible previous transmission has been terminated. This is indicated by a ’0’ in the MONITOR Channel Active MAC status bit.

After having written the MONITOR Data Transmit (MOX) register, the microprocessor sets the MONITOR Transmit Control bit MXC to ’1’. This enables the MX bit to go active (’0’), indicating the presence of valid MONITOR data (contents of MOX) in the corresponding frame. As a result, the receiving device stores the MONITOR byte in its MONITOR Receive MOR register and generates an MDR interrupt status.

Alerted by the MDR interrupt, the microprocessor reads the MONITOR Receive (MOR) register. When it is ready to accept data (e.g. based on the value in MOR, which in a point-to-multipoint application might be the address of the destination device), it sets the MR control bit MRC to ’1’ to enable the receiver to store succeeding MONITOR channel bytes and acknowledge them according to the MONITOR channel protocol. In addition, it enables other MONITOR channel interrupts by setting MONITOR Interrupt Enable (MIE) to ’1’.

As a result, the first MONITOR byte is acknowledged by the receiving device setting the MR bit to ’0’. This causes a MONITOR Data Acknowledge MDA interrupt status at the transmitter.

A new MONITOR data byte can now be written by the microprocessor in MOX. The MX bit is still in the active (0) state. The transmitter indicates a new byte in the MONITOR channel by returning the MX bit active after sending it once in the inactive state. As a result, the receiver stores the MONITOR byte in MOR and generates a new MDR interrupt status. When the microprocessor has read the MOR register, the receiver acknowledges the data by returning the MR bit active after sending it once in the inactive state. This in turn causes the transmitter to generate an MDA interrupt status.

This "MDA interrupt – write data – MDR interrupt – read data – MDA interrupt" handshake is repeated as long as the transmitter has data to send. Note that the MONITOR channel protocol imposes no maximum reaction times to the microprocessor.

When the last byte has been acknowledged by the receiver (MDA interrupt status), the microprocessor sets the MONITOR Transmit Control bit MXC to ’0’. This enforces an inactive (’1’) state in the MX bit. Two frames of MX inactive signifies the end of a message. Thus, a MONITOR Channel End of Reception MER interrupt status is generated by the receiver when the MX bit is received in the inactive state in two consecutive frames. As a result, the microprocessor sets the MR control bit MRC to 0, which in turn enforces an inactive state in the MR bit. This marks the end of the transmission, making the MONITOR Channel Active MAC bit return to ’0’.

During a transmission process, it is possible for the receiver to ask a transmission to be aborted by sending an inactive MR bit value in two consecutive frames. This is effected by the microprocessor writing the MR control bit MRC to ’0’. An aborted transmission is indicated by a MONITOR Channel Data Abort MAB interrupt status at the transmitter.

The MONITOR transfer protocol rules are summarized in the following section:

- A pair of MX and MR in the inactive state for two or more consecutive frames indicates an **idle state** or an **end of transmission**.
- A **start of a transmission** is initiated by the transmitter by setting the MXC bit to ’1’ enabling the internal MX control. The receiver acknowledges the received first byte by setting the MR control bit to ’1’ enabling the internal MR control.
- The internal MX,MR control indicates or acknowledges a new byte in the MON slot by toggling MX,MR from the active to the inactive state for one frame.
- Two frames with the MR-bit set to inactive indicate a receiver request for **abort**.
- The transmitter can **delay a transmission** sequence by sending the same byte continuously. In that case the MX-bit remains active in the IOM-2 frame following the first byte occurrence. Delaying a transmission sequence is only possible while the receiver MR-bit and the transmitter MX-bit are active.
- Since a **double last-look criterion** is implemented the receiver is able to receive the MON slot data at least twice (in two consecutive frames), the receiver waits for the acknowledge of the reception of two identical bytes in two successive frames.

- To control this handshake procedure a collision detection mechanism is implemented in the transmitter. This is done by making a **collision check** per bit on the transmitted MONITOR data and the MX bit.
- Monitor data will be transmitted repeatedly until its reception is acknowledged or the transmission time-out timer expires.
- Two frames with the MX bit in the inactive state indicates the **end of a message** (EOM).
- Transmission and reception of monitor messages can be performed simultaneously. This feature is used by the SBCX-X to send back the response before the transmission from the controller is completed (the SBCX-X does not wait for EOM from controller).

3.7.3.2 Error Treatment

In case the SBCX-X does not detect identical monitor messages in two successive frames, transmission is not aborted. Instead the SBCX-X will wait until two identical bytes are received in succession.

A transmission is aborted of the SBCX-X if

- an error in the MR handshaking occurs
- a collision on the IOM-2 bus of the MONITOR data or MX bit occurs
- the transmission time-out timer expires

A reception is aborted by the device if

- an error in the MX handshaking occurs or
- an abort request from the opposite device occurs

MX/MR Treatment in Error Case

In the master mode the MX/MR bits are under control of the microcontroller through MXC or MRC, respectively. An abort is indicated by an MAB interrupt or MER interrupt, respectively.

In the slave mode the MX/MR bits are under control of the device. An abort is always indicated by setting the MX/MR bit inactive for two or more IOM-2 frames. The controller must react with EOM.

Figure 55 shows an example for an abort requested by the receiver, **Figure 56** shows an example for an abort requested by the transmitter and **Figure 57** shows an example for a successful transmission.

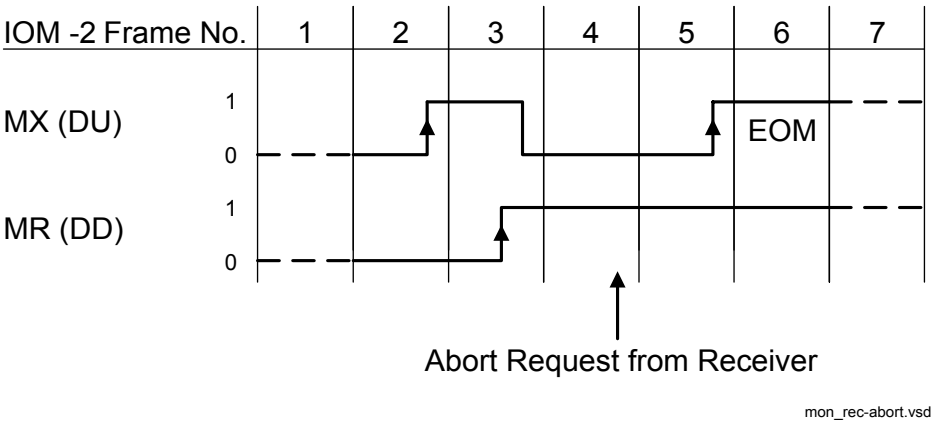


Figure 55 Monitor Channel, Transmission Abort Requested by the Receiver

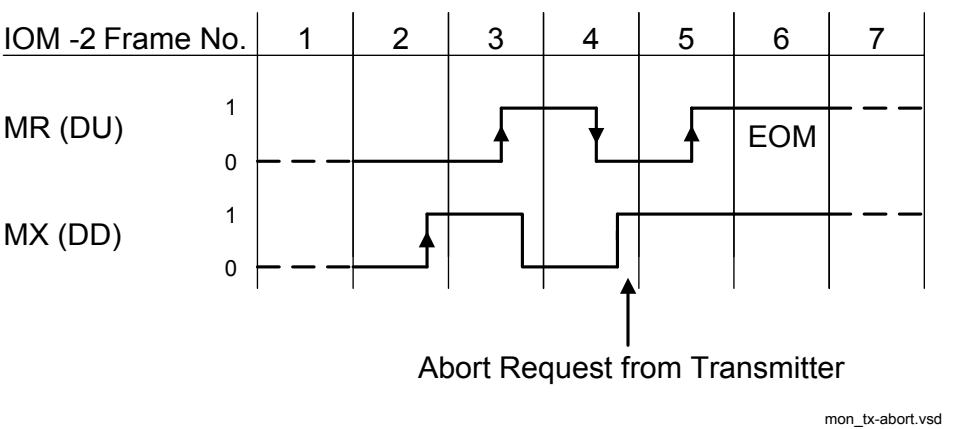


Figure 56 Monitor Channel, Transmission Abort Requested by the Transmitter

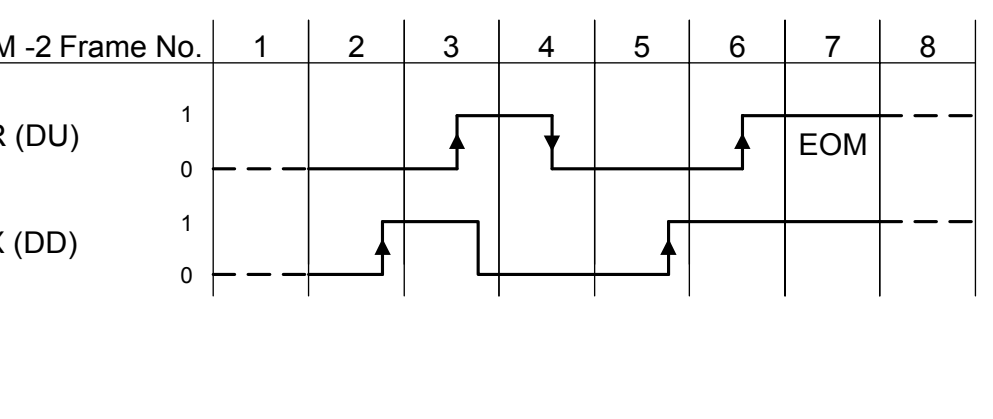


Figure 57 Monitor Channel, Normal End of Transmission

3.7.3.3 MONITOR Channel Programming as a Master Device

As a master device the SBCX-X can program and control other devices attached to the IOM-2 interface. The master mode is selected by default if the serial control interface (SCI) is used by the host. The monitor data is written by the microprocessor in the MOX register and transmitted via IOM-2 DD (DU) line to the programmed/controlled device e.g. ARCOFI-BA PSB 2161 or IEC-Q TE PSB 21911. The transfer of the commands in the MON channel is regulated by the handshake protocol mechanism with MX, MR which is described in the previous chapter **Chapter 3.7.3.1**.
If the transmitted command was a read command the slave device responds by sending the requested data.

The data structure of the transmitted monitor message depends on the device which is programmed. Therefore the first byte of the message is a specific address code which contains in the higher nibble a MONITOR channel address to identify different devices. The length of the messages depends on the accessed device and the type of MONITOR command.

3.7.3.4 MONITOR Channel Programming as a Slave Device

In applications without direct host controller connection the SBCX-X must operate in the MONITOR slave mode which can be selected by pinstrapping the microcontroller interface pins according **Table 3** respectively in **Chapter 3.2**. As a slave device the transceiver part of the SBCX-X is programmed and controlled by a master device at the IOM-2 interface. All programming data required by the SBCX-X is received in the MONITOR time slot on the IOM-2 and is transferred in the MOR register. The transfer of the commands in the MON channel is regulated by the handshake protocol mechanism with MX, MR which is described in the previous **Chapter 3.7.3.1**.
The first byte of the MONITOR message must contain in the higher nibble the MONITOR channel address code which is ’1010’ for the SBCX-X. The lower nibble distinguishes between a programming command or an identification command.

Identification Command

In order to be able to identify unambiguously different hardware designs of the SBCX-X by software, the following identification command is used:

DD 1st byte value	1	0	1	0	0	0	0	0
DD 2nd byte value	0	0	0	0	0	0	0	0

The SBCX-X responds to this DD identification sequence by sending a DU identification sequence:

DESIGN: six bit code, specific for each device in order to identify differences in operation

e.g. 000001 SBCX-X PEB 3081 Version 1.4

DU 1st byte value	1	0	1	0	0	0	0	0	
DU 2nd byte value	0	1	DESIGN						<IDENT>

This identification sequence is usually done once, when the terminal is connected for the first time. This function is used so that the software can distinguish between different possible hardware configurations. However this sequence is not compulsory.

Programming Sequence

The programming sequence is characterized by a '1' being sent in the lower nibble of the received address code. The data structure after this first byte and the principle of a read/ write access to a register is similar to the structure of the serial control interface described in **Chapter 3.2.2**. For write access the header $43_H/47_H$ can be used and for read access the header $40_H/44_H$.

DD 1st byte value	1	0	1	0	0	0	0	1
DD 2nd byte value	Header Byte							
DD 3rd byte value	R/W	Register Address						
DD 4th byte value	Data 1							
DD (nth + 3) byte value	Data n							

All registers can be read back when setting the R/W bit in the byte for the command/ register address. The SBCX-X responds by sending its IOM-2 specific address byte ($A1_h$) followed by the requested data.

Note: Application Hint:

It is not allowed to disable the MX- and MR-control in the programming device at the same time! First, the MX-control must be disabled, then the µC has to wait for an End of Reception before the MR-control may be disabled. Otherwise, the SBCX-X does not recognize an End of Reception.

3.7.3.5 MONITOR Time-Out Procedure

To prevent lock-up situations in a MONITOR transmission a time-out procedure can be enabled by setting the time-out bit (TOUT) in the MONITOR configuration register (MCONF). An internal timer is always started when the transmitter must wait for the reply of the addressed device. After 5 ms without reply the timer expires and the transmission will be aborted with a EOM (End of Message) command by setting the MX bit to '1' for two consecutive IOM-2 frames.

3.7.3.6 MONITOR Interrupt Logic

Figure 58 shows the MONITOR interrupt structure of the SBCX-X. The MONITOR Data Receive interrupt status **MDR** has two enable bits, MONITOR Receive interrupt Enable (**MRE**) and MR bit Control (**MRC**). The MONITOR channel End of Reception **MER**, MONITOR channel Data Acknowledged **MDA** and MONITOR channel Data Abort **MAB** interrupt status bits have a common enable bit MONITOR Interrupt Enable **MIE**.

MRE prevents the occurrence of **MDR** status, including when the first byte of a packet is received. When **MRE** is active (1) but **MRC** is inactive, the **MDR** interrupt status is generated only for the first byte of a receive packet. When both **MRE** and **MRC** are active, **MDR** is always generated and all received MONITOR bytes - marked by a 1-to-0 transition in MX bit - are stored. (Additionally, an active **MRC** enables the control of the MR handshake bit according to the MONITOR channel protocol.)

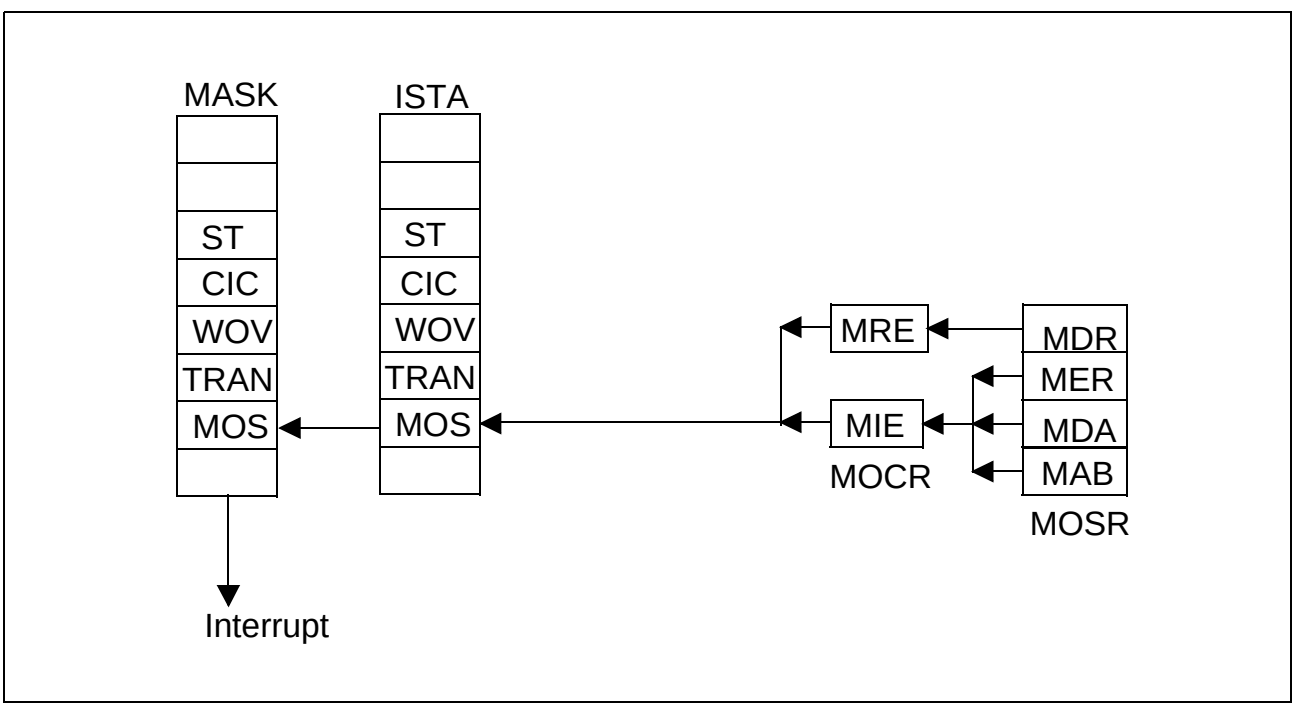


Figure 58 MONITOR Interrupt Structure

3.7.4 C/I Channel Handling

The Command/Indication channel carries real-time status information between the SBCX-X and another device connected to the IOM-2 interface.

- One C/I channel (called C/I0) conveys the commands and indications between the layer-1 and the C/I handler of the SBCX-X. It can be accessed by an external layer-2 device e.g. to control the layer-1 activation/deactivation procedures. C/I0 channel access may be arbitrated via the TIC bus access protocol. In this case the arbitration is done in IOM-2 channel 2 (see **Figure 41**).
  The C/I0 channel is accessed via register CIR0 (in receive direction, layer-1 to layer-2) and register CIX0 (in transmit direction, layer-2 to layer-1). The C/I0 code is four bits long. A listing and explanation of the layer-1 C/I codes can be found in **Chapter 3.5.4**.
  In the receive direction, the code from layer-1 is continuously monitored, with an interrupt being generated anytime a change occurs (ISTA.CIC). A new code must be found in two consecutive IOM-2 frames to be considered valid and to trigger a C/I code change interrupt status (double last look criterion).
  In the transmit direction, the code written in CIX0 is continuously transmitted in C/I0.
- A second C/I channel (called C/I1) can be used to convey real time status information between the SBCX-X and various non-layer-1 peripheral devices e.g. PSB 2161 ARCOFI-BA. The C/I1 channel consists of four or six bits in each direction.The width can be changed from 4bit to 6bit by setting bit CIX1.CICW.
  In 4-bit mode 6-bits are written whereby the higher 2 bits must be set to “1” and 6-bits are read whereby only the 4 LSBs are used for comparison and interrupt generation (i.e. the higher two bits are ignored).
  The C/I1 channel is accessed via registers CIR1 and CIX1. A change in the received C/I1 code is indicated by an interrupt status without double last look criterion.

CIC Interrupt Logic

Figure 59 shows the CIC interrupt structure.

A CIC interrupt may originate

– from a change in received C/I channel 0 code (CIC0)

or

– from a change in received C/I channel 1 code (CIC 1).

The two corresponding status bits CIC0 and CIC1 are read in CIR0 register. CIC1 can be individually disabled by clearing the enable bit CI1E in the CIX1 register. In this case the occurrence of a code change in CIR1 will not be displayed by CIC1 until the corresponding enable bit has been set to one.
Bits CIC0 and CIC1 are cleared by a read of CIR0.
An interrupt status is indicated every time a valid new code is loaded in CIR0 or CIR1. The CIR0 is buffered with a FIFO size of two. If a second code change occurs in the received C/I channel 0 before the first one has been read, immediately after reading of CIR0 a new interrupt will be generated and the new code will be stored in CIR0. If several consecutive codes are detected, only the first and the last code is obtained at the first and second register read, respectively.

For CIR1 no FIFO is available. The actual code of the received C/I channel 1 is always stored in CIR1.

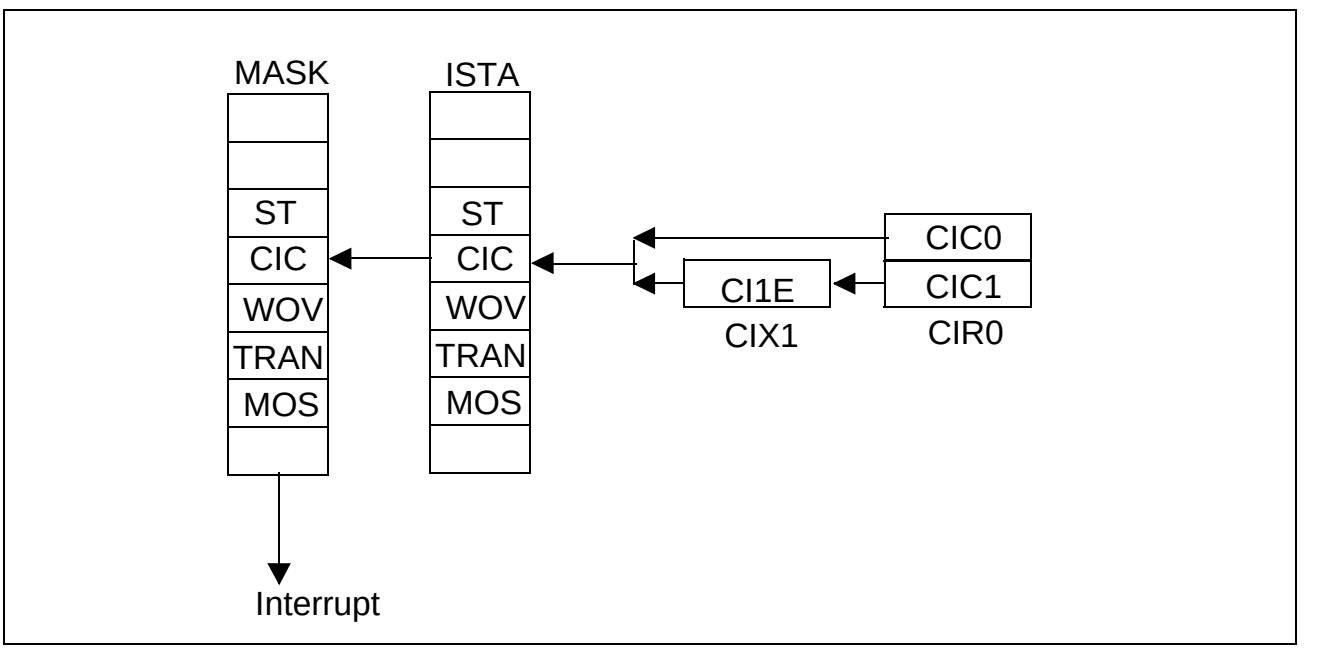


Figure 59 CIC Interrupt Structure

3.7.5 D-Channel Access Control

D-channel access control is defined to guarantee all connected TEs and HDLC controllers a fair chance to transmit data in the D-channel. Collisions are possible

- on the IOM-2 interface if there is more than one HDLC controller connected or
- on the S-interface when there is more than one terminal connected in a point to multipoint configuration (NT → TE1 … TE8).

Both arbitration mechanisms are implemented in the SBCX-X and will be described in the following two chapters.

3.7.5.1 TIC Bus D-Channel Access Control

The TIC bus is imlemented to organize the access to the layer-1 functions provided in the SBCX-X (C/I-channel) and to the D-channel from up to 7 external communication controllers (**Figure 60**).

Note: The TIC Bus can be used in TE/iNT mode only. In other modes it has to be switched off in order not to disturb the layer-1 control. This is done by setting bit DIM 1 in register Mode D and bit 4 in register IOM_CR. For more details please refer to the application note "Reconfigurable PBX".

To this effect the outputs of the D-channel controllers (e.g. ICC - ISDN Communication Controller PEB 2070) are wired-or (negative logic, i.e. a "0" wins) and connected to pin DU. The inputs of the ICCs are connected to pin DD. External pull-up resistors on DU/ DD are required. The arbitration mechanism must be activated by setting TR_MODE2.DIM2-0=00x.

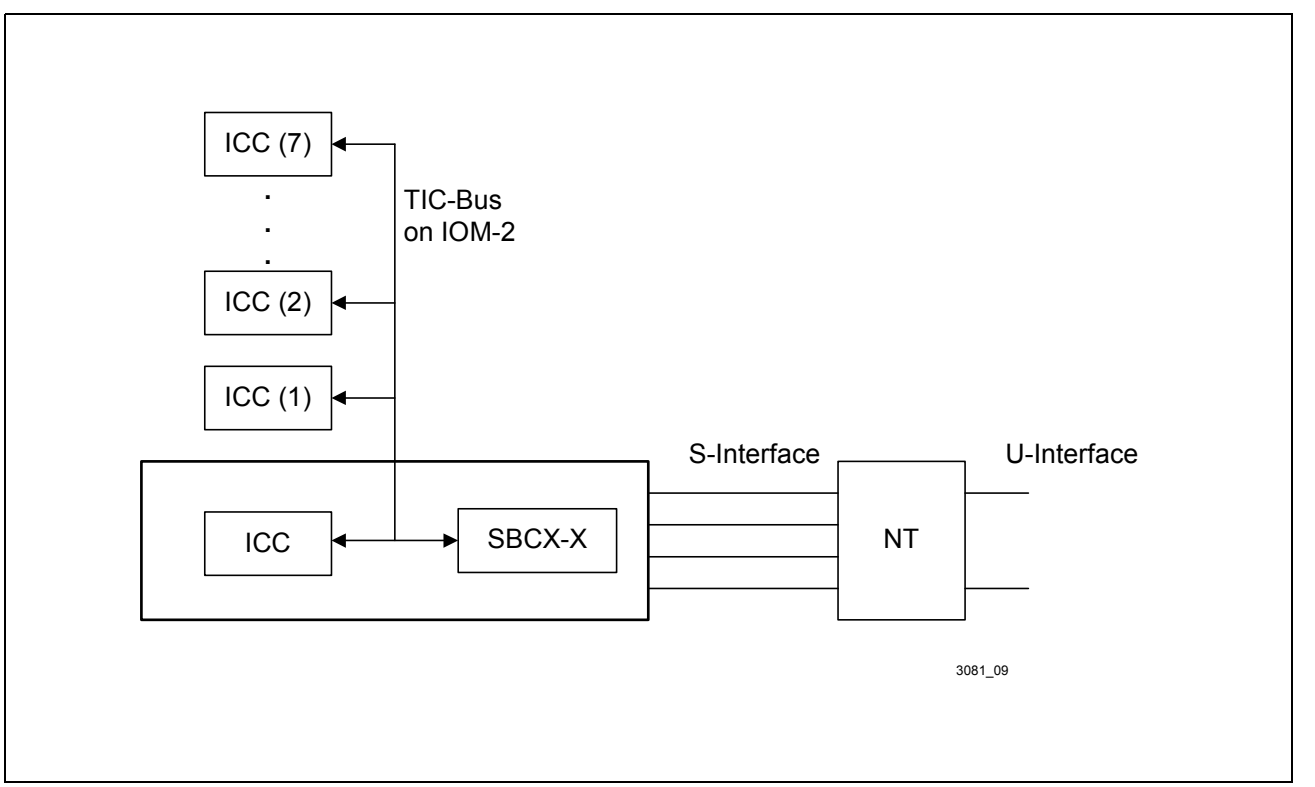


Figure 60 Applications of TIC Bus in IOM-2 Bus Configuration

The arbitration mechanism is implemented in the last octet in IOM-2 channel 2 of the IOM-2 interface (**Figure 61**). An access request to the TIC bus may either be generated by software via a µP access to the C/I channel or by one of the D-channel controllers (ICC). A software access request to the bus is effected by setting the BAC bit (CIX0 register) to '1'.

In the case of an access request to the C/I channel, the SBCX-X checks the Bus Accessed-bit BAC (bit 5 of last octet of CH2 on DU, see **Figure 61**) for the status "bus free“, which is indicated by a logical ’1’. If the bus is free, the SBCX-X transmits its individual TIC bus address TAD. The SBCX-X sends its TIC bus address TAD and compares it bit by bit with the value on DU. If a sent bit set to ’1’ is read back as ’0’ because of the access of another source with a lower TAD wishing access to D- or C/I-channel, the SBCX-X withdraws immediately from the TIC bus, i.e. the remaining TAD bits are not transmitted. The TIC bus is occupied by the device which sends its address error-free. If more than one device attempt to seize the bus simultaneously, the one with the lowest address values wins. This one will set BAC=0 on TIC bus and starts D-channel transmission in the same frame.

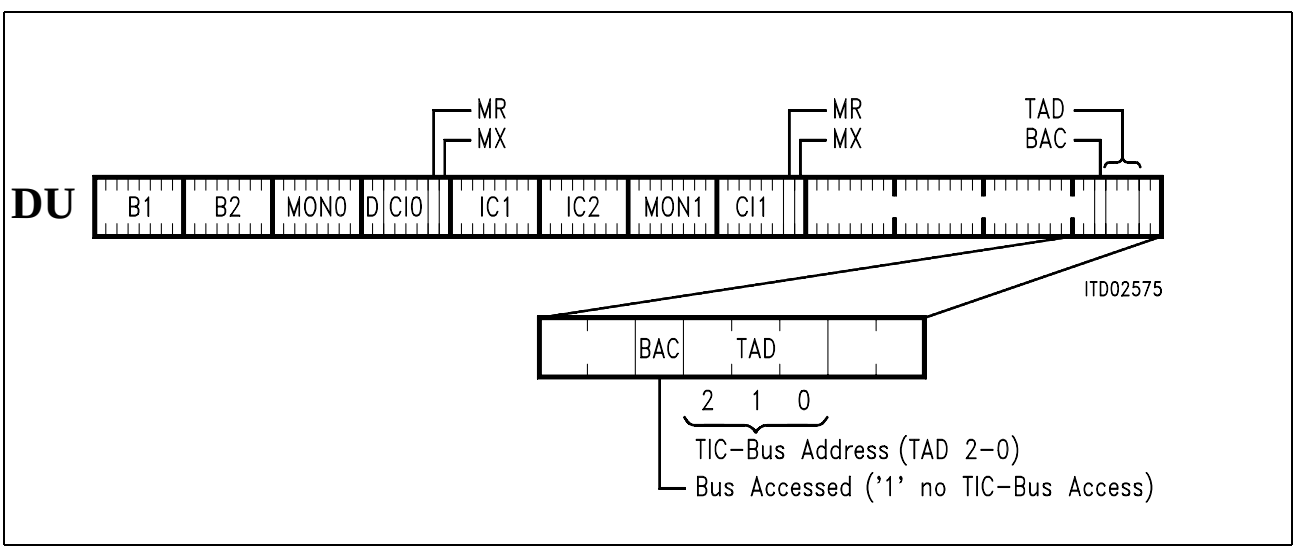


Figure 61 Structure of Last Octet of Ch2 on DU

When the TIC bus is seized by the ICC, the bus is identified to other devices as occupied via the DU Ch2 Bus Accessed-bit state ’0’ until the access request is withdrawn. After a successful bus access, the ICC is automatically set into a lower priority class, that is, a new bus access cannot be performed until the status "bus free" is indicated in two successive frames.

If none of the devices connected to the IOM-2 interface request access to the D and C/I channels, the TIC bus address 7 will be present. The device with this address will therefore have access, by default, to the D and C/I channels.

3.7.5.2 S-Bus Priority Mechanism for D-Channel

The S-bus access procedure specified in ITU I.430 was defined to organize D-channel access with multiple TEs connected to a single S-bus (**Figure 63**).

To implement collision detection the D (channel) and E (echo) bits are used. The D-channel S-bus condition is indicated towards the IOM-2 interface with the S/G bit, i.e. the availability of the S/T interface D channel is indicated in bit 5 "Stop/Go" (S/G) of the DD last octet of Ch2 channel (**Figure 62**).

S/G = 1 : stop
S/G = 0 : go

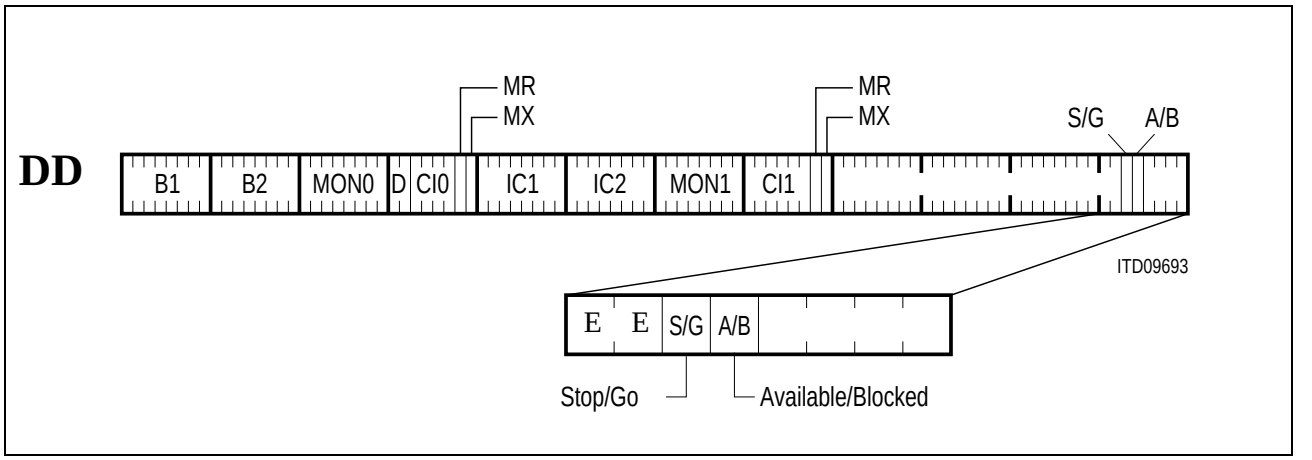


Figure 62 Structure of Last Octet of Ch2 on DD

The Stop/Go bit is available to other layer-2 devices connected to the IOM-2 interface to determine if they can access the S/T bus D channel.

The access to the D-channel is controlled by a priority mechanism which ensures that all competing TEs are given a fair access chance. This priority mechanism discriminates among the kind of information exchanged and information exchange history: Layer-2 frames are transmitted in such a way that signalling information is given priority (priority class 1) over all other types of information exchange (priority class 2). Furthermore, once a TE having successfully completed the transmission of a frame, it is assigned a lower level of priority of that class. The TE is given back its normal level within a priority class when all TEs have had an opportunity to transmit information at the normal level of that priority class.

The priority mechanism is based on a rather simple method: A TE not transmitting layer-2 frames sends binary 1s on the D-channel. As layer-2 frames are delimited by flags consisting of the binary pattern “01111110” and zero bit insertion is used to prevent flag imitation, the D-channel may be considered idle if more than seven consecutive 1s are detected on the D-channel. Hence by monitoring the D echo channel, the TE may determine if the D-channel is currently used by another TE or not.

A TE may start transmission of a layer-2 frame first when a certain number of consecutive 1s has been received on the echo channel. This number is fixed to 8 in priority class 1 and to 10 in priority class 2 for the normal level of priority; for the lower level of priority the number is increased by 1 in each priority class, i.e. 9 for class 1 and 11 for class 2.

A TE, when in the active condition, is monitoring the D echo channel, counting the number of consecutive binary 1s. If a 0 bit is detected, the TE restarts counting the number of consecutive binary 1s. If the required number of 1s according to the actual level of priority has been detected, the TE may start transmission of an HDLC frame. If a collision occurs, the TE immediately shall cease transmission, return to the D-channel monitoring state, and send 1s over the D-channel.

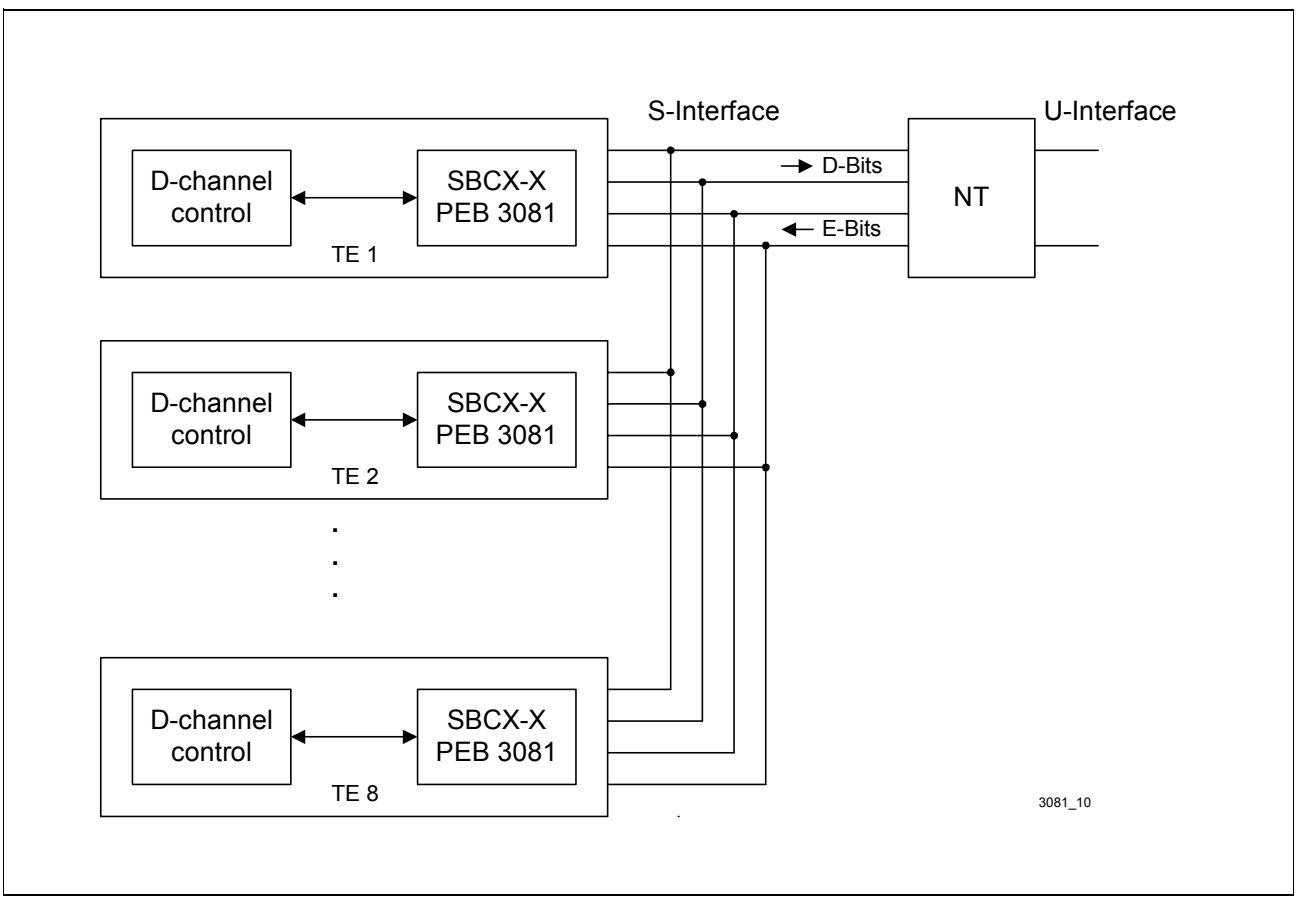


Figure 63 D-Channel Access Control on the S-Interface

S-Bus D-channel Access Control in the SBCX-X

The above described priority mechanism is fully implemented in the SBCX-X. For this purpose the D-channel collision detection according to ITU I.430 must be enabled by setting TR_MODE2.DIM2-0 to ’0x1’. In this case the transceiver continuously compares the received E-echo bits with its own transmitted D data bits.
Depending on the priority class selected, 8 (priority 8) or 10 (priority 10) consecutive ONEs (high priority level) need to be detected before the transceiver sends valid D-channel data on the upstream D-bits on S. In low priority level 9 (priority 8) or 11 (priority 10) consecutive ONEs are required.

The priority class (priority 8 or priority 10) is selected by transferring the appropriate activation command via the Command/Indication (C/I) channel of the IOM-2 interface to the transceiver. If the activation is initiated by a TE, the priority class is selected implicitly by the choice of the activation command. If the S-interface is activated from the NT, an activation command selecting the desired priority class should be programmed at the TE on reception of the activation indication (AI8 or AI10). In the activated state the priority class may be changed whenever required by simply programming the desired activation request command (AR8 or AR10).

3.7.5.3 S-Bus D-Channel Control in LT-T

If the TE frame structure on the IOM-2 interface is selected, the same D-channel access procedures as described in **Chapter 3.7.5.2** are used in LT-T mode.

For other frame structures used in LT-T mode, D-channel access on S is handled similarly, with the difference that the S/G bit is not available on IOM-2 but only on the S/G bit output pin (SGO).

3.7.5.4 D-Channel Control in the Intelligent NT (TIC- and S-Bus)

In intelligent NT applications (selected via register TR_MODE.MODE2-0) one or more D-channel controllers on the IOM-2 interface share the upstream D-channel with all connected TEs on the S interface.

The transceiver incorporates an elaborate statemachine for D-channel priority handling on IOM-2. For the access to the D-channel a similar arbitration mechanism as on the S interface (writing D-bits, reading back E-bits) is performed for all D-channel sources on IOM-2. Due to this an equal and fair access is guaranteed for all D-channel sources on both the S interface and the IOM-2 interface.

This arbitration mechanism is only available in IOM-2 TE mode (12 PCM timeslots) per frame with enabled TIC bus. The access to the upstream D-channel is handled via the S/G bit for the HDLC controllers and via E-bit for all connected terminals on S (E-bits are inverted to block the terminals on S). Furthermore, if more than one HDLC source is requesting D-channel access on IOM-2 the TIC bus mechanism is used.

The arbiter permanently counts the “1s” in the upstream D-channel on IOM-2. If the necessary number of “1s” is counted and an HDLC controller on IOM-2 requests upstream D-channel access (BAC bit is set to 0), the arbiter allows this D-channel controller immediate access and blocks other TEs on S (E-bits are inverted). Similar as on the S-interface the priority for D-channel access on IOM-2 can be configured to 8 or 10 (TR_CMD.DPRIO).

The upstream device can stop all D-channel sources by setting the A/B-bit to 0. The S/G bit is not evaluated in this mode.

The configuration settings of the SBCX-X in intelligent NT applications are summarized in **Table 13**.

Table 13 SBCX-X Configuration Settings in Intelligent NT Applications

Configuration Description	Configuration Setting
Select intelligent NT mode	Transceiver Mode Register: TR_MODE.MODE0 = 0 (NT state machine) or TR_MODE.MODE0 = 1 (LT-S state machine) TR_MODE.MODE1 = 1 TR_MODE.MODE2 = 1
Enable S/G bit evaluation	Transceiver Mode Register 2: TR_MODE2.DIM2-0 = 001

Note: For mode selection in the TR_MODE register the MODE1/2 bits are used to select intelligent NT mode, MODE0 selects NT or LT-S state machine.

With the configuration settings shown above the SBCX-X in intelligent NT applications provides for equal access to the D-channel for terminals connected to the S-interface and for D-channel sources on IOM-2.
For a detailed understanding the following sections provide a complete description on the procedures used by the D-channel priority handler on IOM-2, although it may not be necessary to study that in order to use this mode.

1. NT D-Channel Controller Transmits Upstream

In the initial state (’Ready’ state) neither the local D-channel sources on IOM-2 nor any of the terminals connected to the S-bus transmit in the D-channel.

The SBCX-X S-transceiver thus receives BAC = “1” (IOM-2 DU line) and transmits S/G = “1” (IOM-2 DD line). The access will then be established according to the following procedure:

- Local D-channel source verifies that BAC bit is set to ONE (currently no bus access).
- Local D-channel source issues TIC bus address and verifies that no controller with higher priority requests transmission (TIC bus access must always be performed even if no other D-channel sources are connected to IOM-2).
- Local D-channel source issues BAC = “0” to block other sources on IOM-2 and to announce D-channel access.
- SBCX-X S-transceiver pulls S/G bit to ZERO (’Idle’ state) as soon as n D-bits = ’1’ are counted on IOM-2 (see note) to allow for further D-channel access.
- SBCX-X S-transceiver transmits inverted echo channel (E bits) on the S-bus to block all connected S-bus terminals (E = $\overline{D}$).
- Local D-channel source commences with D data transmission on IOM-2 as long as it receives S/G = “0”.
- After D-channel data transmission is completed the controller sets the BAC bit to ONE.
- SBCX-X S-transceiver transmits non-inverted echo (E = D).
- SBCX-X S-transceiver pulls S/G bit to ONE (’Ready’ state) to block the D-channel controller on IOM-2.

Note: “Local D-channel source” means any D-channel source on the IOM-2 interface. Right after transmission the S/G bit is pulled to ’1’ until n successive D-bits = ’1’ occur on the IOM-2 interface. As soon as n D-bits = ’1’ are seen, the S/G bit is set to ’0’ and the SBCX-X D-channel controller may start transmission again (if TIC bus is occupied). This allows an equal access for D-channel sources on IOM-2 and on the S interface.
The number n depends on configuration settings (selected priority 8 or 10) and the condition of the previous transmission, i.e. if an abort was seen (n = 8 or 10, respectively) or if the last transmission was successful (n = 9 or 11, respectively).

Figure 64 illustrates the signal flow in an intelligent NT and the algorithm of the D-channel priority handler on IOM-2 implemented in the SBCX-X.

2. Terminal Transmits D-Channel Data Upstream

The initial state is identical to that described in the last paragraph. When one of the connected S-bus terminals needs to transmit in the D-channel, access is established according to the following procedure:

- SBCX-X S-transceiver (in intelligent NT) recognizes that the D-channel on the S-bus is active.
- SBCX-X S-transceiver transfers S-bus D-channel data transparently through to the upstream IOM-2 bus (IOM-2 channel 0).

For both cases described above the exchange indicates via the A/B bit (controlled by layer 1) that D-channel transmission on this line is permitted (A/B = “1”). Data transmission could temporarily be prohibited by the exchange when only a single D-channel controller handles more lines (A/B = “0”, ELIC-concept).
In case the exchange prohibits D data transmission on this line the A/B bit is set to “0” (block). For U_{PN} applications with S extension this forces the intelligent NT SBCX-X S-transceiver to transmit an inverted echo channel on the S-bus, thus disabling all terminal requests, and switches S/G to $\overline{A/B}$, which blocks the D-channel controller in the intelligent NT.

Note: Although the SBCX-X S-transceiver operates in LT-S mode and is pinstrapped to IOM-2 channel 0 or 1 it will write into IOM-2 channel 2 at the S/G bit position.

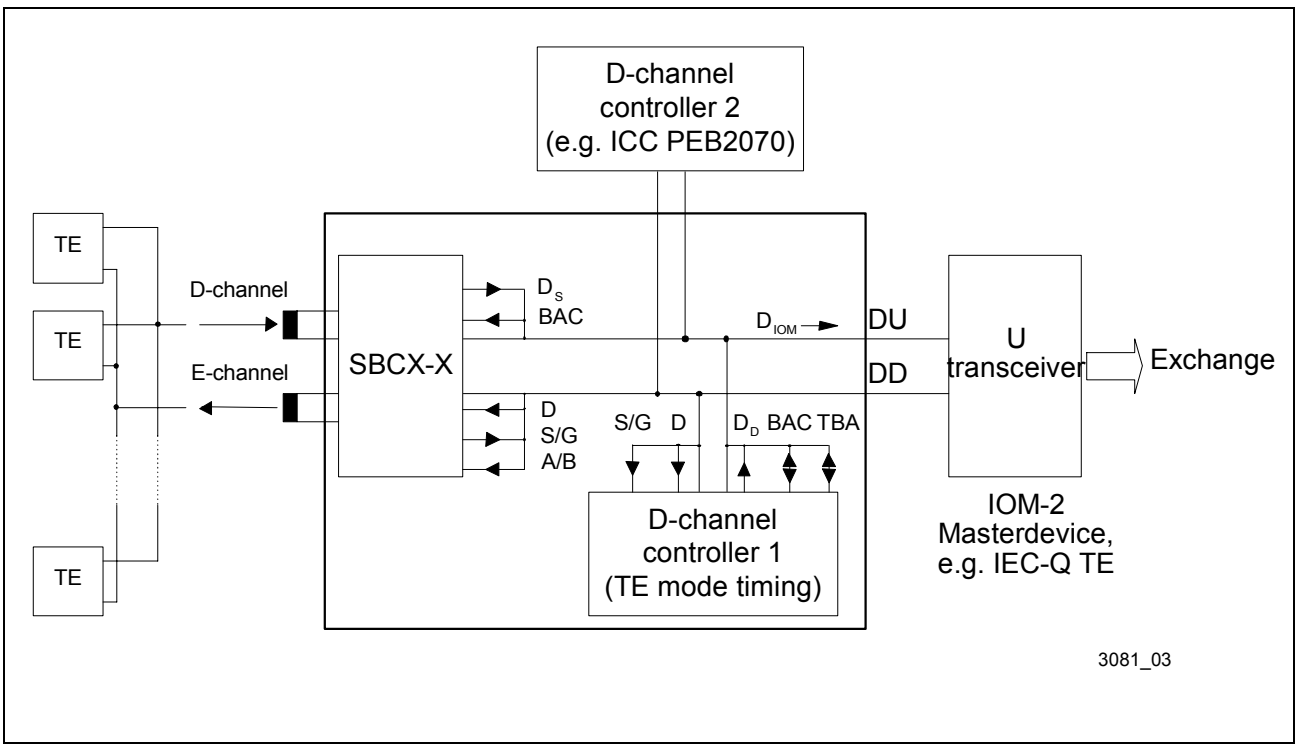


Figure 64 Data Flow for Collision Resolution Procedure in Intelligent NT

3.7.6 Activation/Deactivation of IOM-2 Interface

The IOM-2 interface can be switched off in the inactive state, reducing power consumption to a minimum. In this deactivated state is FSC = ’1’, DCL and BCL = ’0’ and the data lines are ’1’.

The IOM-2 interface can be kept active while the S interface is deactivated by setting the CFS bit to "0" (MODE1 register). This is the case after a hardware reset. If the IOM-2 interface should be switched off while the S interface is deactivated, the CFS bit should be set to ’1’. In this case the internal oscillator is disabled when no signal (INFO 0) is present on the S bus and the C/I command is ’1111’ = DIU. If the TE wants to activate the line, it has first to activate the IOM-2 interface either by using the "Software Power Up" function (IOM_CR.SPU bit) or by setting the CFS bit to "0" again.

The deactivation procedure is shown in **Figure 65**. After detecting the code DIU (Deactivate Indication Upstream) the layer 1 of the SBCX-X responds by transmitting DID (Deactivate Indication Downstream) during subsequent frames and stops the timing signals synchronously with the end of the last C/I (C/I0) channel bit of the fourth frame.

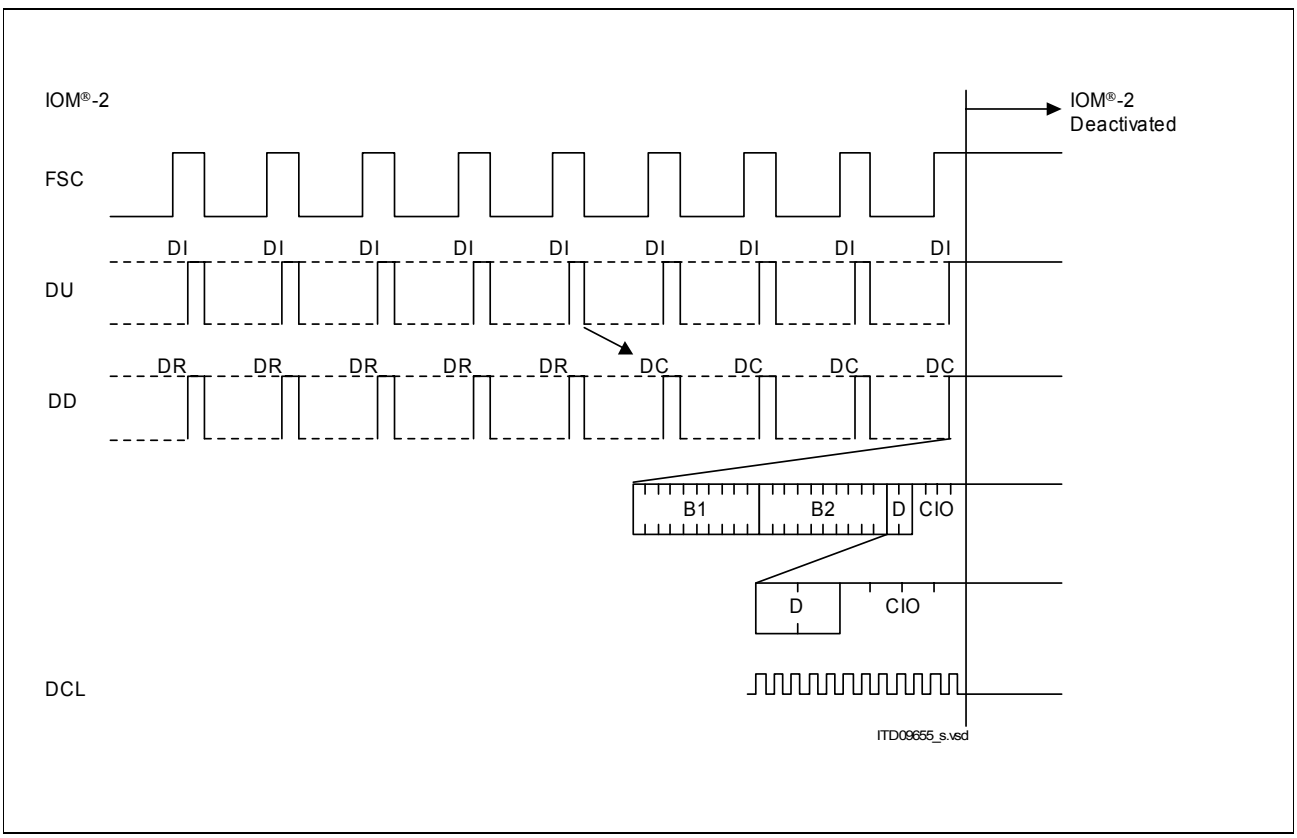


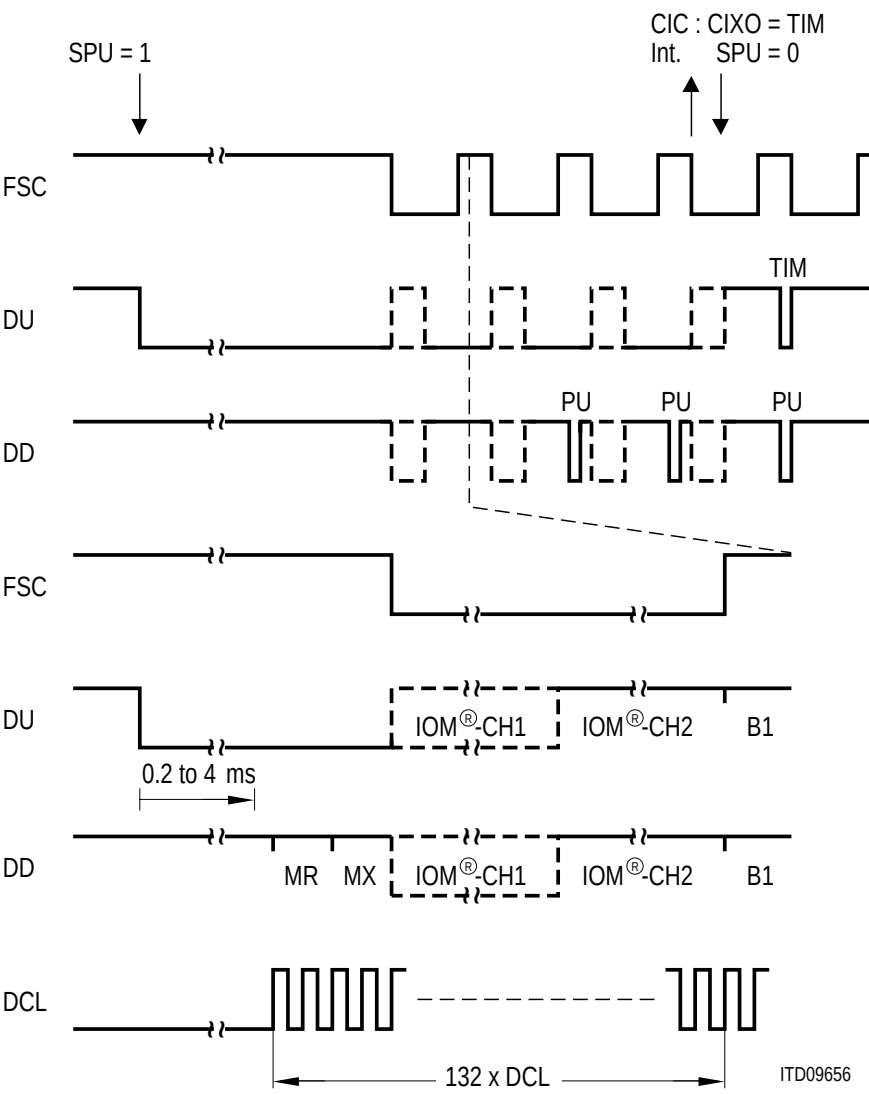
Figure 65 Deactivation of the IOM-2 Interface

The clock pulses will be enabled again when the DU line is pulled low (bit SPU in the IOM_CR register), i.e. the C/I command TIM = "0000" is received by layer 1, or when a non-zero level on the S-line interface is detected (if TR_CONF0.LDD=0). The clocks are turned on after approximately 0.2 to 4 ms depending on the oscillator.

DCL is activated such that its first rising edge occurs with the beginning of the bit following the C/I (C/I0) channel.

After the clocks have been enabled this is indicated by the PU code in the C/I channel and, consequently, by a CIC interrupt. The DU line may be released by resetting the Software Power Up bit IOM_CR.SPU = ’0’ and the C/I code written to CIX0 before (e.g. TIM or AR8) is output on DU.

The SBCX-X supplies IOM-2 timing signals as long as there is no DIU command in the C/I (C/I0) channel. If timing signals are no longer required and activation is not yet requested, this is indicated by programming DIU in the CIX0 register.



Note: The value “132 x DCL” is only valid for IOM configurations with 3 IOM channels.

Figure 66 Activation of the IOM-2 interface

Asynchronous Awake (LT-S, NT, Int. NT mode)

The transceiver is in power down mode (deactivated state) and MODE1.CFS=1 (TR_CONF0.LDD is don't care in this case). Due to any signal on the line the level detect circuit will asynchronously pull the DU line on IOM-2 to "0" which is deactivated again after 2 ms if the oscillator is fully operational. If the oscillator is just starting up in operational mode, the 2 ms duration is extended correspondingly.

3.8 Auxiliary Interface

The AUX interface provides various functions, which depend on the operation mode (TE, LT-T, LT-S, NT or intelligent NT mode) selected by pins MODE0 and MODE1/$\overline{\text{EAW}}$ (see **Table 14**). After reset the pins are switched as inputs until further configuration is done by the host.

Table 14 AUX Pin Functions

Pin	TE, Int. NT mode	LT-T, LT-S, NT mode
AUX0	AUX0 (i/o)	CH0 (i)
AUX1	AUX1 (i/o)	CH1 (i)
AUX2	AUX2 (i/o)	CH2 (i)

General Purpose I/O AUX0-2 (TE, Int. NT mode)

These pins can be used as programmable I/O lines.

As inputs (AOE.OEx=1) the state at the pin is latched in when the host performes read operation to register ARX.

As outputs (AOE.OEx=0) the value in register ATX is driven on the pins with a minimum delay after the write operation to this register is performed. They can be configured as open drain (ACFG1.ODx=0) or push/pull outputs (ACFG1.ODx=1). The status ('1' or '0') at output pins can be read back from register ARX, which may be different from the ATX value, e.g. if another device drives a different level.

Channel Select CH0-2 (LT-T, LT-S, NT mode)

In linecard mode one FSC frame is a multiplex of up to eight IOM-2 channels, each of them consisting of B1-, B2-, MONITOR-, D- and C/I-channel and MR- and MX-bits.
One of eight channels on the IOM-2 interface is selected by CH0-2. These pins must be strapped to VDD or VSS according to **Table 15**.

Table 15 IOM-2 Channel Selection

CH2	CH1	CH0	Channel on IOM-2
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

For DCL = 1.536 MHz one of the IOM-2 channels 0 - 2 can be selected, for DCL = 4.096 MHz any of the eight IOM-2 channels can be selected.

The channel select pins have direct effect on the timeslot selection of the following registers:

- TR_TSDP_BC1
- TR_TSDP_BC2
- TR_CR, TRC_CR
- DCI_CR, DCIC_CR
- MON_CR

4 Detailed Register Description

The register mapping of the SBCX-X is shown in **Figure 67**.

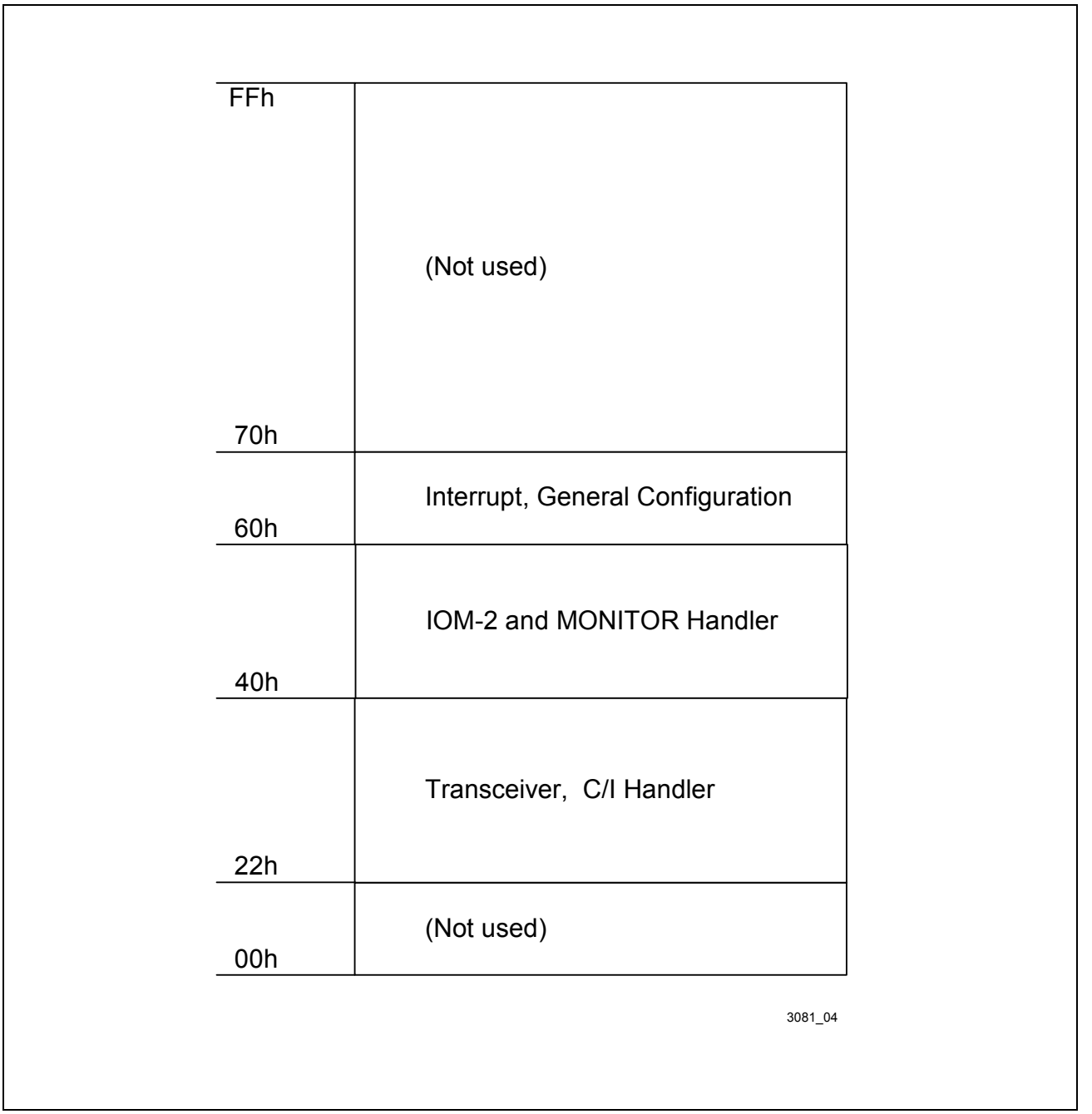


Figure 67 Register Mapping of the SBCX-X

The register set ranging from 22_H-$3F_H$ pertains to the transceiver and C/I-channel handler registers.

The address range from 40_H-$5B_H$ is assigned to the IOM handler with the registers for timeslot and data port selection (TSDP) and the control registers (CR) for the transceiver data (TR), Monitor data (MON), C/I data (CI) and controller access data (CDA), serial data strobe signal (SDS), IOM interface (IOM) and synchronous transfer interrupt (STI).

The address range from $5C_H$-$5F_H$ pertains to the MONITOR handler.

General interrupt and configuration registers are contained in the address range 60_H-65_H.

The register summaries of the SBCX-X are shown in the following tables containing the abbreviation of the register name and the register bits, the register address, the reset values and the register type (Read/Write). A detailed register description follows these register summaries.

The register summaries and the description are sorted in ascending order of the register address.

Transceiver, C/I-Channel Handler, Auxiliary Interface

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
	reserved								00_H-21_H		
TR_MODE2	0	0	0	0	0	DIM2	DIM1	DIM0	22_H	R/W	00_H
	reserved								23-$2D_H$		
CIR0	CODR0				CIC0	CIC1	S/G	BAS	$2E_H$	R	$F3_H$
CIX0	CODX0				TBA2	TBA1	TBA0	BAC	$2E_H$	W	FE_H
CIR1	CODR1						CICW	CI1E	$2F_H$	R	FE_H
CIX1	CODX1						CICW	CI1E	$2F_H$	W	FE_H
TR_CONF0	DIS_TR	BUS	EN_ICV	0	L1SW	0	EXLP	LDD	30_H	R/W	01H
TR_CONF1	0	RPLL_ADJ	EN_SFSC	0	0	x	x	x	31_H	R/W	
TR_CONF2	DIS_TX	PDS	0	RLP	0	0	SGP	SGD	32_H	R/W	80_H

Transceiver, C/I-Channel Handler, Auxiliary Interface

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
TR_STA	RINF		SLIP	ICV	0	FSYN	0	LD	33_H	R	00_H
TR_CMD	XINF			DPRIO	TDDIS	PD	LP_A	0	34_H	R/W	08_H
SQRR1	MSYN	MFEN	0	0	SQR11	SQR12	SQR13	SQR14	35_H	R	40_H
SQXR1	0	MFEN	0	0	SQX11	SQX12	SQX13	SQX14	35_H	W	$4F_H$
SQRR2	SQR21	SQR22	SQR23	SQR24	SQR31	SQR32	SQR33	SQR34	36_H	R	00_H
SQXR2	SQX21	SQX22	SQX23	SQX24	SQX31	SQX32	SQX33	SQX34	36_H	W	00_H
SQRR3	SQR41	SQR42	SQR43	SQR44	SQR51	SQR52	SQR53	SQR54	37_H	R	00_H
SQXR3	SQX41	SQX42	SQX43	SQX44	SQX51	SQX52	SQX53	SQX54	37_H	W	00_H
ISTATR	0	x	x	x	LD	RIC	SQC	SQW	38_H	R	00_H
MASKTR	1	1	1	1	LD	RIC	SQC	SQW	39_H	R/W	FF_H
TR_ MODE	0	0	0	0	DCH_ INH	MODE 2	MODE 1	MODE 0	$3A_H$	R/W	00_H
	reserved								$3B_H$		
ACFG1	0	0	0	0	0	OD2	OD1	OD0	$3C_H$	R/W	00_H
ACFG2	0	0	0	0	ACL	LED	0	0	$3D_H$	R/W	00_H
AOE	1	1	1	1	1	OE2	OE1	OE0	$3E_H$	R/W	FF_H
ARX	-	-	-	-	-	AR2	AR1	AR0	$3F_H$	R	
ATX	0	0	0	0	0	AT2	AT1	AT0	$3F_H$	W	00_H

IOM Handler (Timeslot , Data Port Selection, CDA Data and CDA Control Register)

Name	7	6	5	4	3	2	1	0	ADDR	R/W	RES
CDA10	Controller Data Access Register (CH10)								40_H	R/W	FF_H
CDA11	Controller Data Access Register (CH11)								41_H	R/W	FF_H
CDA20	Controller Data Access Register (CH20)								42_H	R/W	FF_H
CDA21	Controller Data Access Register (CH21)								43_H	R/W	FF_H
CDA_ TSDP10	DPS	0	0	TSS					44_H	R/W	00_H
CDA_ TSDP11	DPS	0	0	TSS					45_H	R/W	01_H
CDA_ TSDP20	DPS	0	0	TSS					46_H	R/W	80_H
CDA_ TSDP21	DPS	0	0	TSS					47_H	R/W	81_H
	reserved								$48\text{-}4B_H$		
TR_ TSDP_ BC1	DPS	0	0	TSS					$4C_H$	R/W	00_H
TR_ TSDP_ BC2	DPS	0	0	TSS					4DH	R/W	01_H
CDA1_ CR	0	0	EN_ TBM	EN_I1	EN_I0	EN_O1	EN_O0	SWAP	$4E_H$	R/W	00_H
CDA2_ CR	0	0	EN_ TBM	EN_I1	EN_I0	EN_O1	EN_O0	SWAP	$4F_H$	R/W	00_H

IOM Handler (Control Registers, Synchronous Transfer Interrupt Control), MONITOR Handler

Name	7	6	5	4	3	2	1	0	ADDR	R/W	RES
TR_CR (CI_CS=0)	EN_D	EN_B2R	EN_B1R	EN_B2X	EN_B1X	CS2-0			50_H	R/W	$F8_H$
TRC_CR (CI_CS=1)	0	0	0	0	0	CS2-0			50_H	R/W	00_H
	reserved								$51\text{-}52_H$		
DCI_CR (CI_CS=0)	DPS_CI1	EN_CI1	0	0	0	0	0	0	53_H	R/W	80_H
DCIC_CR (CI_CS=1)	0	0	0	0	0	CS2-0			53_H	R/W	00_H
MON_CR	DPS	EN_MON	0	0	0	CS2-0			54_H	R/W	40_H
SDS1_CR	ENS_TSS	ENS_TSS+1	ENS_TSS+3	TSS					55_H	R/W	00_H
SDS2_CR	ENS_TSS	ENS_TSS+1	ENS_TSS+3	TSS					56_H	R/W	00_H
IOM_CR	SPU	DIS_AW	CI_CS	TIC_DIS	EN_BCL	CLKM	DIS_OD	DIS_IOM	57_H	R/W	08_H
STI	STOV21	STOV20	STOV11	STOV10	STI21	STI20	STI11	STI10	58_H	R	00_H
ASTI	0	0	0	0	ACK21	ACK20	ACK11	ACK10	58_H	W	00_H
MSTI	STOV21	STOV20	STOV11	STOV10	STI21	STI20	STI11	STI10	59_H	R/W	FF_H
SDS_CONF	0	0	0	0	DIOM_INV	DIOM_SDS	SDS2_BCL	SDS1_BCL	$5A_H$	R/W	00_H
MCDA	MCDA21		MCDA20		MCDA11		MCDA10		$5B_H$	R	FF_H

MOR	MONITOR Receive Data								$5C_H$	R	FF_H
MOX	MONITOR Transmit Data								$5C_H$	W	FF_H
MOSR	MDR	MER	MDA	MAB	0	0	0	0	$5D_H$	R	00_H
MOCR	MRE	MRC	MIE	MXC	0	0	0	0	$5E_H$	R/W	00_H
MSTA	0	0	0	0	0	MAC	0	TOUT	$5F_H$	R	00_H
MCONF	0	0	0	0	0	0	0	TOUT	$5F_H$	W	00_H

Interrupt, General Configuration Registers

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
ISTA	0	0	ST	CIC	AUX	TRAN	MOS	0	60_H	R	00_H
MASK	1	1	ST	CIC	AUX	TRAN	MOS	1	60_H	W	FF_H
AUXI	0	0	EAW	WOV	TIN	0	0	0	61_H	R	00_H
AUXM	1	1	EAW	WOV	TIN	1	1	1	61_H	W	FF_H
MODE1	0	0	0	WTC1	WTC2	CFS	RSS2	RSS1	62_H	R/W	00_H
MODE2	0	0	0	0	INT_ POL	0	0	PPSDX	63_H	R/W	00_H
ID	0	0	DESIGN						64_H	R	01_H
SRES	RES_ CI	0	0	RES_ MON	0	RES_ IOM	RES_ TR	RES_ RSTO	64_H	W	00_H
TIMR	TMD	0	CNT						65_H	R/W	00_H
	reserved								66_H- $6F_H$		

4.1 Transceiver and C/I Registers

4.1.1 TR_MODE2 - Transceiver Mode Register 2

Value after reset: 00_H

	7							0	
TR_ MODE2	0	0	0	0	0	DIM2	DIM1	DIM0	RD/WR (22)

DIM2-0 ... Digital Interface Modes

These bits define the characteristics of the IOM Data Ports (DU, DD). The DIM0 bit enables/disables the collission detection. The DIM1 bit enables/disables the TIC bus access. The effect of the individual DIM bits is summarized in the table below**.**

DIM2	DIM1	DIM0	Characteristics
0		0	Transparent D-channel, the collission detection is disabled
0		1	Stop/go bit evaluated for D-channel access handling
0	0		Last octet of IOM channel 2 used for TIC bus access
0	1		TIC bus access is disabled
1	x	x	Reserved

Example: ’010’ selects transparent D-channel, collision detection disabled and TIC bus disabled.

4.1.2 CIR0 - Command/Indication Receive 0

Value after reset: $F3_H$

	7					0	
CIR0	CODR0		CIC0	CIC1	S/G	BAS	RD (2E)

CODR0 ... C/I Code 0 Receive

Value of the received Command/Indication code. A C/I-code is loaded in CODR0 only after being the same in two consecutive IOM-frames and the previous code has been read from CIR0.

CIC0 ... C/I Code 0 Change

A change in the received Command/Indication code has been recognized. This bit is set only when a new code is detected in two consecutive IOM-frames. It is reset by a read of CIR0.

CIC1 ... C/I Code 1 Change

A change in the received Command/Indication code in IOM-channel 1 has been recognized. This bit is set when a new code is detected in one IOM-frame. It is reset by a read of CIR0.

S/G ... Stop/Go Bit Monitoring

Indicates the availability of the upstream D-channel on the S/T interface.
1: Stop
0: Go

BAS ... Bus Access Status

Indicates the state of the TIC-bus:

0: the SBCX-X itself occupies the D- and C/I-channel
1: another device occupies the D- and C/I-channel

Note: The CODR0 bits are updated every time a new C/I-code is detected in two consecutive IOM-frames. If several consecutive valid new codes are detected and CIR0 is not read, only the first and the last C/I code is made available in CIR0 at the first and second read of that register, respectively.

4.1.3 CIX0 - Command/Indication Transmit 0

Value after reset: FE_H

	7				0	
CIX0	CODX0	TBA2	TBA1	TBA0	BAC	WR (2E)

CODX0 ... C/I-Code 0 Transmit

Code to be transmitted in the C/I-channel 0.
The code is only transmitted if the TIC bus is occupied. If TIC bus is enabled but occupied by another device, only “1s” are transmitted.

TBA2-0 ... TIC Bus Address

Defines the individual address for the SBCX-X on the IOM bus.

This address is used to access the C/I- and D-channel on the IOM interface.

Note: If only one device is liable to transmit in the C/I- and D-channels of the IOM it should always be given the address value ’7’.

BAC ... Bus Access Control

Only valid if the TIC-bus feature is enabled (MODED.DIM2-0).

If this bit is set, the SBCX-X will try to access the TIC-bus to occupy the C/I-channel even if no D-channel frame has to be transmitted. It should be reset when the access has been completed to grant a similar access to other devices transmitting in that IOM-channel.

Note: Access is always granted by default to the SBCX-X with TIC-Bus Address (TBA2-0, STCR register) ’7’, which has the lowest priority in a bus configuration.

4.1.4 CIR1 - Command/Indication Receive 1

Value after reset: FE_H

	7			0	
CIR1	CODR1	CICW	CI1E		RD (2F)

CODR1 ... C/I-Code 1 Receive

CICW, CI1E ... C/I-Channel Width, C/I-Channel 1 Interrupt Enable

These two bits contain the read back values from CIX1 register (see below).

4.1.5 CIX1 - Command/Indication Transmit 1

Value after reset: FE_H

	7							0	
CIX1	CODX1						CICW	CI1E	WR (2F)

CODX1 ... C/I-Code 1 Transmit

Bits 7-2 of C/I-channel 1 timeslot.

CICW... C/I-Channel Width

CICW selects between a 4 bit (’0’) and 6 bit (’1’) C/I1 channel width.

The C/I1 handler always reads and writes 6-bit values but if 4-bit is selected, the higher two bits are ignored for interrupt generation. However in write direction the full CODX1 code is transmitted, i.e. the host must write the higher two bits to “1”.

CI1E ... C/I-Channel 1 Interrupt Enable

Interrupt generation ISTA.CIC of CIR0.CIC1 is enabled (1) or masked (0).

4.1.6 TR_CONF0 - Transceiver Configuration Register 0

Value after reset: 01_H

	7							0	
TR_ CONF0	DIS_ TR	BUS	EN_ ICV	0	L1SW	0	EXLP	LDD	RD/WR (30)

DIS_TR ... Disable Transceiver

Setting DIS_TR to “1” disables the transceiver. In order to reenable the transceiver again, a transceiver reset must be issued (SRES.RES_TR = 1). The transceiver must not be reenabled by setting DIS_TR from “1” to “0”.

For general information please refer to **Chapter 3.3.9**.

BUS ... Point-to-Point / Bus Selection (NT/LT-S/Int. NT mode only)

0: Adaptive Timing (Point-to-Point, extended passive bus).
1: Fixed Timing (Short passive bus).

EN_ICV ... Enable Illegal Code Violation

0: normal operation

1: ICV enabled. The receipt of at least one illegal code violation within one multiframe is indicated by the C/I indication ’1011’ (CVR) in two consecutive IOM frames.

L1SW ... Enable Layer 1 State Machine in Software

0: Layer 1 state machine of the SBCX-X is used

1: Layer 1 state machine is disabled. The functionality can be realized in software. The commands can be written to register TR_CMD and the status can be read from TR_STA.

For general information please refer to **Chapter 3.5**.

EXLP ... External loop

In case the analog loopback is activated with C/I = ARL or with the LP_A bit in the TR_CMD register the loop is a

0: internal loop next to the line pins

1: external loop which has to be closed between SR1/2 and SX1/SX2

Note:The external loop is only useful if bit DIS_TX of register TR_CONF2 is set to ’0’.

For general information please refer to **Chapter 3.3.10**.

LDD ... Level Detection Discard

0: Automatic clock generation after detection of any signal on the line in power down state

1: No clock generation after detection of any signal on the line in power down state

Note: If an interrupt by the level detect circuitry is generated, the microcontroller has to set this bit to ’0’ for an activation of the S/T interface.

For general information please refer to **Chapter 3.3.8** and **Chapter 3.7.6**.

4.1.7 TR_CONF1 - Transceiver Configuration Register 1

Value after reset: $0x_H$

	7							0	
TR_CONF1	0	RPLL_ADJ	EN_SFSC	0	0	x	x	x	RD/WR (31)

RPLL_ADJ ... Receive PLL Adjustment

0: DPLL tracking step is 0.5 XTAL period per S-frame

1: DPLL tracking step is 1 XTAL period per S-frame

EN_SFSC ... Enable Short FSC

0: No short FSC is generated

1: A short FSC is generated once per multiframe (every 40th IOM frame)

x ... Undefined

The value of these bits depends on the selected mode. It is important to note that these bits must not be overwritten to a different value when accessing this register.

4.1.8 TR_CONF2 - Transmitter Configuration Register 2

Value after reset: 80_H

	7							0	
TR_CONF2	DIS_TX	PDS	0	RLP	0	0	SGP	SGD	RD/WR (32)

DIS_TX ... Disable Line Driver

0: Transmitter is enabled
1: Transmitter is disabled

For general information please refer to **Chapter 3.3.9**.

PDS ... Phase Deviation Select

Defines the phase deviation of the S-transmitter.
0: The phase deviation is 2 S-bits minus 7 oscillator periods plus analog delay plus delay of the external circuitry.
1: The phase deviation is 2 S-bits minus 9 oscillator periods plus analog delay plus delay of the external circuitry.

For general information please refer to **Chapter 3.3.7**.

RLP ... Remote Line Loop

0: Remote Line Loop open
1: Remote Line Loop closed
For general information please refer to **Chapter 3.3.10**.

SGP ... Stop/Go Bit Polarity

Defines the polarity of the S/G bit output on pin SGO.

0: low active (SGO=0 means “go”; SGO=1 means “stop”)
1: high active (SGO=1 means “go”; SGO=0 means “stop”)

SGD ... Stop/Go Bit Duration

Defines the duration of the S/G bit output on pin SGO.

0: active during the D-channel timeslot
1: active during the whole corresponding IOM frame (starts and ends with the beginning of the D-channel timeslot)

Note: Outside the active window of SGO (defined in SGD) the level on pin SGO remains in the “stop”-state depending on the selected polarity (SGP), i.e. SGO=1 (if SGP=0) or SGO=0 (if SGP=1) outside the active window.

4.1.9 TR_STA - Transceiver Status Register

Value after reset: 00_H

	7						0	
TR_STA	RINF	SLIP	ICV	0	FSYN	0	LD	RD (33)

Important: This register is used only if the Layer 1 state machine of the SBCX-X is disabled (TR_CONF0.L1SW = 1) and implemented in software! With the SBCX-X layer 1 state machine enabled, the signals from this register are automatically evaluated.

For general information please refer to **Chapter 3.5**.

RINF ... Receiver INFO

00: Received INFO 0
01: Received any signal except INFO 0,2,3,4
10: Reserved (NT mode) or INFO 2 (TE mode)
11: Received INFO 3 (NT mode) or INFO 4 (TE mode)

SLIP ... SLIP Detected

A ’1’ in this bit position indicates that a SLIP is detected in the receive or transmit path.

ICV ... Illegal Code Violation

0: No illegal code violation is detected
1: Illegal code violation (ANSI T1.605) in data stream is detected

FSYN ... Frame Synchronization State

0: The S/T receiver is not synchronized
1: The S/T receiver has synchronized to the framing bit F

LD ... Level Detection

0: No receive signal has been detected on the line.
1: Any receive signal has been detected on the line.

4.1.10 TR_CMD - Transceiver Command Register

Value after reset: 08_H

	7					0	
TR_CMD	XINF	DPRIO	TDDIS	PD	LP_A	0	RD/WR (34)

Important: This register is only writable if the Layer 1 state machine of the SBCX-X is disabled (TR_CONF0.L1SW = 1)! With the SBCX-X layer 1 state machine enabled, the signals from this register are automatically generated, but nevertheless this register can always be read.
DPRIO can also be written in intelligent NT mode.

XINF ... Transmit INFO

000: Transmit INFO 0
001: reserved
010: Transmit INFO 1 (TE mode) or INFO 2 (NT mode)
011: Transmit INFO 3 (TE mode) or INFO 4 (NT mode)
100: Send continous pulses at 192 kbit/s alternating or 96 kHz rectangular, respectively (SCP)
101: Send single pulses at 4 kbit/s with alternating polarity corresponding to 2 kHz fundamental mode (SSP)
11x: reserved

DPRIO ... D-Channel Priority (always writable in Int. NT mode)

0: Priority Class 1 for D channel access on IOM (Int. NT) or on S interface (TE/LT-T)
1: Priority Class 2 for D channel access on IOM (Int. NT) or on S interface (TE/LT-T)

TDDIS ... Transmit Data Disabled (TE mode)

0: The B and D channel data are transparently transmitted on the S/T interface if INFO 3 is being transmitted
1: The B and D channel data are set to logical ’1’ on the S/T interface if INFO 3 is being transmitted

PD ... Power Down

0: The transceiver is set to operational mode
1: The transceiver is set to power down mode

For general information please refer to **Chapter 3.5.1.2**.

LP_A ... Loop Analog

The setting of this bit corresponds to the C/I command ARL.

0: Analog loop is open

1: Analog loop is closed internally or externally according to the EXLP bit in the TR_CONF0 register

For general information please refer to **Chapter 3.3.10**.

4.1.11 SQRR1 - S/Q-Channel Receive Register 1

Value after reset: 40_H

	7							0	
SQRR	MSYN	MFEN	0	0	SQR11	SQR12	SQR13	SQR14	RD (35)

For general information please refer to **Chapter 3.3.2**.

MSYN ... Multiframe Synchronization State

0: The S/T receiver has not synchronized to the received F_A and M bits

1: The S/T receiver has synchronized to the received F_A and M bits

MFEN ... Multiframe Enable

Read-back of the MFEN bit of the SQXR register

SQR11-14 ... Received S Bits

Received S bits in frames 1, 6, 11 and 16 (TE mode)
received Q bits in frames 1, 6, 11 and 16 (NT mode).

4.1.12 SQXR1- S/Q-Channel TX Register 1

Value after reset: $4F_H$

	7							0	
SQXR1	0	MFEN	0	0	SQX11	SQX12	SQX13	SQX14	WR (35)

MFEN ... Multiframe Enable

Used to enable or disable the multiframe structure (see **Chapter 3.3.2**)

0: S/T multiframe is disabled
1: S/T multiframe is enabled
Readback value in SQRR1.

SQX11-14 ... Transmitted S/Q Bits

Transmitted Q bits (F_A bit position) in frames 1, 6, 11 and 16 (TE mode), transmitted S bits (F_A bit position) in frames 1, 6, 11 and 16 (NT mode).

4.1.13 SQRR2 - S/Q-Channel Receive Register 2

Value after reset: 00_H

	7							0	
SQRR2	SQR21	SQR22	SQR23	SQR24	SQR31	SQR32	SQR33	SQR34	RD (36)

SQR21-24, SQR31-34... Received S Bits (TE mode only)

Received S bits in frames 2, 7, 12 and 17 (SQR21-24, subchannel 2), and in frames 3, 8, 13 and 18 (SQR31-34, subchannel 3).

4.1.14 SQXR2 - S/Q-Channel TX Register 2

Value after reset: 00_H

	7							0	
SQXR2	SQX21	SQX22	SQX23	SQX24	SQX31	SQX32	SQX33	SQX34	WR (36)

SQX21-24, SQX31-34... Transmitted S Bits (NT mode only)

Transmitted S bits in frames 2, 7, 12 and 17 (SQX21-24, subchannel 2), and in frames 3, 8, 13 and 18 (SQX31-34, subchannel 3).

4.1.15 SQRR3 - S/Q-Channel Receive Register 3

Value after reset: 00_H

	7							0	
SQRR3	SQR41	SQR42	SQR43	SQR44	SQR51	SQR52	SQR53	SQR54	RD (37)

SQR41-44, SQR51-54... Received S Bits (TE mode only)

Received S bits in frames 4, 9, 14 and 19 (SQR41-44, subchannel 4), and in frames 5, 10, 15 and 20 (SQR51-54, subchannel 5).

4.1.16 SQXR3 - S/Q-Channel TX Register 3

Value after reset: 00_H

	7							0	
SQXR3	SQX41	SQX42	SQX43	SQX44	SQX51	SQX52	SQX53	SQX54	WR (37)

SQX41-44, SQX51-54... Transmitted S Bits (NT mode only)

Transmitted S bits in frames 4, 9, 14 and 19 (SQX41-44, subchannel 4), and in frames 5, 10, 15 and 20 (SQX51-54, subchannel 5).

4.1.17 ISTATR - Interrupt Status Register Transceiver

Value after reset: 00_H

	7							0	
ISTATR	0	x	x	x	LD	RIC	SQC	SQW	RD (38)

For all interrupts in the ISTATR register the following logical states are defined:

0: Interrupt is not acitvated
1: Interrupt is acitvated

x ... Reserved

Bits set to “1” in this bit position must be ignored.

LD ... Level Detection

Any receive signal has been detected on the line. This bit is set to “1” (i.e. an interrupt is generated if not masked) as long as any receiver signal is detected on the line.

RIC ... Receiver INFO Change

RIC is activated if one of the TR_STA bits RINF or ICV has changed. This bit is reset by reading the TR_STA register.

SQC ... S/Q-Channel Change

A change in the received S-channel (TE) or Q-channel (NT) has been detected. The new code can be read from the SQRxx bits of registers SQRR1-3 within the duration of the next multiframe (5 ms). This bit is reset by a read access to the corresponding SQRRx register.

SQW ... S/Q-Channel Writable

The S/Q channel data for the next multiframe is writable.
The register for the Q (S) bits to be transmitted (received) has to be written (read) within the duration of the next multiframe (5 ms). This bit is reset by writing register SQXRx.

4.1.18 MASKTR - Mask Transceiver Interrupt

Value after reset: FF_H

	7							0	
MASKTR	1	1	1	1	LD	RIC	SQC	SQW	RD/WR (39)

The transceiver interrupts LD, RIC, SQC and SQW are enabled (0) or disabled (1).

4.1.19 TR_MODE - Transceiver Mode Register 1

Value after reset: $000000xx_B$

	7							0	
TR_MODE	0	0	0	0	DCH_INH	MODE2	MODE1	MODE0	RD/WR (3A)

For general information please refer also to **Chapter 3.7.5.4**.

DCH_INH ... D-Channel Inhibit (NT, LT-S, Int. NT mode only)

Setting this bit to ’1’ has the effect that the S-transceiver blocks the access to the D-channel on S by inverting the E-bits.

The pin DCI, which performs the same funtion, is internally combined (EXOR-logic) with DCH_INH, i.e. either setting the bit to ’1’ or pulling the pin high will block the D-channel access, however activating pin and bit simultaneously must not be done.

If this bit was not set before, reading DCH_INH reflects the status on pin DCI, i.e. the D-channel inhibit function is controlled by the pin. If the function should be controlled by programming DCH_INH, the pin DCI must be strapped to “0” or “1”.

MODE2-0 ... Transceiver Mode

000: TE mode
001: LT-T mode
010: NT mode
011: LT-S mode
110: Intelligent NT mode (with NT state machine)
111: Intelligent NT mode (with LT-S state machine)
100: reserved
101: reserved

Note: The three modes TE, LT-T and LT-S can be selected by pin strapping (reset values for bits TR_MODE.MODE0,1 loaded from pins MODE0,1), all other modes are programmable only.

4.2 Auxiliary Interface Registers

4.2.1 ACFG1 - Auxiliary Configuration Register 1

Value after reset: 00_H

	7							0	
ACFG1	0	0	0	0	0	OD2	OD1	OD0	RD/WR (3C)

For general information please refer to **Chapter 3.8**.

OD2-0 ... Output Driver Select for AUX2 - AUX0

0: output is open drain
1: output is push/pull

Note: The ODx configuration is only valid if the corresponding output is enabled in the AOE register.
AUX0-2 are only available in TE and Int. NT mode and not in all other modes (used as channel select).

4.2.2 ACFG2 - Auxiliary Configuration Register 2

Value after reset: 00_H

	7							0	
ACFG2	0	0	0	0	ACL	LED	0	0	RD/WR (3D)

ACL ... $\overline{\text{ACL}}$ Function Select

0: Pin $\overline{\text{ACL}}$ automatically indicates the S-bus activation status by a LOW level.

1: The output state of $\overline{\text{ACL}}$ is programmable by the host in bit LED.

Note: An LED with preresistance may directly be connected to $\overline{ACL}$.

LED ... LED Control

If enabled (ACL=1) the LED with preresistance connected between VDD and $\overline{\text{ACL}}$ is switched ...

0: Off (high level on pin $\overline{\text{ACL}}$)

1: On (low level on pin $\overline{\text{ACL}}$)

4.2.3 AOE - Auxiliary Output Enable Register

Value after reset: FF_H

	7							0	
AOE	1	1	1	1	1	OE2	OE1	OE0	RD/WR (3E)

For general information please refer to **Chapter 3.8**.

OE2-0 ... Output Enable for AUX2 - AUX0

0: Pin AUX2-0 is configured as output. The value of the corresponding bit in the ATX register is driven on AUX2-0.

1: Pin AUX2-0 is configured as input. The value of the corresponding bit can be read from the ARX register.

Note: In NT and LT modes the pins AUX0-2 are not available as I/O pins.

4.2.4 ARX - Auxiliary Interface Receive Register

Value after reset: (not defined)

	7							0	
ARX	-	-	-	-	-	AR2	AR1	AR0	RD (3F)

AR2-0 ... Auxiliary Receive

The value of AR2-0 always reflects the level at pin AUX2-0 at the time when ARX is read by the host even if a pin is configured as output.

Note: In NT and LT modes the pins AUX0-2 are not available as I/O pins.

4.2.5 ATX - Auxiliary Interface Transmit Register

Value after reset: 00_H

	7							0	
ATX	0	0	0	0	0	AT2	AT1	AT0	WR (3F)

AT2-0 ... Auxiliary Transmit

A ’0’ or ’1’ in AT2-0 will drive a low or a high level at pin AUX2-0 if the corresponding output is enabled in the AOE register.

Note: In NT and LT modes the pins AUX0-2 are not available as I/O pins.

4.3 IOM-2 and MONITOR Handler

4.3.1 CDAxy - Controller Data Access Register xy

	7							0	
CDAxy	Controller Data Access Register								RD/WR (40-43)

Data registers CDAxy which can be accessed from the controller.

Register	Register Address	Value after Reset
CDA10	40_H	FF_H
CDA11	41_H	FF_H
CDA20	42_H	FF_H
CDA21	43_H	FF_H

4.3.2 XXX_TSDPxy - Time Slot and Data Port Selection for CHxy

	7				0	
XXX_ TSDPxy	DPS	0	0	TSS		RD/WR (44-4D)

Register	Register Address	Value after Reset
CDA_TSDP10	44_H	00_H (= output on B1-DD)
CDA_TSDP11	45_H	01_H (= output on B2-DD)
CDA_TSDP20	46_H	80_H (= output on B1-DU)
CDA_TSDP21	47_H	81_H (= output on B2-DU)
TR_TSDP_BC1	$4C_H$	00_H (= transceiver output on B1-DD), see note
TR_TSDP_BC2	$4D_H$	01_H (= transceiver output on B2-DD), see note

This register determines the time slots and the data ports on the IOM-2 interface for the data channels 'xy' of the functional units 'XXX' which are Controller Data Access (CDA) and Transceiver (TR). The position of B-channel data from the S-interface is programmed in TR_TSDP_BC1 and TR_TSDP_BC2.

DPS ... Data Port Selection

0:The data channel xy of the functional unit XXX is output on DD.
The data channel xy of the functional unit XXX is input from DU.
1:The data channel xy of the functional unit XXX is output on DU.
The data channel xy of the functional unit XXX is input from DD.

Note: For the CDA (controller data access) data the input is determined by the CDA_CRx.SWAP bit. If SWAP = '0' the input for the CDAxy data is vice versa to the output setting for CDAxy. If the SWAP = '1' the input from CDAx0 is vice versa to the output setting of CDAx1 and the input from CDAx1 is vice versa to the output setting of CDAx0. See controller data access description in ***Chapter 3.7.1.1****.*

TSS ... Timeslot Selection

Selects one of 32 timeslots (0...31) on the IOM-2 interface for the data channels.

Note: The reset values for TR_TSDP_BC1/2 are depending on the mode selection (MODE0/1) and channel selection (CH0-2).

4.3.3 CDAx_CR - Control Register Controller Data Access CH1x

	7							0	
CDAx_CR	0	0	EN_TBM	EN_I1	EN_I0	EN_O1	EN_O0	SWAP	RD/WR (4E-4F)

Register	Register Address	Value after Reset
CDA1_CR	$4E_H$	00_H
CDA2_CR	$4F_H$	00_H

For general information please refer to **Chapter 3.7.1.1**.

EN_TBM ... Enable TIC Bus Monitoring

0: The TIC bus monitoring is disabled

1: The TIC bus monitoring with the CDAx0 register is enabled. The TSDPx0 register must be set to 08_H for monitoring from DU or 88_H for monitoring from DD, respectively. (This selection is only valid if IOM_CR.TIC_DIS = 0).

EN_I1, EN_I0 ... Enable Input CDAx0, CDAx1

0: The input of the CDAx0, CDAx1 register is disabled

1: The input of the CDAx0, CDAx1 register is enabled

EN_O1, EN_O0 ... Enable Output CDAx0, CDAx1

0: The output of the CDAx0, CDAx1 register is disabled

1: The output of the CDAx0, CDAx1 register is enabled

SWAP ... Swap Inputs

0: The time slot and data port for the input of the CDAxy register is defined by its own TSDPxy register. The data port for the CDAxy input is vice versa to the output setting for CDAxy.

1: The input (time slot and data port) of the CDAx0 is defined by the TSDP register of CDAx1 and the input of CDAx1 is defined by the TSDP register of CDAx0. The data port for the CDAx0 input is vice versa to the output setting for CDAx1. The data port for the CDAx1 input is vice versa to the output setting for CDAx0. The input definition for time slot and data port CDAx0 are thus swapped to CDAx1 and for CDAx1 to CDAx0. The outputs are not affected by the SWAP bit.

4.3.4 TR_CR - Control Register Transceiver Data (IOM_CR.CI_CS=0)

Value after reset: $F8_H$

	7					0	
TR_CR	EN_D	EN_B2R	EN_B1R	EN_B2X	EN_B1X	CS2-0	RD/WR (50)

Read and write access to this register is only possible if IOM_CR.CI_CS = 0.

EN_D ... Enable Transceiver D-Channel Data
EN_B2R ... Enable Transceiver B2 Receive Data
EN_B1R ... Enable Transceiver B1 Receive Data
EN_B2X ... Enable Transceiver B2 Transmit Data
EN_B1X ... Enable Transceiver B1 Transmit Data

This register is used to individually enable/disable the D-channel (both RX and TX direction) and the receive/transmit paths for the B-channels of the S-transceiver.

0: The corresponding data path to the transceiver is disabled.
1: The corresponding data path to the transceiver is enabled.

Note: "Receive Data" refers to the data which is received on the S interface and forwarded to IOM-2. "Transmit data" refers to the data which is coming from IOM-2 and transmitted on the S interface.

CS2-0 ... Channel Select for Transceiver D-channel

This register is used to select one of eight IOM channels to which the transceiver D-channel data is related to.

Note: The reset value is determined by the channel select pins CH2-0 which are directly mapped to CS2-0. It should be noted that writing TR_CR.CS2-0 will also write to TRC_CR.CS2-0 and therefore modify the channel selection for the transceiver C/I0 data.

4.3.5 TRC_CR - Control Register Transceiver C/I0 (IOM_CR.CI_CS=1)

Value after reset: 00_H

	7					0	
TRC_CR	0	0	0	0	0	CS2-0	RD/WR (50)

Write access to this register is possible if IOM_CR.CI_CS = 0 or IOM_CR.CI_CS = 1.
Read access to this register is possible only if IOM_CR.CI_CS = 1.

CS2-0 ... Channel Select for the Transceiver C/I0 Channel

This register is used to select one of eight IOM channels to which the transceiver C/I0 channel data is related to. The reset value is determined by the channel select pins CH2-0 and the MODE2-bit.

4.3.6 DCI_CR - Control Register for CI1 Handler (IOM_CR.CI_CS=0)

Value after reset: 80_H

	7							0	
DCI_CR	DPS_ CI1	EN_ CI1	0	0	0	0	0	0	RD/WR (53)

Read and write access to this register is only possible if IOM_CR.CI_CS = 0. It should be noted that a writing the DCI_CR register will also perform a write access to DCIC_CR, i.e. the lower 3 bits of DCI_CR will be written to DCIC_CR.CS2-0.

DPS_CI1 ... Data Port Selection CI1 Handler Data

0: The CI1 handler data is output on DD and input from DU
1: The CI1 handler data is output on DU and input from DD

EN_CI1 ... Enable CI1 Handler Data

0: CI1 handler data access is disabled
1: CI1 handler data access is enabled

Note: The timeslot for the C/I1 handler cannot be programmed but is fixed to IOM channel 1.

4.3.7 DCIC_CR - Control Register for CI0 Handler (IOM_CR.CI_CS=1)

Value after reset: 00_H

	7					0	
DCIC_CR	0	0	0	0	0	CS2-0	RD/WR (53)

Write access to this register is possible if IOM_CR.CI_CS = 0 or IOM_CR.CI_CS = 1.
Read access to this register is possible only if IOM_CR.CI_CS = 1.

CS2-0 ... Channel Select for C/I0 Handler

This register is used to select one of eight IOM channels. If enabled, the data of the C/I0 handler is connected to the corresponding C/I0 timeslot of that IOM channel.

The reset value is determined by the channel select pins CH2-0 which are mapped to CS2-0.

4.3.8 MON_CR - Control Register Monitor Data

Value after reset: 40_H

	7					0	
MON_CR	DPS	EN_ MON	0	0	0	CS2-0	RD/WR (54)

For general information please refer to **Chapter 3.7.3**.

DPS ... Data Port Selection

0: The Monitor data is output on DD and input from DU

1: The Monitor data is output on DU and input from DD

EN_MON ... Enable Output

0: The Monitor data input and output is disabled

1: The Monitor data input and output is enabled

CS2-0 ... MONITOR Channel Selection

000: The MONITOR data is input/output on MON0 (3rd timeslot on IOM-2)

001: The MONITOR data is input/output on MON1 (7th timeslot on IOM-2)

010: The MONITOR data is input/output on MON2 (11th timeslot on IOM-2)

:

111: The MONITOR data is input/output on MON7 (31st timeslot on IOM-2)

Note: The reset value is determined by the channel select pins CH2-0 which are directly mapped to CS2-0.

4.3.9 SDSx_CR - Control Register Serial Data Strobe x

Value after reset: 00_H

	7				0	
SDSx_CR	ENS_ TSS	ENS_ TSS+1	ENS_ TSS+3	TSS		RD/WR (55-56)

Register	Register Address	Value after Reset
SDS1_CR	55_H	00_H
SDS2_CR	56_H	00_H

This register is used to select position and length of the strobe signals. The length can be any combination of two 8-bit timeslot (ENS_TSS, ENS_TSS+1) and one 2-bit timeslot (ENS_TSS+3).

For general information please refer to **Chapter 3.7.2** and **Chapter 3.7.2.2**.

ENS_TSS ... Enable Serial Data Strobe of timeslot TSS
ENS_TSS+1 ... Enable Serial Data Strobe of timeslot TSS+1

0: The serial data strobe signal SDSx is inactive during TSS, TSS+1

1: The serial data strobe signal SDSx is active during TSS, TSS+1

ENS_TSS+3 ... Enable Serial Data Strobe of timeslot TSS+3 (D-Channel)

0: The serial data strobe signal SDSx is inactive during the D-channel (bit7, 6) of TSS+3

1: The serial data strobe signal SDSx is active during the D-channel (bit7, 6) of TSS+3

TSS ... Timeslot Selection

Selects one of 32 timeslots on the IOM-2 interface (with respect to FSC) during which SDSx is active high or provides a strobed BCL clock output (see SDS_CONF.SDS1/2_BCL). The data strobe signal allows standard data devices to access a programmable channel.

4.3.10 IOM_CR - Control Register IOM Data

Value after reset: 08_H

	7							0	
IOM_CR	SPU	DIS_ AW	CI_CS	TIC_ DIS	EN_ BCL	CLKM	DIS_ OD	DIS_ IOM	RD/WR (57)

SPU ... Software Power Up

0: The DU line is normally used for transmitting data

1: Setting this bit to ’1’ will pull the DU line to low. This will enforce connected layer 1 devices to deliver IOM-clocking.

After a subsequent ISTA.CIC-interrupt (C/I-code change) and reception of the C/I-code ”PU” (Power Up indication in TE-mode) the microcontroller writes an AR or TIM command as C/I-code in the CIX0-register, resets the SPU bit and waits for the following CIC-interrupt.

For general information please refer to **Chapter 3.7.6**.

DIS_AW ... Disable Asynchronous Awake (for NT, LT-S and Int. NT mode)

Setting this bit to “1” disables the Asynchronous Awake function of the transceiver.

CI_CS ... C/I Channel Selection

The channel selection for D-channel and C/I-channel is done in the channel select bits CH2-0 of register TR_CR (for the transceiver) and DCI_CR (for the C/I-channel controller).

0: A write access to CS2-0 has effect on the configuration of D- and C/I-channel, whereas a read access delivers the D-channel configuration only.

1: A write access to CS2-0 has effect on the configuration of the C/I-channel only, whereas a read access delivers the C/I-channel configuration only.

TIC_DIS ... TIC Bus Disable

0: The last octet of IOM channel 2 (12th timeslot) is used as TIC bus (in a frame timing mode with 12 timeslots only).

1: The TIC bus is disabled. The last octet of the last IOM time slot (TS 11) can be used as every time slot.

EN_BCL ... Enable Bit Clock BCL/SCLK

0: The BCL/SCLK clock is disabled
1: The BCL/SCLK clock is enabled.

CLKM ... Clock Mode

If the transceiver is disabled (DIS_TR = ’1’) or in NT, LT-S and Int. NT mode the DCL from the IOM-2 interface is an input.

0: A double bit clock is connected to DCL

1: A single bit clock is connected to DCL

For general information please refer to **Chapter 3.7**.

DIS_OD ... Disable Open Drain Drivers

0: DU/DD are open drain drivers

1: DU/DD are push pull drivers

DIS_IOM ... Disable IOM

DIS_IOM should be set to ’1’ if external devices connected to the IOM interface should be “disconnected“ e.g. for power saving purposes or for not disturbing the internal IOM connection. However, the SBCX-X internal operation is independent of the DIS_IOM bit.

0: The IOM interface is enabled

1: The IOM interface is disabled. The FSC, DCL clock outputs have high impedance; clock inputs are active; DU, DD data line inputs are switched off and outputs have high impedance; except in TE/LT-T mode the DU line is input (“0”-level causes activation), so the DU pin must be terminated (pull up resistor).

4.3.11 STI - Synchronous Transfer Interrupt

Value after reset: 00_H

	7							0	
STI	STOV 21	STOV 20	STOV 11	STOV 10	STI 21	STI 20	STI 11	STI 10	RD (58)

For all interrupts in the STI register the following logical states are applied:

0: Interrupt is not activated
1: Interrupt is activated

The interrupts are automatically reset by reading the STI register. For general information please refer to **Chapter 3.7.1.1**.

STOVxy ... Synchronous Transfer Overflow Interrupt

Enabled STOV interrupts for a certain STIxy interrupt are generated when the STIxy has not been acknowledged in time via the ACKxy bit in the ASTI register. This must be one (for DPS='0') or zero (for DPS='1') BCL clocks before the time slot which is selected for the STOV.

STIxy ... Synchronous Transfer Interrupt

Depending on the DPS bit in the corresponding TSDPxy register the Synchronous Transfer Interrupt STIxy is generated two (for DPS='0') or one (for DPS='1') BCL clock after the selected time slot (TSDPxy.TSS).

Note: STOVxy and ACKxy are useful for synchronizing microcontroller accesses and receive/transmit operations. One BCL clock is equivalent to two DCL clock cycles.

4.3.12 ASTI - Acknowledge Synchronous Transfer Interrupt

Value after reset: 00_H

	7							0	
ASTI	0	0	0	0	ACK 21	ACK 20	ACK 11	ACK 10	WR (58)

For general information please refer to **Chapter 3.7.1.1**.

ACKxy ... Acknowledge Synchronous Transfer Interrupt

After an STIxy interrupt the microcontroller has to acknowledge the interrupt by setting the corresponding ACKxy bit to “1”.

4.3.13 MSTI - Mask Synchronous Transfer Interrupt

Value after reset: FF_H

	7							0	
MSTI	STOV 21	STOV 20	STOV 11	STOV 10	STI 21	STI 20	STI 11	STI 10	RD/WR (59)

For the MSTI register the following logical states are applied:

0: Interrupt is not masked
1: Interrupt is masked

For general information please refer to **Chapter 3.7.1.1**.

STOVxy ... Synchronous Transfer Overflow for STIxy

Mask bits for the corresponding STOVxy interrupt bits.

STIxy ... Synchronous Transfer Interrupt xy

Mask bits for the corresponding STIxy interrupt bits.

4.3.14 SDS_CONF - Configuration Register for Serial Data Strobes

Value after reset: 00_H

	7							0	
SDS_ CONF	0	0	0	0	DIOM_ INV	DIOM_ SDS	SDS2_ BCL	SDS1_ BCL	RD/WR (5A)

For general information on SDS1/2_BCL please refer to **Chapter 3.7.2**.

DIOM_INV ... DU/DD on IOM Timeslot Inverted

0: DU/DD are active during SDS1 HIGH phase and inactive during the LOW phase.
1: DU/DD are active during SDS1 LOW phase and inactive during the HIGH phase.
This bit has only effect if DIOM_SDS is set to ’1’ otherwise DIOM_INV is don’t care.

DIOM_SDS ... DU/DD on IOM Controlled via SDS1

0: The pin SDS1 and its configuration settings are used for serial data strobe only. The IOM-2 data lines are not affected.
1: The DU/DD lines are deactivated during the High/Low phase (selected via DIOM_INV) of the SDS1 signal. The SDS1 timeslot is selected in SDS1_CR.

SDSx_BCL ... Enable IOM Bit Clock for SDSx

0: The serial data strobe is generated in the programmed timeslot.
1: The IOM bit clock is generated in the programmed timeslot.

4.3.15 MCDA - Monitoring CDA Bits

Value after reset: FF_H

	7						0		
MCDA	MCDA21		MCDA20		MCDA11		MCDA10		RD (5B)
	Bit7	Bit6	Bit7	Bit6	Bit7	Bit6	Bit7	Bit6	

MCDAxy ... Monitoring CDAxy Bits

Bit 7 and Bit 6 of the CDAxy registers are mapped into the MCDA register.

This can be used for monitoring the D-channel bits on DU and DD and the 'Echo bits' on the TIC bus with the same register

4.3.16 MOR - MONITOR Receive Channel

Value after reset: FF_H

	7							0	
MOR	Monitor Receiver Data								RD (5C)

Contains the MONITOR data received in the IOM-2 MONITOR channel according to the MONITOR channel protocol. The MONITOR channel (0-7) can be selected by setting the monitor channel select bit MON_CR.MCS.

4.3.17 MOX - MONITOR Transmit Channel

Value after reset: FF_H

	7							0	
MOX	Monitor Transmit Data								WR (5C)

Contains the MONITOR data to be transmitted in IOM-2 MONITOR channel according to the MONITOR channel protocol.The MONITOR channel (0-7) can be selected by setting the monitor channel select bit MON_CR.MCS

4.3.18 MOSR - MONITOR Interrupt Status Register

Value after reset: 00_H

	7							0	
MOSR	MDR	MER	MDA	MAB	0	0	0	0	RD (5D)

MDR ... MONITOR channel Data Received

MER ... MONITOR channel End of Reception

MDA ... MONITOR channel Data Acknowledged

The remote end has acknowledged the MONITOR byte being transmitted.

MAB ... MONITOR channel Data Abort

4.3.19 MOCR - MONITOR Control Register

Value after reset: 00_H

	7							0	
MOCR	MRE	MRC	MIE	MXC	0	0	0	0	RD/WR (5E)

MRE ... MONITOR Receive Interrupt Enable

0: MONITOR interrupt status MDR generation is masked

1: MONITOR interrupt status MDR generation is enabled

MRC ... MR Bit Control

Determines the value of the MR bit:

0: MR is always ’1’. In addition, the MDR interrupt is blocked, except for the first byte of a packet (if MRE = 1).

1: MR is internally controlled by the SBCX-X according to MONITOR channel protocol. In addition, the MDR interrupt is enabled for all received bytes according to the MONITOR channel protocol (if MRE = 1).

MIE ... MONITOR Interrupt Enable

MONITOR interrupt status MER, MDA, MAB generation is enabled (1) or masked (0).

MXC ... MX Bit Control

Determines the value of the MX bit:
0: The MX bit is always ’1’.
1: The MX bit is internally controlled by the SBCX-X according to MONITOR channel protocol.

4.3.20 MSTA - MONITOR Status Register

Value after reset: 00_H

MSTA	0	0	0	0	0	MAC	0	TOUT	RD (5F)

MAC ... MONITOR Transmit Channel Active

The data transmisson in the MONITOR channel is in progress.

TOUT ... Time-Out

Read-back value of the TOUT bit.

4.3.21 MCONF - MONITOR Configuration Register

Value after reset: 00_H

MCONF	0	0	0	0	0	0	0	TOUT	WR (5F)

TOUT... Time-Out

0: The monitor time-out function is disabled
1: The monitor time-out function is enabled

4.4 Interrupt and General Configuration

4.4.1 ISTA - Interrupt Status Register

Value after reset: 00_H

	7							0	
ISTA	0	0	ST	CIC	AUX	TRAN	MOS	0	RD (60)

For all interrupts in the ISTA register following logical states are applied:

0: Interrupt is not acitvated
1: Interrupt is acitvated

ST ... Synchronous Transfer

This interrupt is generated to enable the microcontroller to lock on to the IOM timing for synchronous transfers. The source can be read from the STI register.

CIC ... C/I Channel Change

A change in C/I channel 0 or C/I channel 1 has been recognized. The actual value can be read from CIR0 or CIR1.

AUX ... Auxiliary Interrupts

Signals an interrupt generated from external awake (pin $\overline{\text{EAW}}$), watchdog timer overflow (WOV) or from the timer (TIN). The source can be read from the auxiliary interrupt register AUXI.

TRAN ... Transceiver Interrupt

An interrupt originated in the transceiver interrupt status register (ISTATR) has been recognized.

MOS ... MONITOR Status

A change in the MONITOR Status Register (MOSR) has occured.

Note: A read of the ISTA register clears none of the interrupts. They are only cleared by reading the corresponding status register.

4.4.2 MASK - Mask Register

Value after reset: FF_H

	7							0	
MASK	1	1	ST	CIC	AUX	TRAN	MOS	1	WR (60)

For the MASK register following logical states are applied:

0: Interrupt is enabled
1: Interrupt is disabled

Each interrupt source in the ISTA register can selectively be masked/disabled by setting the corresponding bit in MASK to ’1’. Masked interrupt status bits are not indicated when ISTA is read. Instead, they remain internally stored and pending, until the mask bit is reset to ’0’.

Note: In the event of a C/I channel change, CIC is set in ISTA even if the corresponding mask bit in MASK is set, but no interrupt is generated.

4.4.3 AUXI - Auxiliary Interrupt Status Register

Value after reset: 00_H

	7							0	
AUXI	0	0	EAW	WOV	TIN	0	0	0	RD (61)

For all interrupts in the ISTA register following logical states are applied:

0: Interrupt is not acitvated
1: Interrupt is acitvated

EAW ... External Awake Interrupt

An interrupt from the $\overline{\text{EAW}}$ pin has been detected.

WOV ... Watchdog Timer Overflow

Signals the expiration of the watchdog timer, which means that the microcontroller has failed to set the watchdog timer control bits WTC1 and WTC2 (MODE1 register) in the correct manner. A reset pulse has been generated by the SBCX-X.

TIN ... Timer Interrupt

An interrupt originated from the timer is recognized, i.e the timer has expired.

4.4.4 AUXM - Auxiliary Mask Register

Value after reset: FF_H

	7							0	
AUXM	1	1	EAW	WOV	TIN	1	1	1	WR (61)

For the MASK register following logical states are applied:

0: Interrupt is enabled
1: Interrupt is disabled

Each interrupt source in the AUXI register can selectively be masked/disabled by setting the corresponding bit in AUXM to ’1’. Masked interrupt status bits are not indicated when AUXI is read. Instead, they remain internally stored and pending, until the mask bit is reset to ’0’.

4.4.5 MODE1 - Mode1 Register

Value after reset: 00_H

	7							0	
MODE1	0	0	0	WTC1	WTC2	CFS	RSS2	RSS1	RD/WR (62)

WTC1, 2 ... Watchdog Timer Control 1, 2

After the watchdog timer mode has been selected (RSS = ’11’) the watchdog timer is started. During every time period of 128 ms the microcontroller has to program the WTC1 and WTC2 bit in the following sequence

	WTC1	WTC2
1.	1	0
2.	0	1

to reset and restart the watchdog timer.
If WTC1/2 is not written fast enough in this way, the timer expires and a WOV-interrupt (AUXI register) together with a reset pulse is generated.

CFS ... Configuration Select

This bit determines clock relations and recovery on S/T and IOM interfaces.

0: The IOM interface clock and frame signals are always active, "Power Down" state included.
The states "Power Down" and "Power Up" are thus functionally identical except for the indication: PD = 1111 and PU = 0111.
With the C/I command Timing (TIM) the microcontroller can enforce the "Power Up" state and with C/I command Deactivation Indication (DI) the "Power Down" state is reached again.
However, it is also possible to activate the S-interface directly with the C/I command Activate Request (AR 8/10/L) without the TIM command.

1: The IOM interface clock and frame signals are normally inactive ("Power Down").
For activating the IOM-2 clocks the "Power Up" state can be induced by software (IOM_CR.SPU) or by resetting CFS again.
After that the S-interface can be activated with the C/I command Activate Request (AR 8/10/L). The "Power Down" state can be reached again with the C/I command Deactivation Indication (DI).

Note: After reset the IOM interface is always active. To reach the "Power Down" state the CFS-bit has to be set.

For general information please refer to **Chapter 3.3.8**.

RSS2, RSS1... Reset Source Selection 2,1

The SBCX-X reset sources for the $\overline{\text{RSTO}}$ output pin can be selected according to the table below.

RSS		C/I Code Change	EAW	Watchdog Timer
Bit 1	Bit 0			
0	0	--	--	--
0	1	(reserved)		
1	0	x	x	--
1	1	--	--	x

- If RSS = ’00’ no above listed reset source is selected and therefore no reset is generated at $\overline{\text{RSTO}}$.
- **Watchdog Timer**
  After the selection of the watchdog timer (RSS = ’11’) the timer is reset and started. During every time period of 128 ms the microcontroller has to program the WTC1 and WTC2 bits in two consecutive bit pattern (see description of the WTC1, 2 bits) otherwise the watchdog timer expires and a reset pulse of 125 µs ≤ t≤ 250 µs is generated. Deactivation of the watchdog timer is only possible with a hardware reset.
- If RSS = ’10’ is selected the following two reset sources generate a reset pulse of 125 µs ≤ t ≤ 250 µs at the $\overline{\text{RSTO}}$ pin:
  - External (Subscriber) Awake ($\overline{\text{EAW}}$)
  The **$\overline{\text{EAW}}$** input pin serves as a request signal from the subscriber to initiate the awake function in a terminal and generates a reset pulse (in TE mode only).
  - Exchange Awake (C/I Code)
  A C/I Code change generates a reset pulse.

After a reset pulse generated by the SBCX-X and the corresponding interrupt (WOV or CIC) the actual reset source can be read from the ISTA.

4.4.6 MODE2 - Mode2 Register

Value after reset: 00_H

	7							0	
MODE2	0	0	0	0	INT_ POL	0	0	PPSDX	RD/WR (63)

INT_POL ... Interrupt Polarity

Selects the polarity of the interrupt pin $\overline{\text{INT}}$.
0: low active with open drain characteristic (default)
1: high active with push pull characteristic

PPSDX ... Push/Pull Output for SDX (SCI Interface)

0: The SDX pin has open drain characteristic
1: The SDX pin has push/pull characteristic

4.4.7 ID - Identification Register

Value after reset: 01_H

	7							0	
ID	0	0	DESIGN						RD (64)

DESIGN ... Design Number

The design number allows to identify different hardware designs of the SBCX-X by software.

01_H: Version 1.4

(all other codes reserved)

4.4.8 SRES - Software Reset Register

Value after reset: 00_H

	7							0	
SRES	RES_ CI	0	0	RES_ MON	0	RES_ IOM	RES_ TR	RES_ RSTO	WR (64)

RES_xx ... Reset Functional Block xx

A reset can be activated on the functional block C/I-handler, Monitor channel, IOM handler, S-transceiver and to pin $\overline{\text{RSTO}}$.

Setting one of these bits to “1” causes the corresponding block to be reset for a duration of 4 BCL clock cycles, except RES_RSTO which is activated for a duration of 125 ... 250µs. The bits are automatically reset to “0” again.

4.4.9 TIMR - Timer Register

Value after reset: 00_H

	7			0	
TIMR	TMD	0	CNT		RD/WR (65)

TMD ... Timer Mode

The timer can be used in two different modes of operation.

0: Count Down Timer.
An interrupt is generated only once after a time period of 1 ... 63 ms.

1: Periodic Timer.
An interrupt is periodically generated every 1 ... 63 ms (see CNT).

CNT ... Timer Counter

0: Timer off.

1 ... 63: Timer period = 1 ... 63 ms

By writing ’0’ to CNT the timer is immediately stopped. A value different from that determines the time period after which an interrupt will be generated.
If the timer is already started with a certain CNT value and is written again before an interrupt has been released, the timer will be reset to the new value and restarted again. An interrupt is indicated to the host in AUXI.TIN.

Note: Reading back this value delivers back the current counter value which may differ from the programmed value if the counter is running.

5 Electrical Characteristics

5.1 Absolute Maximum Ratings

Parameter	Symbol	Limit Values		Unit
		min.	max.	
Ambient temperature under bias	T_A	0	+70	°C
Storage temperature	T_{STG}	– 55	150	°C
Input/output voltage on any pin with respect to ground	V_S	– 0.3	5.25	V
Maximum voltage on any pin with respect to ground	V_{max}		5.5	V

Note: Stresses above those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.
The supply voltage must show a monotonic rise.

5.2 DC Characteristics

V_{DD}/V_{SS} = 3.3 V ± 5%; T_A = 0 to 70 °C

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
H-input level (except pins SR1/2)	V_{IH}	2.0		5.25	V	
L-input level (except pins SR1/2)	V_{IL}	– 0.3		0.8	V	
H-output level (except pin XTAL2, SX1/2)	V_{OH}	2.4			V	I_{OH} = - 400 µA
L-output level (except pin XTAL2, SX1/2)	V_{OL}			0.45	V	I_{OL} = 6 mA (DU, DD, C768) I_{OL} = 4.5 mA ($\overline{ACL}$) I_{OL} = 2 mA (all others)
Input leakage current Output leakage current (all pins except SX1/2,SR1/2,XTAL1/2)	I_{LI} I_{LO}			± 1 ± 1	µA µA	0V< V_{IN}<V_{DD} 0V< V_{OUT}<V_{DD}
Power supply current-Power Down - Clocks Off - Clocks On	 I_{PD1} I_{PD2}			 300 3	 µA mA	Inputs at V_{SS} / V_{DD} No output loads except SX1,2 (50 Ω)
Power supply current - S operational (96 kHz) - B1=00_H,B2=FF_H, D=0	 I_{OP1} I_{OP2} I_{OP3}			 30 30 25	 mA mA mA	 DCL=1536 kHz DCL=4096 kHz DCL=1536 kHz

5.3 Capacitances

T_A = 25 °C, V_{DD} = 3.3 V ± 5 % V_{SSA} = 0 V, V_{SS} = 0 V, f_c = 1 MHz, unmeasured pins grounded.

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Input Capacitance I/O Capacitance	C_{IN} $C_{I/O}$		7 7	pF pF	All pins except SX1,2 and XTAL1,2
Output Capacitance against V_{SS}	C_{OUT}		10	pF	pins SX1,2

5.4 Oscillator Specification

Recommended Oscillator Circuits

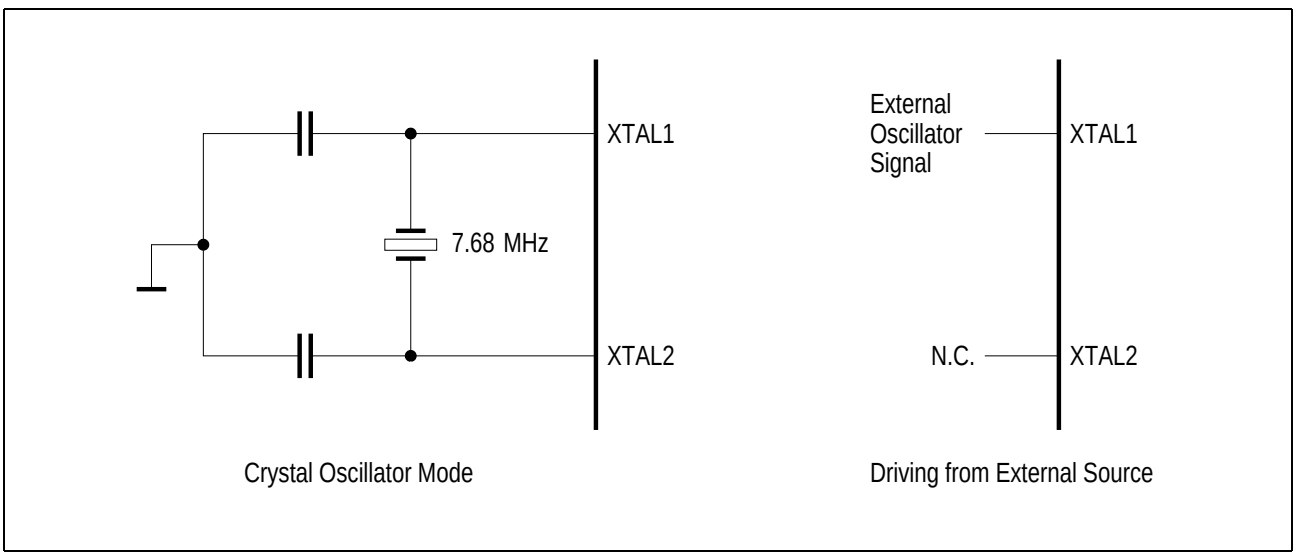


Figure 68 Oscillator Circuits

Parameter	Symbol	Limit Values	Unit
Frequency	f	7.680	MHz
Frequency calibration tolerance		max. 100	ppm
Load capacitance	C_L	max. 40	pF
Oscillator mode		fundamental	

Note: It is important to note that the load capacitance depends on the recommendation of the crystal specification. Typical values are 22 ... 33 pF.

XTAL1 Clock Characteristics (external oscillator input)

Parameter	Limit Values	
	min.	max.
Duty cycle	1:2	2:1

5.5 AC Characteristics

T_A = 0 to 70 °C, V_{DD} = 3.3 V ± 5 %

Inputs are driven to 2.4 V for a logical "1" and to 0.45 V for a logical "0". Timing measurements are made at 2.0 V for a logical "1" and 0.8 V for a logical "0". The AC testing input/output waveforms are shown in **Figure 69.**

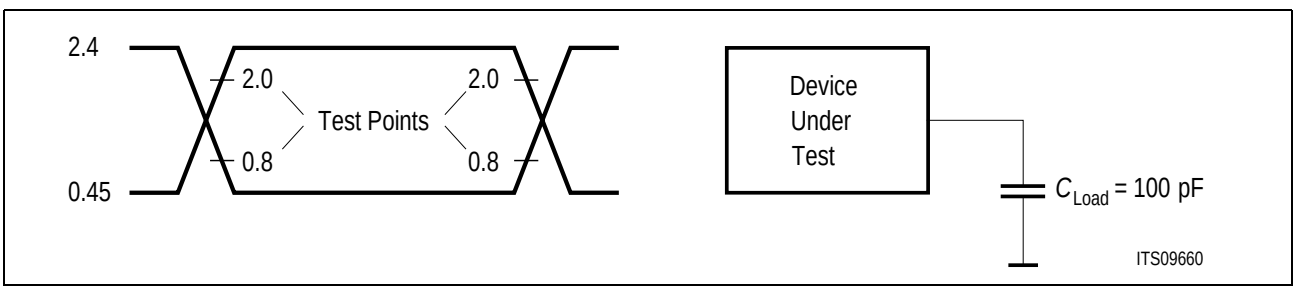


Figure 69 Input/Output Waveform for AC Tests

5.6 IOM-2 Interface Timing

Data is transmitted with the rising edge of DCL and sampled with its falling edge. Below figure shows double clock mode timing (the length of a timeslot is 2 DCL cycles), however, the timing parameters are valid both in single and double clock mode. For the direction of DU,DD (input or output) please refer to **Chapter 3.4**.

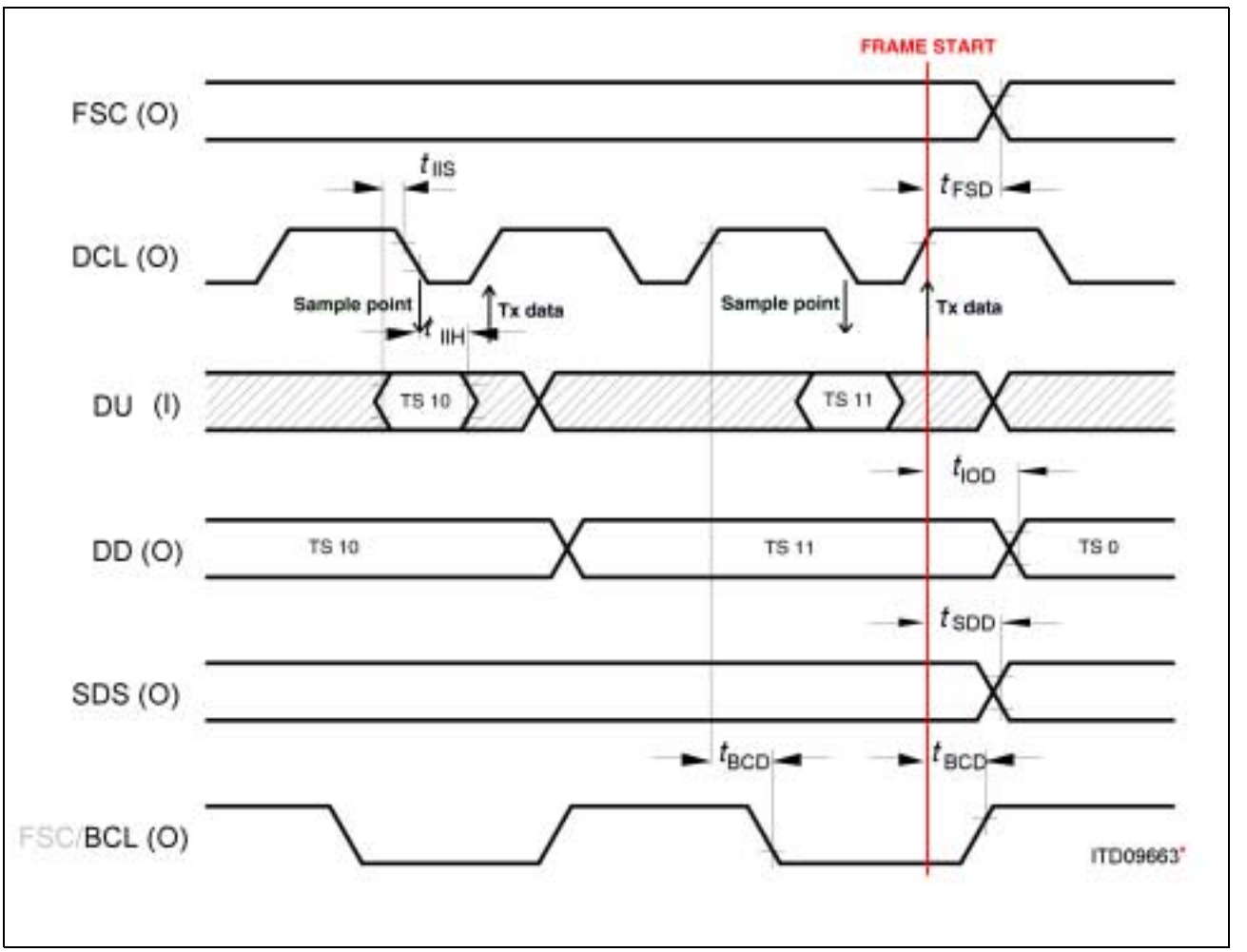


Figure 70 IOM-2 Timing (TE mode)

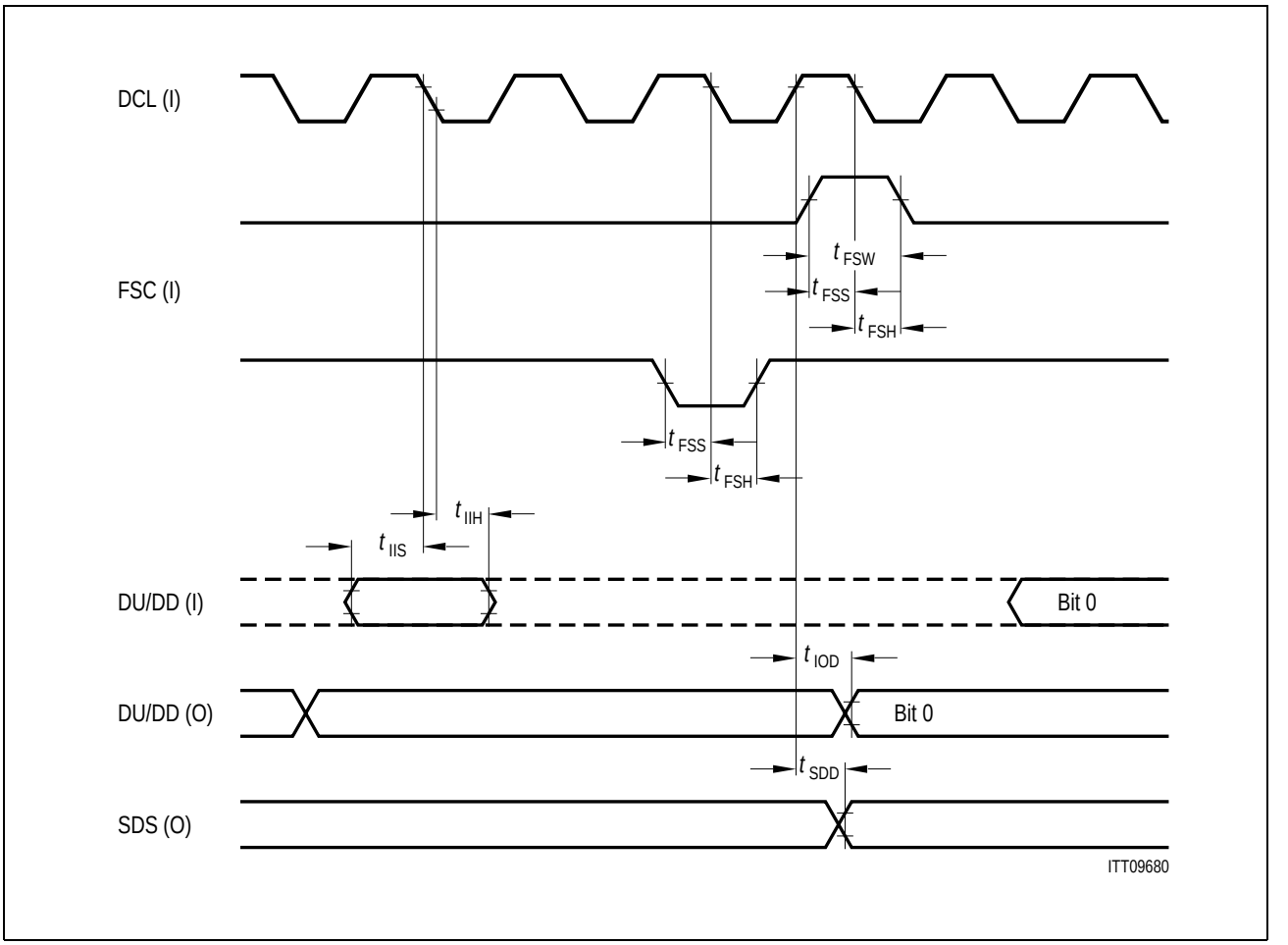


Figure 71 IOM-2 Timing (LT-S, LT-T, NT mode)

Parameter	Symbol	Limit Values		Unit
		min.	max.	
IOM output data delay	t_{IOD}		60	ns
IOM input data setup	t_{IIS}	4		ns
IOM input data hold	t_{IIH}	3		ns
FSC strobe delay (see note)	t_{FSD}	-135	15	ns
Strobe signal delay	t_{SDD}		50	ns
BCL delay	t_{BCD}		30	ns
Frame sync setup	t_{FSS}	20		ns
Frame sync hold	t_{FSH}	30		ns
Frame sync width	t_{FSW}	40		ns

Note: Min. value in synchronous state, max. value in non-synchronous state. This results in a phase shift of FSC when the S-Bus gets activated, this is the FSC signal is shifted by 135 ns. This applies only to TE mode.

DCL Clock Output Characteristics

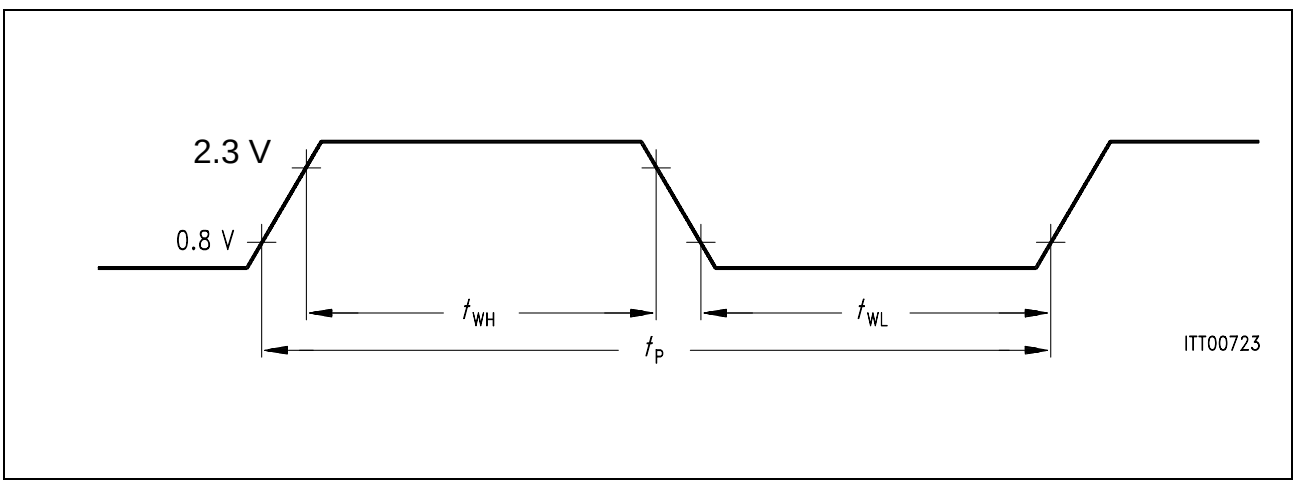


Figure 72 Definition of Clock Period and Width

Symbol	Limit Values			Unit	Test Condition
	min.	typ.	max.		
t_P	585	651	717	ns	osc ± 100 ppm
t_{WH}	260	325	391	ns	osc ± 100 ppm
t_{WL}	260	325	391	ns	osc ± 100 ppm

DCL Clock Input Characteristics

Parameter	Limit Values		Unit
	min.	max.	
Duty cycle	40	60	%

5.7 Serial Control Interface (SCI) Timing

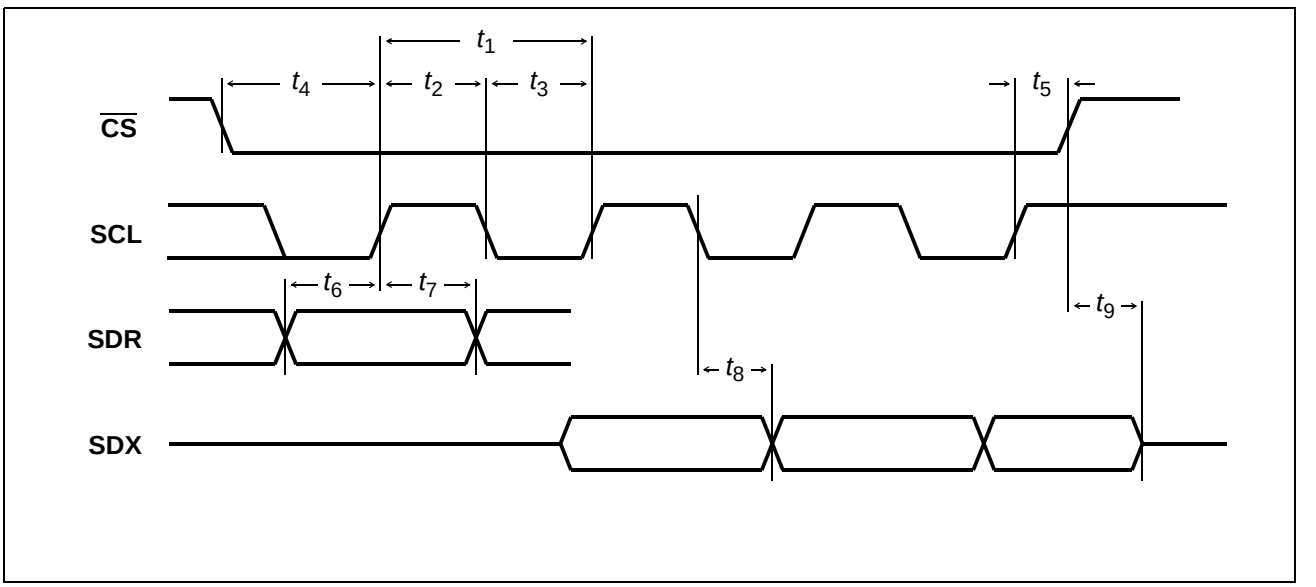


Figure 73 SCI Interface

Parameter SCI Interface	Symbol	Limit Values		Unit
		min.	max.	
SCL cycle time	t_1	200		ns
SCL high time	t_2	100		ns
SCL low time	t_3	100		ns
$\overline{CS}$ setup time	t_4	2		ns
$\overline{CS}$ hold time	t_5	10		ns
SDR setup time	t_6	10		ns
SDR hold time	t_7	6		ns
SDX data out delay	t_8		30	ns
$\overline{CS}$ high to SDX tristate	t_9		40	ns

5.8 Reset

Parameter	Symbol	Limit Values	Unit	Test Conditions
		min.		
Length of active low state	t_{RES}	4	ms	Power On/Power Down to Power Up (Standby)
		2 x DCL clock cycles		During Power Up (Standby)

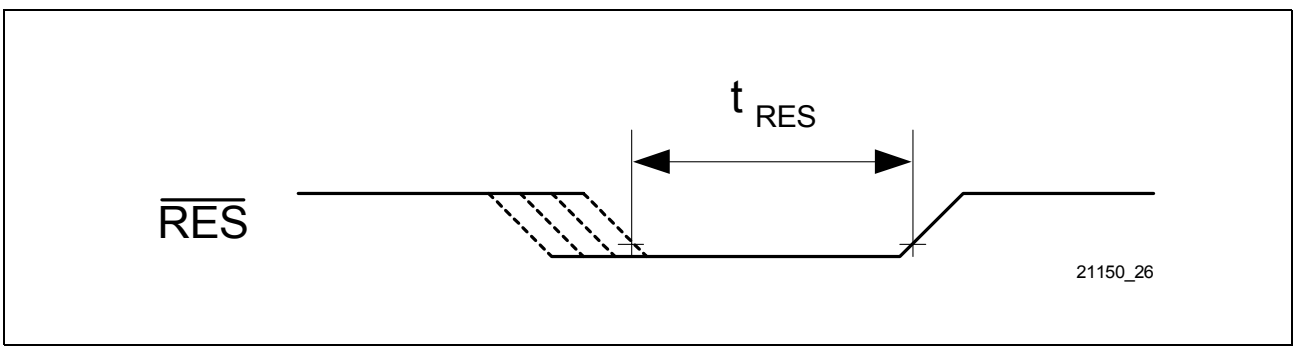


Figure 74 Reset Signal $\overline{RES}$

5.9 S-Transceiver

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
V_{DD}= 3.3 V ± 5 %; V_{SS}= 0 V; T_A = 0 to 70 °C						
Absolute value of output pulse amplitude | VSX2 – VSX1 |	V_X			1.17	V	$R_L = \infty$
Transmitter output current	I_X			26	mA	R_L = 5.6 Ω
Transmitter output impedance (SX1,2)	Z_X	10 0			kΩ Ω	Inactive or during binary one; during binary zero R_L = 50 Ω
Receiver Input impedance (SR1,2)	Z_R	30			kΩ	V_{DD} = 3.3 V

5.10 Recommended Transformer Specification

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Transformer ratio			1:1			
Main inductance	L	25 20			mH mH	no DC current, 10 kHz 2.5 mA DC current, 10 kHz
Leakage inductance	L_L			8 6	µH µH	NT/LT-S mode, 10 kHz TE/LT-T mode, 10 kHz
Capacitance between primary and secondary side	C			80	pF	1 kHz
Copper resistance	R	1.7	2.0	2.3	W	

Note: In TE/LT-T mode, at the pulse shape measurement with a load of 400 Ω (e.g. K 1403 approval test "Pulse shape") overshots might occur with a leakage inductance greater than 6 µH.

5.11 Line Overload Protection

The maximum input current for the S-transceiver lines (under overvoltage conditions) is given as a function of the width of a rectangular input current pulse. The desctruction limits are shown in **Figure 75**.

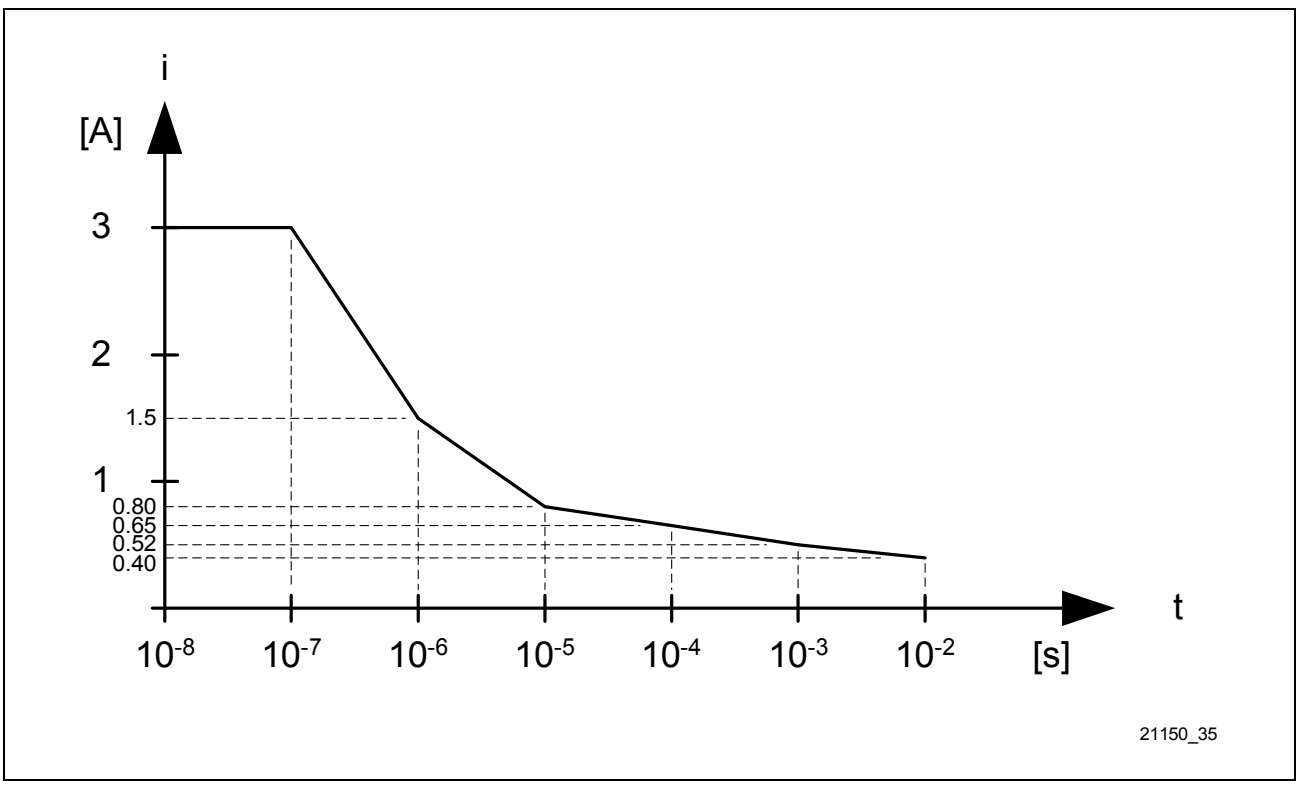


Figure 75 Maximum Line Input Current

5.12 EMC / ESD Aspects

To improve performance with respect to EMC and ESD requirements it is recommended to provide additional capacitors in the middle tap of the transformers (see **Figure 76** below). The values for C1 and C2 should be in the range 1 ... 10 nF. They can be located either on the chip side of the transformer (option 1) or on the S bus side (option 2), but not on both sides.

This improves EMC immunity acording to EN55024 which is mandatory since 2001-07-01.

Note: The figure does not show any other components required for protection circuit in receive and transmit direction as this is not affected by including C1 and C2.

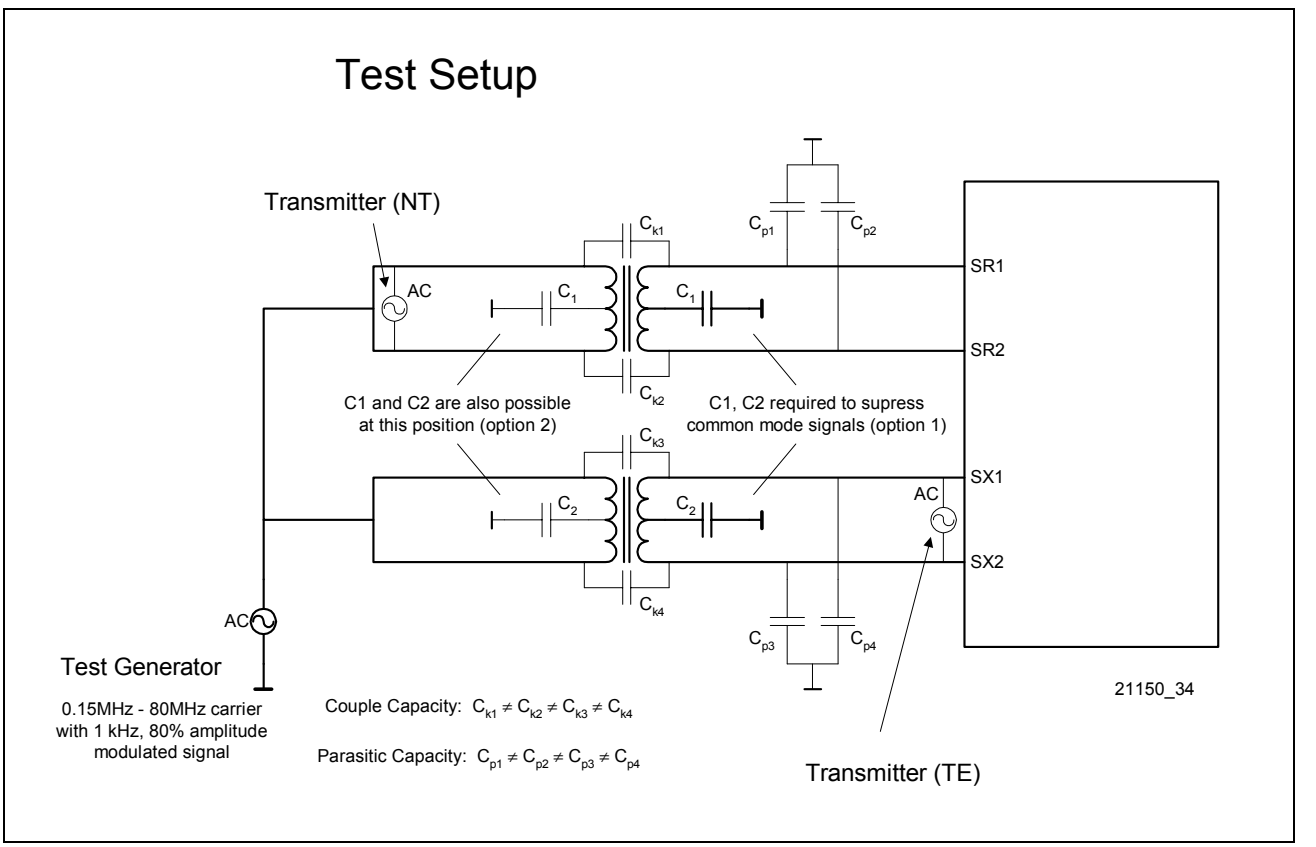
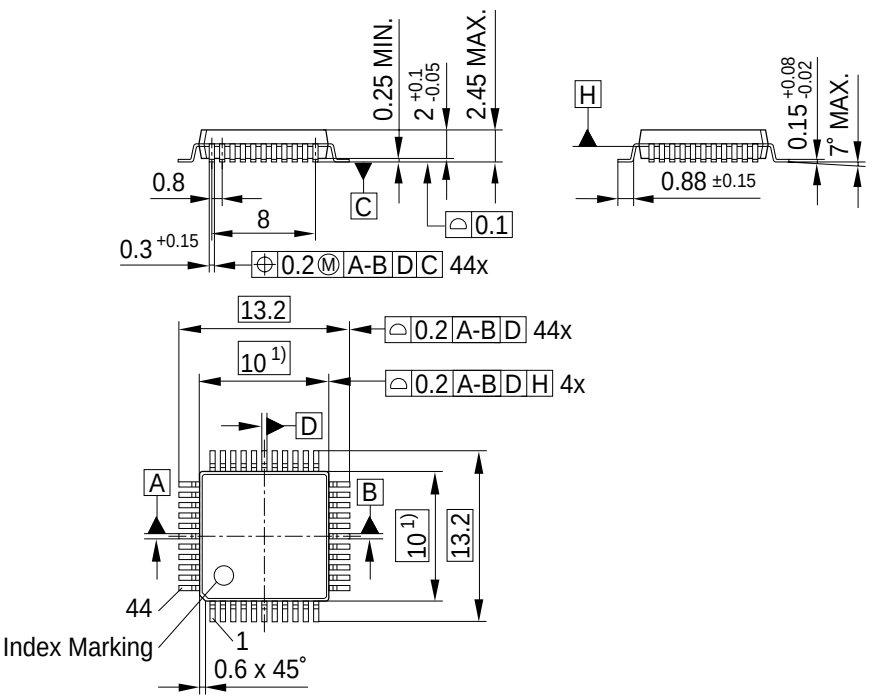


Figure 76 Transformer Circuitry

6 Package Outlines

P-MQFP-44
(Plastic Metric Quad Flat Package)



1) Does not include plastic or metal protrusion of 0.25 max. per side

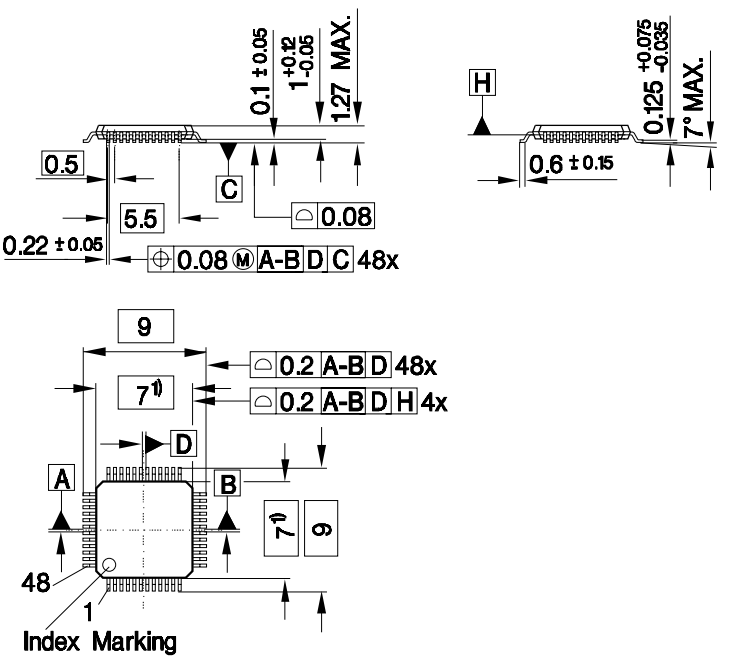
GPM05622

You can find all of the current packages, types of packing, and others on the Infineon Internet Page “Products”: **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

P-TQFP-48
(Plastic Thin Quad Flat Package)



1) Does not include plastic or metal protrusion of 0.25 max. per side

GPP05612

You can find all of the current packages, types of packing, and others on the Infineon Internet Page “Products”: **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

7 Appendix

Transceiver, C/I-Channel Handler, Auxiliary Interface

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
	reserved								00_H-21_H		
TR_MODE2	0	0	0	0	0	DIM2	DIM1	DIM0	22_H	R/W	00_H
	reserved								$23\text{-}2D_H$		
CIR0	CODR0				CIC0	CIC1	S/G	BAS	$2E_H$	R	$F3_H$
CIX0	CODX0				TBA2	TBA1	TBA0	BAC	$2E_H$	W	FE_H
CIR1	CODR1						CICW	CI1E	$2F_H$	R	FE_H
CIX1	CODX1						CICW	CI1E	$2F_H$	W	FE_H
TR_CONF0	DIS_TR	BUS	EN_ICV	0	L1SW	0	EXLP	LDD	30_H	R/W	01H
TR_CONF1	0	RPLL_ADJ	EN_SFSC	0	0	x	x	x	31_H	R/W	
TR_CONF2	DIS_TX	PDS	0	RLP	0	0	SGP	SGD	32_H	R/W	80_H
TR_STA	RINF		SLIP	ICV	0	FSYN	0	LD	33_H	R	00_H
TR_CMD	XINF			DPRIO	TDDIS	PD	LP_A	0	34_H	R/W	08_H
SQRR1	MSYN	MFEN	0	0	SQR11	SQR12	SQR13	SQR14	35_H	R	40_H
SQXR1	0	MFEN	0	0	SQX11	SQX12	SQX13	SQX14	35_H	W	$4F_H$
SQRR2	SQR21	SQR22	SQR23	SQR24	SQR31	SQR32	SQR33	SQR34	36_H	R	00_H
SQXR2	SQX21	SQX22	SQX23	SQX24	SQX31	SQX32	SQX33	SQX34	36_H	W	00_H
SQRR3	SQR41	SQR42	SQR43	SQR44	SQR51	SQR52	SQR53	SQR54	37_H	R	00_H
SQXR3	SQX41	SQX42	SQX43	SQX44	SQX51	SQX52	SQX53	SQX54	37_H	W	00_H

Transceiver, C/I-Channel Handler, Auxiliary Interface

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
ISTATR	0	x	x	x	LD	RIC	SQC	SQW	38_H	R	00_H
MASKTR	1	1	1	1	LD	RIC	SQC	SQW	39_H	R/W	FF_H
TR_ MODE	0	0	0	0	DCH_ INH	MODE 2	MODE 1	MODE 0	$3A_H$	R/W	00_H
	reserved								$3B_H$		
ACFG1	0	0	0	0	0	OD2	OD1	OD0	$3C_H$	R/W	00_H
ACFG2	0	0	0	0	ACL	LED	0	0	$3D_H$	R/W	00_H
AOE	1	1	1	1	1	OE2	OE1	OE0	$3E_H$	R/W	FF_H
ARX	-	-	-	-	-	AR2	AR1	AR0	$3F_H$	R	
ATX	0	0	0	0	0	AT2	AT1	AT0	$3F_H$	W	00_H

IOM Handler (Timeslot , Data Port Selection, CDA Data and CDA Control Register)

Name	7	6	5	4	3	2	1	0	ADDR	R/W	RES
CDA10	Controller Data Access Register (CH10)								40_H	R/W	FF_H
CDA11	Controller Data Access Register (CH11)								41_H	R/W	FF_H
CDA20	Controller Data Access Register (CH20)								42_H	R/W	FF_H
CDA21	Controller Data Access Register (CH21)								43_H	R/W	FF_H
CDA_ TSDP10	DPS	0	0	TSS					44_H	R/W	00_H
CDA_ TSDP11	DPS	0	0	TSS					45_H	R/W	01_H
CDA_ TSDP20	DPS	0	0	TSS					46_H	R/W	80_H

CDA_TSDP21	DPS	0	0	TSS					47_H	R/W	81_H
	reserved								$48\text{-}4B_H$		
TR_TSDP_BC1	DPS	0	0	TSS					$4C_H$	R/W	00_H
TR_TSDP_BC2	DPS	0	0	TSS					4DH	R/W	01_H
CDA1_CR	0	0	EN_TBM	EN_I1	EN_I0	EN_O1	EN_O0	SWAP	$4E_H$	R/W	00_H
CDA2_CR	0	0	EN_TBM	EN_I1	EN_I0	EN_O1	EN_O0	SWAP	$4F_H$	R/W	00_H

IOM Handler (Control Registers, Synchronous Transfer Interrupt Control), MONITOR Handler

Name	7	6	5	4	3	2	1	0	ADDR	R/W	RES
TR_CR (CI_CS=0)	EN_D	EN_B2R	EN_B1R	EN_B2X	EN_B1X	CS2-0			50_H	R/W	$F8_H$
TRC_CR (CI_CS=1)	0	0	0	0	0	CS2-0			50_H	R/W	00_H
	reserved								$51\text{-}52_H$		
DCI_CR (CI_CS=0)	DPS_CI1	EN_CI1	0	0	0	0	0	0	53_H	R/W	80_H
DCIC_CR (CI_CS=1)	0	0	0	0	0	CS2-0			53_H	R/W	00_H
MON_CR	DPS	EN_MON	0	0	0	CS2-0			54_H	R/W	40_H
SDS1_CR	ENS_TSS	ENS_TSS+1	ENS_TSS+3	TSS					55_H	R/W	00_H

SDS2_CR	ENS_ TSS	ENS_ TSS+1	ENS_ TSS+3	TSS					56_H	R/W	00_H
IOM_CR	SPU	DIS_ AW	CI_CS	TIC_ DIS	EN_ BCL	CLKM	DIS_ OD	DIS_ IOM	57_H	R/W	08_H
STI	STOV 21	STOV 20	STOV 11	STOV 10	STI 21	STI 20	STI 11	STI 10	58_H	R	00_H
ASTI	0	0	0	0	ACK 21	ACK 20	ACK 11	ACK 10	58_H	W	00_H
MSTI	STOV 21	STOV 20	STOV 11	STOV 10	STI 21	STI 20	STI 11	STI 10	59_H	R/W	FF_H
SDS_ CONF	0	0	0	0	DIOM_ INV	DIOM_ SDS	SDS2_ BCL	SDS1_ BCL	$5A_H$	R/W	00_H
MCDA	MCDA21		MCDA20		MCDA11		MCDA10		$5B_H$	R	FF_H
MOR	MONITOR Receive Data								$5C_H$	R	FF_H
MOX	MONITOR Transmit Data								$5C_H$	W	FF_H
MOSR	MDR	MER	MDA	MAB	0	0	0	0	$5D_H$	R	00_H
MOCR	MRE	MRC	MIE	MXC	0	0	0	0	$5E_H$	R/W	00_H
MSTA	0	0	0	0	0	MAC	0	TOUT	$5F_H$	R	00_H
MCONF	0	0	0	0	0	0	0	TOUT	$5F_H$	W	00_H

Interrupt, General Configuration Registers

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
ISTA	0	0	ST	CIC	AUX	TRAN	MOS	0	60_H	R	00_H
MASK	1	1	ST	CIC	AUX	TRAN	MOS	1	60_H	W	FF_H
AUXI	0	0	EAW	WOV	TIN	0	0	0	61_H	R	00_H
AUXM	1	1	EAW	WOV	TIN	1	1	1	61_H	W	FF_H
MODE1	0	0	0	WTC1	WTC2	CFS	RSS2	RSS1	62_H	R/W	00_H

Interrupt, General Configuration Registers

NAME	7	6	5	4	3	2	1	0	ADDR	R/W	RES
MODE2	0	0	0	0	INT_ POL	0	0	PPSDX	63_H	R/W	00_H
ID	0	0	DESIGN						64_H	R	01_H
SRES	RES_ CI	0	0	RES_ MON	0	RES_ IOM	RES_ TR	RES_ RSTO	64_H	W	00_H
TIMR	TMD	0	CNT						65_H	R/W	00_H
	reserved								66_H- $6F_H$		

Index

A

Absolute maximum ratings 165
AC characteristics 169
ACFG1 register 140
ACFG2 register 140
ACKxy bits 153
ACL bit 140
Activation 76
Activation indication - pin ACL 35
Activation LED 35
Activation/deactivation of IOM-2 interface 116
AOE register 141
Appendix 180
Applications 16
AR2-0 bits 141
Architecture 23
ARX register 141
ASTI register 153
Asynchronous awake 118
AT2-0 bits 142
ATX register 142
AUX bit 158
AUXI register 159
Auxiliary interface 118
AUXM register 160

B

BAC bit 128
BAS bit 127
BUS bit 129

C

C/I channel 106
Capacitances 167
CDA_TSDPxy registers 143
CDAx_CR register 144
CDAxy registers 142
CFS bit 160
CI_CS bit 150
CI1E bit 128
CIC bit 158
CIC1/0 bits 127
CICW bit 128
CIR0 register 127
CIR1 register 128
CIX0 register 128
CIX1 register 129
CLKM bit 150
Clock generation 53
CNT bits 164
CODR0 bits 127
CODR1 bits 128
CODX0 bits 128
CODX1 bits 129
Control of layer-1 58
Controller data access 84

D

DC characteristics 166
DCH_INH bit 139
D-channel access control
- Intelligent NT 112
- S-bus D-channel control in LT-T 112
- S-bus priority mechanism 110
- TIC bus 108

DCI_CR register 146
Deactivation 76
Delay between IOM-2 and S 42
DESIGN bits 163
Device architecture 23
DIM2-0 bits 126
DIS_AW bit 150
DIS_IOM bit 150
DIS_OD bit 150
DIS_TR bit 129
DIS_TX bit 131
DPRIO bit 134
DPS bit 143, 148
DPS_CI1 bit 146

E

EAW bit 159
Electrical characteristics 165
EN_B2/1R bits 145

Index

EN_B2/1X bits 145
EN_BCL bit 150
EN_CI1 bit 146
EN_D bit 145
EN_I0 bit 144
EN_I1 bit 144
EN_ICV bit 129
EN_MON bit 148
EN_O0 bit 144
EN_O1 bit 144
EN_SFSC bit 131
EN_TBM bit 144
ENS_TSSx bits 149
Exchange awake 32
EXLP bit 129
External reset input 32

F

Features 14
FSYN bit 133
Functional blocks 23

I

I/O lines 118
ICV bit 133
ID register 163
INT_POL bit 162
Intelligent NT 112
Interrupt structure 29
IOM_CR register 150
IOM-2 79
- Frame structure (LT) 81
- Frame structure (NT) 81
- Frame structure (TE) 80
- Handler 82
- Interface Timing 169
- LT-S, LT-T, NT modes 79
- Monitor channel 97
- TE mode 79

ISTA register 158
ISTATR register 137

J

Jitter 56

L

L1SW bit 129
LD bit 133, 137
LDD bit 129
LED bit 140
LED output 35
Level detection 50
Logic symbol 15
Looping data 85
LP_A bit 134
LT-T mode 112

M

MAB bit 156
MAC bit 157
MASK register 159
MASKTR register 138
MCDA register 155
MCDAxy bits 155
MCONF register 157
MDA bit 156
MDR bit 156
MER bit 156
MFEN bit 135, 136
Microcontroller interfaces 25
MIE bit 156
MOCR register 156
MODE1 register 160
MODE2 register 162
MODE2-0 bits 139
MON_CR register 148
Monitor channel
- Error treatment 101
- Handshake procedure 98
- Interrupt logic 105
- Master device 103
- Slave device 103
- Time-out procedure 104

Monitoring data 89

Index

Monitoring TIC bus 89
MOR register 155
MOS bit 158
MOSR register 156
MOX register 155
MRC bit 156
MRE bit 156
MSTA register 157
MSTI register 153
MSYN bit 135
Multiframing 40
MXC bit 156

O

OD2-0 bits 140
OE2-0 bits 141
Oscillator 168
Oscillator clock output 57
Overview 11

P

Package Outlines 178
PD bit 134
PDS bit 131
Pin configuration 17
PPSDX bit 162

R

Receive PLL 56
Register description 120
RES_xxx bits 163
Reset generation 31
Reset source selection 31
Reset timing 173
RIC bit 137
RINF bits 133
RLP bit 131
RPLL_ADJ bit 131
RSS2/1 bits 160

S

S/G bit 114, 127
S/T-Interface 36
  Circuitry 47
  Coding 38
  Delay compensation 50
  External protection circuitry 47
  Multiframing 40
  Receiver characteristics 46
  Transceiver enable/disable 50
  Transmitter characteristics 45
S-bus priority mechanism 110
SCI - serial control interface 26
SCI interface timing 172
SDS 94
SDS_CONF register 154
SDS2/1_BCL bits 154
SDSx_CR registers 149
Serial data strobe 94
SGD bit 131
SGP bit 131
Shifting data 85
SLIP bit 133
Software reset 32
SPU bit 150
SQC bit 137
SQR11-14 bits 135
SQR21-24 bits 136
SQR31-34 bits 136
SQR41-44 bits 137
SQR51-54 bits 137
SQRR1 register 135
SQRR2 register 136
SQRR3 register 137
SQW bit 137
SQX11-14 bits 136
SQX21-24 137
SQX31-34 bits 137
SQX41-44 bits 137
SQX51-54 bits 137
SQXR1 register 136
SQXR2 register 137
SQXR3 register 137
SRES register 163
ST bit 158
State machine

Index

LT-S mode 67
NT mode 71
TE and LT-T mode 60
STI register 152
STIxy bits 152, 153
Stop/Go bit 114, 127
STOVxy bits 152, 153
Strobed data clock 94
Subscriber awake 32
SWAP bit 144
Synchronous transfer 90

T

TBA2-0 bits 128
TDDIS bit 134
Test functions 51
TIC bus 108
TIC_DIS bit 150
Timer 33
TIMR register 164
TIN bit 159
TMD bit 164
TOUT bit 157
TR_CMD register 134
TR_CONF0 register 129
TR_CONF1 register 131
TR_CONF2 register 131
TR_CR register 145
TR_MODE register 139
TR_MODE2 register 126
TR_STA register 133
TR_TSDP_BC1/2 registers 143
TRAN bit 158
Transceiver enable/disable 50
Transformer specification 175
TSS bits 143, 149
Typical applications 16

W

Watchdog timer 32
WOV bit 159
WTC1/2 bits 160

X

XINF bits 134

http://www.infineon.com

Published by Infineon Technologies AG