Common Detector Interface (CDI)

Specifications

Protocol Version 1.0
Document Revision B

Date of last change: 27 May 2013

May 2013

Abstract:

   This document specifies the common detector interface (CDI) for banknote sorting machines (BSMs) and the detectors installed thereon for inspecting banknotes.

Revision History

Interface Revision	Document Revision	Comment	Date
0.8		Revision of Draft 1.6 following successful acceptance on all tested Banknote Sorting Machines	30 November 2012
0.9		Revision for supplier input	11 December 2012
1.0		Final release	6 February 2013
1.0	A	Textual revisions and clarifications on using CDI for other 'non-feature' Detectors	19 March 2013
1.0	B	Clarification on Detector speed and operation requirements in 2.1, change of maximum distance Banknote Present to Banknote Info from 999mm to 2000mm	27 May 2013

N.B.:

Interface revision 1.0 is the first official release of the CDI specifications and therefore the only version that is to be supported by any Detector or Banknote Sorting Machine.

Any earlier interface revisions must not be supported.

Main Authors:

   Thomas Kern, Oesterreichische Banknoten- und Sicherheitsdruck GmbH
   Peter Markus, De Nederlandsche Bank

Editor:

   Harald Deinhammer, European Central Bank

Contributors:

   Jean-Claude Fremy, Banque de France
   Rodney Adams, De La Rue
   Matthias Hecht, Giesecke & Devrient
   Takuji Kato, Toshiba

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1   Glossary

Banknote ID	Unique number assigned to a banknote by the Banknote Sorting Machine software to identify the banknote while present in the Banknote Sorting Machine
Banknote Present	Dedicated interface line representing the banknote; used to align the inspection process by the Detector and to synchronise the Banknote ID with the banknote and Detector result
Banknote Sorting Machine	Machine used for processing banknotes that is capable of sorting banknotes according to the results of the Detector(s)
Banknote Edge, Leading	Edge of the banknote first in transport direction
Banknote Edge, Trailing	Edge of the banknote last in transport direction
BSM	*Abbreviation for Banknote Sorting Machine*
Detector	A device for inspecting banknotes for authentication or fitness on a Banknote Sorting Machine. A Detector can either consist only of the housing as specified, or, alternatively, consist of a measurement head (conforming to the Detector Housing specifications) and an External Evaluation Unit.
DET	*Abbreviation for Detector*
Detector Ready	Dedicated interface line from the Detector to the Banknote Sorting Machine to indicate that the Detector is ready for receiving commands
Detector Reset	Dedicated interface line from the Banknote Sorting Machine to the Detector to carry out a hardware reset of the Detector
ESP	External service port used to connect a PC directly to the Detector.
External Evaluation Unit	Any kind of hardware, typically a PC, conducting interim data processing tasks and, in case being used, providing the CDI connector to the Banknote Sorting Machine. Details of the External Evaluation Unit need to be agreed between the Detector- and BSM-manufacturer.
Inspection Rate	Number of measurements per Transport Clock pulse
Nominal Detector Position	First edge of the defined Detector casing in transport direction (-32.5mm from the central CDI mounting registration)
Telegram	Data block, part of a message, used for Raw Data transfer between Detector and Banknote Sorting Machine
Transport Clock	Dedicated interface line with square wave pulse from the Banknote Sorting Machine to the Detector to synchronise the transport speed with the Inspection Rate of the Detector
Raw Data	Data collected by the Detector for inspection of a feature (e.g. detailed line-scan data of a feature on a banknote)
Supplemental Data	A set of measurement data provided by the Detector describing the intensity and/or specific properties of the measured feature

2   Overview of the Common Detector Interface

The aim of this document is to provide a common interface between banknote Detectors and National Central Bank-type large and medium sized Banknote Sorting Machines (BSMs) for standardised data exchange on the features/banknote characteristics.

The CDI specification covers:
- Mechanical fitting into the Banknote Sorting Machine
- Electrical specifications
- Interface protocol
- Handling of Supplemental and Raw Data

The CDI has been developed mainly for integrating third-party Detectors for machine readable features into a BSM, but it can as well be used for the communication between "standard" Detectors (e.g. fitness, soil, thickness or denomination recognition) supplied by third parties or coming directly from the BSM supplier. In such cases (e.g. denomination recognition) the results of the Detector may need to be processed by the BSM, but the general data transfer and storage structure remains the same.

Also, in case the mechanical outline of the Detector cannot be met due to the working principle, the other aspects of the CDI can still be used and the Detector be labelled 'CDI compliant', as long as any deviations from the complete CDI specifications are listed in the manual as stated in chapter 2.1 (last bullet point).

The table below provides some examples on how the CDI can be implemented on standard Detectors:

Detector Type	CDI Implementation
Fitness	Options: 1. Judgement on Fit/Unfit made directly by Detector and BSM sorting according to Detector decision delivered via CDI. 2. Detector sends standardised soil level to BSM as Supplemental Data. BSM checks against soil level threshold In case the Detector relies on more complex data analysis (e.g. image processing), this shall be carried out via an External Evaluation Unit, which then provides the CDI connection to the BSM.
Denomination	BSM sends only BanknoteID and dummy BanknoteINFO. Detector returns Denomination/Orientation information as Supplemental Data, which is processed by BSM and later supplied to other CDI compliant Detectors.

Table 1: Examples for CDI implementation on standard Detectors

2.1 Detector requirements

Please note that as of issuance of these specifications one type of BSM is only able to store a selection of 15 byte out of the total maximum 120 byte of Supplemental Data per Detector for the total required 1,000,000 banknotes (The complete 120 byte are only available for the last 1,000 notes)

Detector manufacturers shall therefore aim to provide a comprehensive set of Supplemental Data using 15 bytes.

The remainder can be used for other, less relevant note specific information.

A Detector has to support the following capabilities:
- Operate in BSMs sorting up to 50 banknotes per second
- Support 'Late Banknote Info' and 'Early Banknote Info' operation modes (see Chapter 4.6.1 for details)
- Storage of Supplemental Data
- Storage of Raw Data
- External Service Port (USB 1.1 or higher) which can be used <u>by authorised personnel only</u> to connect a PC in order to:
  - o monitor the Detector
  - o adjust detection parameters
  - o export Supplemental or Raw Data as defined in Chapter 7
  - o accomplish first level diagnosis
- Be powered via an external power supply with an input range of 100-230V @50-60Hz. Alternatively, and upon bilateral agreement between the BSM suppler and Detector manufacturer, the Detector can use the DC Power supply (<42V) of the BSM directly.
- Be built dust protected according to at least IP50 to guarantee a long lifetime in a BSM[1]
- Has to comply with all applicable CE regulations
- The heat dissipation shall not exceed 30W. In case heat dissipation exceeds 30W, this must be agreed with the respective BSM manufacturer.
- The maximum weight of the Detector must not exceed 10 kilograms.
- The ESP shall be at the front of the Detector and located in a way that it is possible to operate the BSM with the covers closed while a connector is plugged into the ESP.

Furthermore, an English user manual containing the following items has to be provided:
- The Supplemental Data provided (including names and data types <u>but explicitly excluding the meaning of each value</u>)
- Installation, maintenance, calibration and cleaning procedures
- References of the electrical components (part/reference numbers) to implement the CDI
- A table of all Detector specific error codes used for:
  - o Detector status
  - o banknote result
- A list of available raw data types
- If applicable, any known deviations from these CDI specifications

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[1] This IP classification is for the electrical part of the Detector only. Other classifications may apply to the (e.g. optical, mechanical) measurement head.

2.2 Banknote Sorting Machine requirements

A BSM has to support the following capabilities:
- May have a maximum banknote sorting capacity of 50 banknotes per second
- Have at least two mechanical Detector slots fully complying with the CDI specification
- Be capable of handling Supplemental Data and Raw Data as described in Chapter 6
- Provide possibility to export the collected data via a USB 1.1 compliant interface
- The manufacturer shall ensure that the Detector ESP port is accessible with closed BSM doors.
- Provide an easy to use GUI for NCB staff with sufficient user rights (e.g. supervisor or admin) to edit the Detector setup with the following functions:
  - add/remove Detector (enable/disable the respective CDI)
  - change Detector settings (description, type and software version)
    (To make sure that any BSM is only working with the correct Detector setup, the BSM has to compare these settings against the Detector Description as described in Chapter 4.4.2.5.)

Furthermore, an English user manual containing the following items has to be provided:
- A step-by-step explanation how to
  - install a Detector on the BSM including mechanical adjustments, setting parameters and/or necessary software adaptations
  - activate / deactivate a Detector
  - access and export the Supplemental Data
  - access and store the Raw Data
- References of the electrical components (part/reference numbers) to implement the CDI
- Detailed description of the CDI functions (e.g. (setting parameters, listing Raw Data) available to the respective user privileges (e.g. admin, supervisor, technician, operator)
- Location of CDI connector on BSM side
- If applicable, any known deviations from these CDI specifications

3 Electrical Interface

3.1 Power Supply

3.1.1 Power Supply – Detector side

Each Detector:
- Is expected to be powered with DC voltage <42V
- Has to be delivered with a power supply
    - equipped with a IEC-60320 C14 coupler
    - supporting 100-230V @50-60Hz
- May not consume more than 100W from the BSM power supply at any time

3.1.2 Power Supply – Banknote Sorting Machine side

The BSM has to provide:
- A power supply of 100-230V @50-60Hz with at least 1A for each CDI Detector as a cable with an IEC-60320 C13 connector (see above)

Figure 1: Power supply connector – BSM side

Alternatively, and upon bilateral agreement between the BSM supplier and Detector manufacturer, the Detector can use the DC Power supply (<42V) of the BSM directly.

3.2 Communication interface

The Communication interface is realised by a high-speed serial transmission and additional digital lines.
The serial and digital lines have to be galvanically separated to prevent electrical damage to either the Detector or BSM. The +5V for powering the Detector photo-couplers shall be supplied by the BSM via pins 16 and 19 of the CDI connector.

For the serial lines RX and TX, as well as the Transport Clock and the Banknote Present signal RS422 is used as the transmission procedure.
For these four signals an isolated RS422 transceiver capable of 460.8 kBit/s shall be used. (E.g. Analog Devices ADM2482E)

The Detector Reset and Detector Ready line has to be implemented as a current loop as shown in the following schematics.

Whilst the hardware Detector Ready line is mandatory for a Detector, its evaluation by the BSM is optional. The BSM can either use the hardware Detector Ready line or the software Detector Ready in the Protocol Version message provided by the Detector.

In case of any Detector malfunction the Reset sent by the BSM has to be sent via the hardware Detector Reset line.

A valid hardware reset has to be at least 10ms long. Furthermore a Detector must not react on hardware reset signals less than 100µs.

The electrical drawings shown below are for guidance only. Additional EMC protection (e.g. in the form of RC filtering or Ferrite rings) is recommended for both the BSM and Detector.
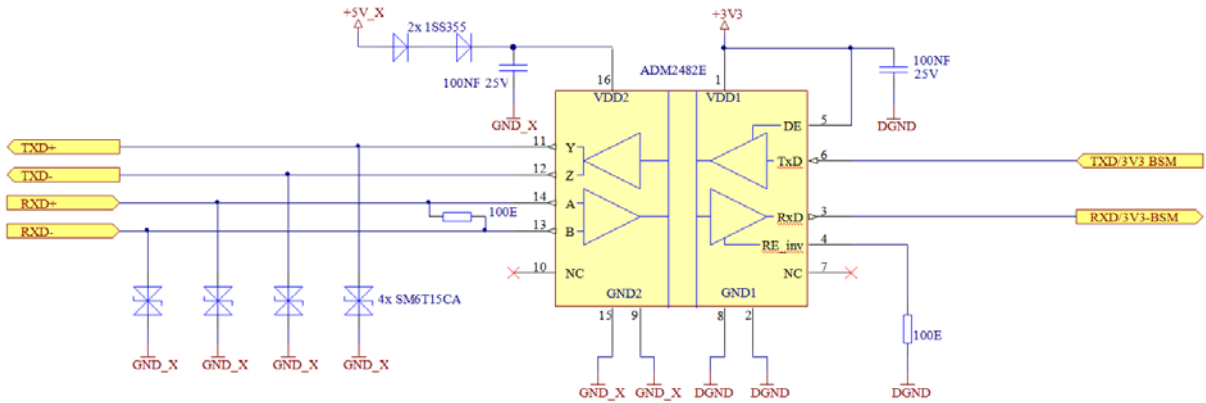
Figure 2: RX / TX BSM side

Figure 3: Transport Clock - BSM side

Figure 4: Banknote Present - BSM side

Figure 5: Reset - BSM side

Figure 6: Ready - BSM side

3.2.1 Electrical interface - Detector side

Figure 7: RX/TX - Detector side
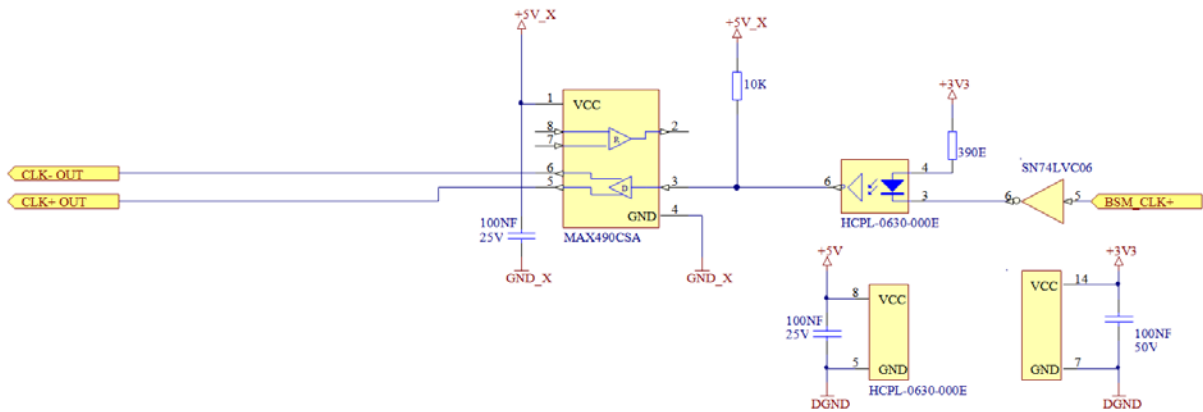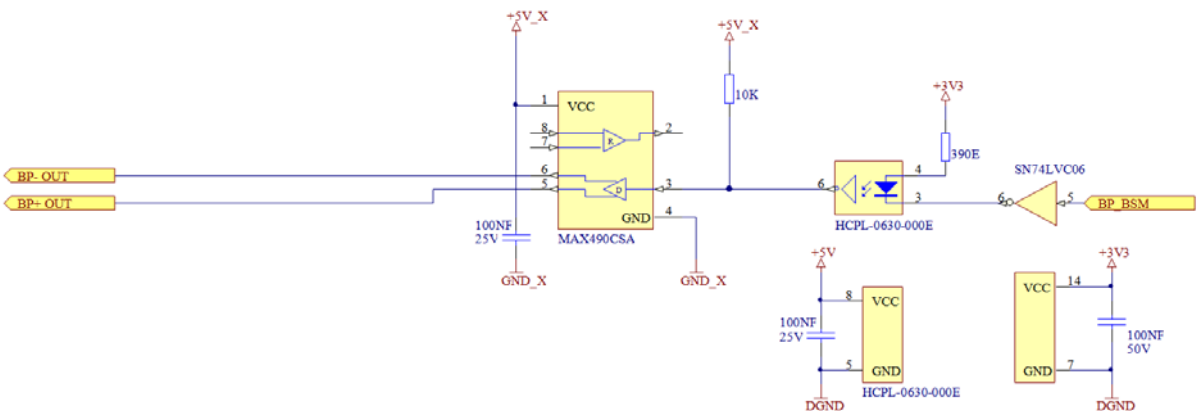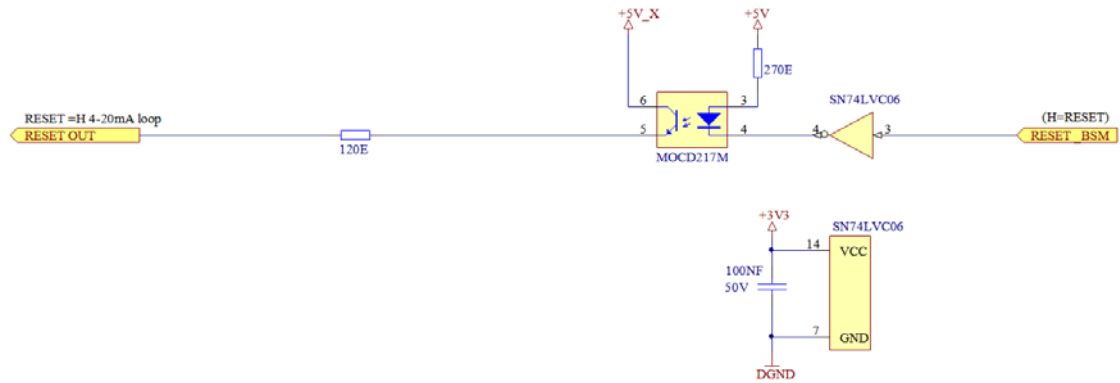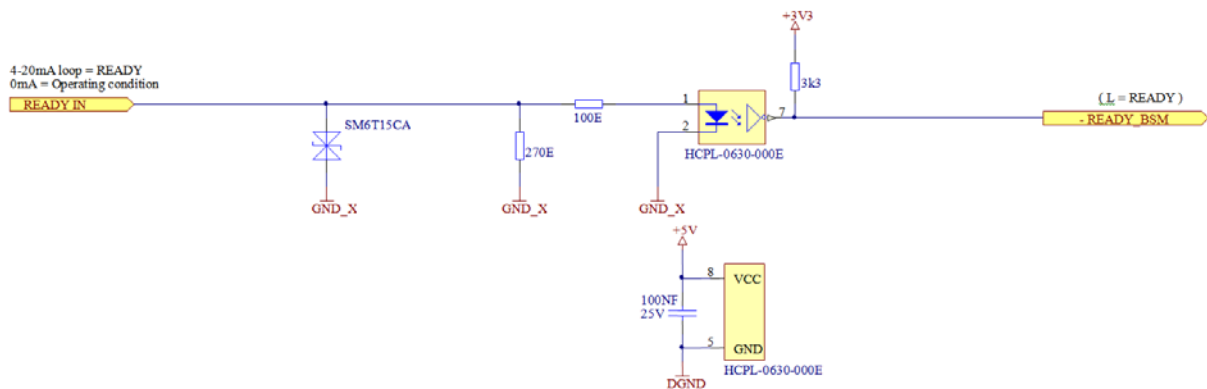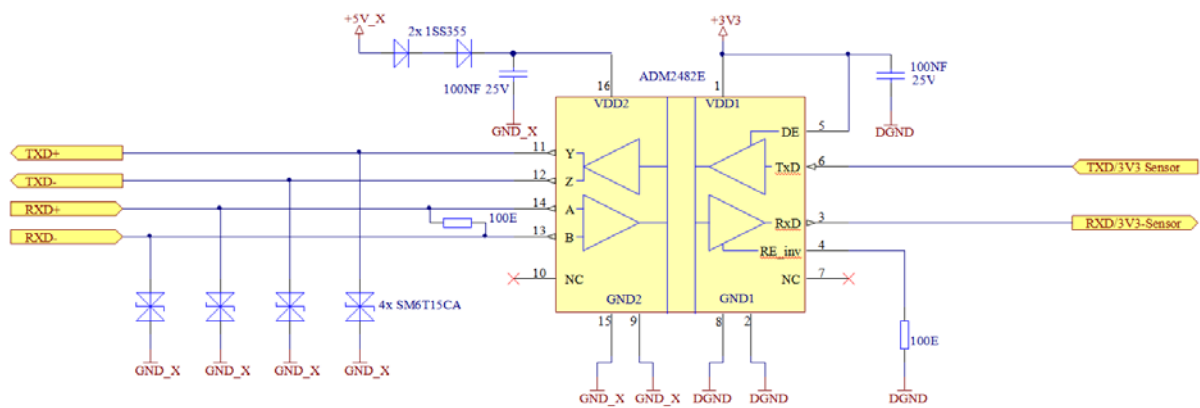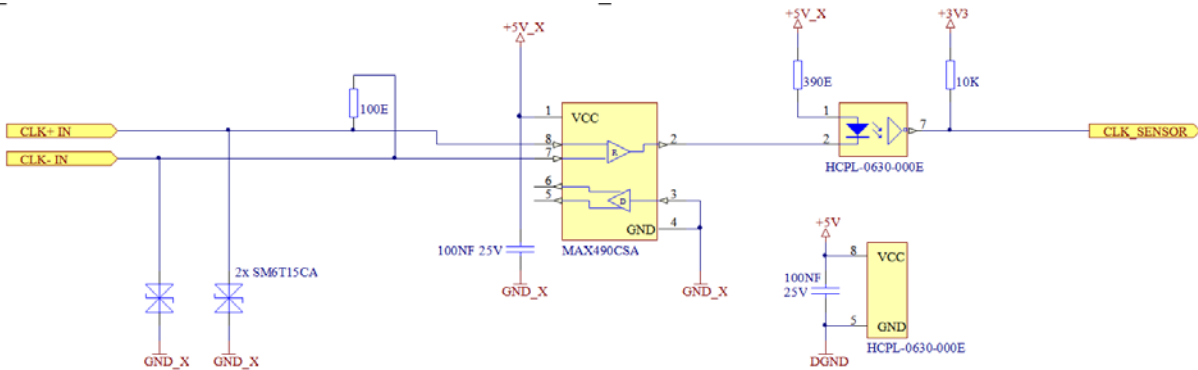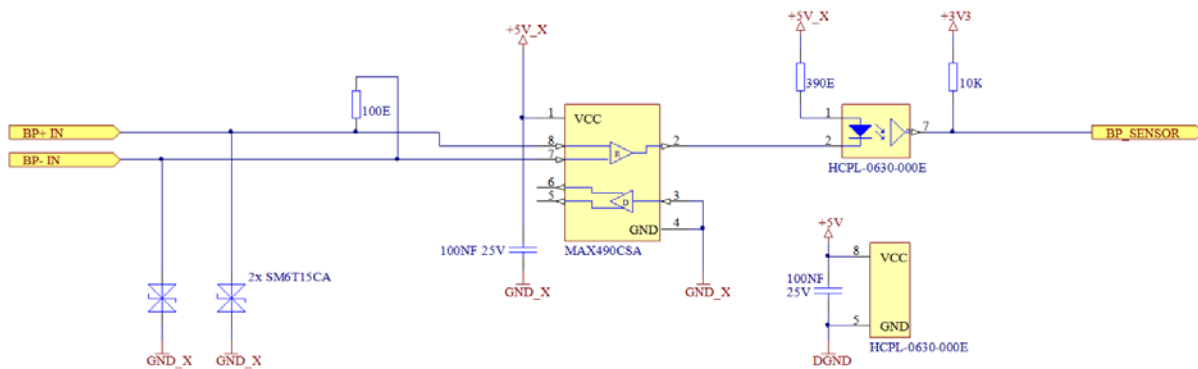
Figure 8: Transport Clock - Detector side

Figure 9: Banknote Present - Detector side
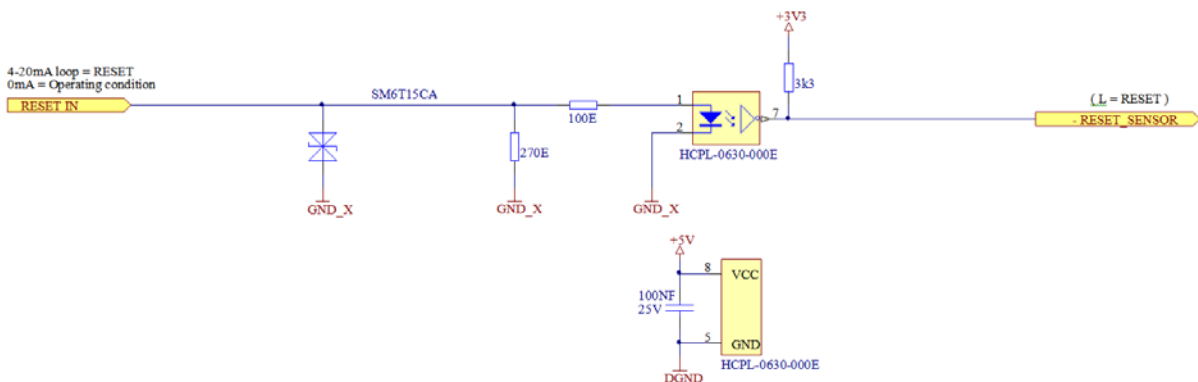
Figure 10: Reset - Detector side
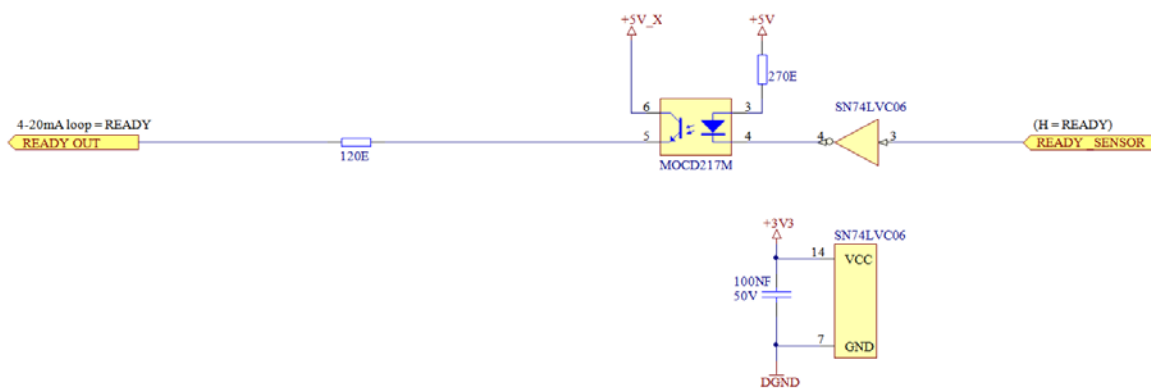
Figure 11: Ready - Detector side

4 Software Interface

The message will be communicated between the BSM and Detector by a serial line with the following specifications:

- Baud rate: 460.8 kBit/s
- Data Bits: 8
- Parity: None
- Stop Bits: 1

The maximum length of any message is 2000 byte without escaping, including CRC, STX and ETX. Therefore each CDI device must be able to receive up to 4000 byte in one block.

4.1 Forbidden Characters in Text or Character values

All Text or Character values in the messages are interpreted as standard ASCII.
Only printable characters (0x20 – 0x7E) are allowed.

Additionally the following characters are forbidden:

\ (0x2F)	/ (0x5C)	: (0x3A)	" (0x22)	* (0x2A)
? (0x3F)	< (0x3C)	> (0x3E)	| (0x7C)	_ (0x5F)[2]

Table 2: List of forbidden characters

4.2 Encoding of Message Frames

There is a set of special (reserved) characters, namely 0xF8 to 0xFE.
The following special characters are functionally defined:

0xFC	CDI_STX	0xF8	reserved
0xFD	CDI_ETX	0xF9	reserved
0xFE	CDI_ESC	0xFA	reserved
		0xFB	reserved

Special characters appear only in the data stream if their special function is meant.
All data characters xx that equal a special character are translated into a two byte sequence CDI_ESC yy, where yy is the one's complement of xx. All other characters remain as they are.

A CDI transmission frame for a MESSAGE FRAME

Byte0	Byte1	…	ByteN

is then built as

CDI_STX	TByte0	TByte1	…	TByteN	CRC	CDI_ETX

where tbyte0 ... tbytes are the translated (ESCaped) versions of byte0 ... byteN, as described before.

As CRC the standard CRC-CCITT: 0x1021 = x16 + x12 + x5 + 1 with initial value 0xFFFF is used.

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[2] The "_" character is forbidden as it is used for separating the data fields in the filenames.

Message		0x84	0x19			
With Checksum		0x84	0x19	0x4B	0x49	
Escaped Message		0x84	0x19	0x4B	0x49	
Final Message frame	0xFC	0x84	0x19	0x4B	0x49	0xFD

Table 3: Example1 Feed Off 2,5s expected pause length:

Message		0x84	0xFA				
With Checksum		0x84	0xFA	0x06	0x84		
Escaped Message		0x84	0xFE	0x5	0x06	0x84	
Final Message frame	0xFC	0x84	0xFE	0x5	0x06	0x84	0xFD

Table 4: Example2 Feed Off 25s expected pause length:

4.3   Transmission Byte Ordering

All multi byte values have to be transferred LSB (least significant byte) first.

4.4   Command Message Overview

Command ID	Name	Direction	Length (Byte)[3]	Operation phase
0x10	Software Detector Reset 0x10	BSM→DET	5	Initialisation phase
0x11	Protocol Version 0x11	BSM→DET	7	
0x21	Protocol Version answer 0x21	DET→BSM	8	
0x12	Machine Info 0x12	BSM→DET	40	
0x22	Detector Info 0x22	DET→BSM	33-1988	
0x81	Banknote ID 0x81	BSM→DET	9	Banknote Sorting phase
0x82	Banknote Info 0x82	BSM→DET	12	
0x83	Banknote IDandInfo 0x83	BSM→DET	12	
0x41	Banknote Result 0x41	DET→BSM	13-133	
0x84	Feed Off 0x84	BSM→DET	6	
0x44	Feed Off answer 0x44	DET→BSM	38	
0x85	Feed On 0x85	BSM→DET	5	
0x45	Feed On answer 0x45	DET→BSM	38	
0x86	Raw Data request 0x86	BSM→DET	6	Feed Off phase
0x46	Raw Data answer 0x46	DET→BSM	10-2000	

Table 5: Command Message overview

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[3] Including CRC, STX and ETX

4.5   Initialisation Phase

4.5.1   Initialisation Phase Flow

Communication is started by the sorting application in the BSM upon start-up or a positive edge of the Detector Ready signal (Detector start up).

After start-up the Detector sends the Protocol Version Answer Message with Status Byte set to 03…Detector Start-up.
The BSM responds to this message with the normal communication start-up as described below. If the BSM is not ready to start communication with the Detector, this message may be ignored and communication will start at a later point.

1. Protocol Version sent to the Detector
2. Detector response:
    a. no Answer within 2 seconds or an answer with "Not Ready" → Command is repeated twice → An understandable error message consisting of the Detector slot or Detector ID is sent to operator via BSM operator screen
    b. Answer with "Wrong Protocol" → Command repeated with requested protocol version if available inside the BSM, otherwise communication has failed and an understandable error message is sent to operator screen on BSM
    c. Answer with "OK" → Goto 3
3. Machine Info is sent to Detector
4. Detector Info is sent to BSM

The BSM will always propose the latest supported protocol version. Therefore the Detector shall not request a higher protocol version.
The BSM shall be backwards compatible and support lower protocol versions if requested. At least the previous protocol version must be supported by the BSM.

4.5.2 Initialisation Phase Commands

4.5.2.1 Software Detector Reset 0x10

The BSM requests a software restart of the Detector. The Detector reacts with an immediate reset including a complete purge of Supplemental and Raw Data[4].

After start-up the Detector sends the Protocol Version Answer Message with Status Byte set to 03…Detector Start-up.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x10	Command ID

4.5.2.2 Protocol Version 0x11

Protocol Version Command is used by the BSM to initialise the communication to the Detector.
If there is any communication problem, i.e. no communication at all, no matching protocol version or Detector not getting ready the BSM must not start operation and inform the operator about the communication problem via a clear message on the user interface.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x11	Command ID
1	1	…	Protocol Version LSB
2	1	…	Protocol Version MSB

4.5.2.3 Protocol Version answer 0x21

Protocol Version answer is used by the Detector to answer to the protocol version command from the BSM. To inform the BSM of a Detector (re)start the Detector has to send this command independently after start.

In case of any error, the Detector Status Code value shall be accessible on the BSM.

Direction: BSM in, DET out			
Offset	Length	Code / Data	Content
0	1	0x21	Command ID
1	1		Detector Status 0….OK See more in Table 5 below
2	1	…	Requested Protocol Version LSB
3	1	…	Requested Protocol Version MSB

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[4] The BSM shall in this case NOT purge data available on the BSM.

Detector Status Codes	
Value	**Meaning**
0	OK
1	Not ready (temporarily), BSM to retry
2	Wrong Protocol
3	Detector Start-up, BSM to retry
4	Environmental conditions not met (e.g. too cold), BSM to retry
5	Calibration needed
6	Hardware error
7	Self-test failed
8-31	Reserved
32-255	Detector specific (must be described in Detector manual together with resolution measures) An according error message must be given by the BSM.

Table 6: Command Message overview

4.5.2.4 Machine Info 0x12

After negotiation of the protocol, the BSM will send information about its configuration.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x12	Command ID
1	16	ASCII	Machine Description String (see Chapter 4.1 for encoding details)
17	1	…	Approx. Machine Speed in 100mm/s (20=2m/s)
18	1	…	Detector Slot Number
19	1	…	Detector position 0..Right/Top 1..Bottom/Left
20	2	16bit UINT	Max. Distance in mm Machine Banknote Present to Judge
22	2	16bit UINT	Min. Distance in mm Machine Banknote Present to Detector position
24	2	16bit UINT	Max. Distance in mm Machine Banknote Present to Detector position
26	2	16bit UINT	Length in mm of Banknote Present 0: Banknote Present signal will represent real banknote length (preferred option) 50…200: a fixed Banknote Present signal is used
28	1	…	Banknote Info available 0x01…Late 0x02…Early
29	2		Current Year
31	1		Current Month
32	1		Current Day
33	1		Current Hour (24h format)
34	1		Current Minute
35	1		Current Second

Current Date/Time
17. August 2011 13:24:56 would be represented as:
 0xDB 0x07 (2011) 0x08 (Aug.) 0x11 (17.) 0x0D (13) 0x18 (24) 0x38 (56)

Maximum distance Banknote Present to Judge (Leading Banknote Edge present to Result) describes the latest point where a Detector has to send a sensor result to the BSM. Even if the decision-making for a banknote is not finished the Detector is expected to send a Reject at this point with the result code "Calculation not finished"

Minimum / Maximum Distance Banknote Present (Leading Banknote Edge to Detector position) describe the possible distance the banknote present signal can be sent to the Detector before the banknote reaches the Detector nominal position.
The upper limit for the Minimum possible offset the BSM may offer is 999mm.
The lower limit for the Maximum possible offset the BSM has to offer is 25mm.
The upper limit shall be restricted by the BSM to the maximum distance where no reasonable transport jitter occurs.

e.g.:
(1) On some machines the selectable offset for the Banknote Present signal can be 0 to 25mm:

       Minimum Distance Banknote Present = 0
       Maximum Distance Banknote Present = 25 (must not be < 25)
           ➔ Detector may select e.g. 17

(2) On some machines the selectable offset for the Banknote Present signal is fixed to 170mm (must be >= 25):

       Minimum Distance Banknote Present = 170
       Maximum Distance Banknote Present = 170 (must not be < 25)
           ➔ Detector may only select 170

Length of Banknote Present informs the Detector of the expected length of the Banknote Present signal. The length may be fixed to this given value or may reflect the real banknote length (if this parameter is set to 0).
A valid Banknote Present signal has a leading edge distance to the previous Trailing Banknote Edge of minimum 30mm and a minimum length of 50mm.

Banknote Info Late/Early describes if the Banknote Info (Denomination / Orientation) is sent together with the Banknote ID by the BanknoteIDandINFO command (early) or separated via the Banknote ID and Banknote Info command (late). (Detailed descriptions see 4.6.1)

Resolution of Transport Clock:
The BSM must support a 1mm and 0.5mm transport clock (see Detector Info 0x22)

4.5.2.5 Detector Info 0x22

As answer to the Machine Info command the Detector sends information about its configuration.
The Detector information (Detector Type, Detector Description String, Detector Software Version and Required Detector Position) will be compared with the configuration of the BSM and in any case of mismatch between the BSM and Detector information the BSM shall stop the communication and inform the BSM operator via an understandable error message.

The Detector description string shall give an intuitive Detector / feature name and should also be found written on the Detector. For Detector Description String and Detector Software Version not used characters shall be filled with blanks (0x20).

In case of any interface error the BSM cannot start the operation and shall inform the operator about the interface problems with an understandable error message on the operator screen.

Direction: BSM in, DET out			
Offset	Length	Code / Data	Content
0	1	0x22	Command ID
1	1	…	Detector Type 0 … Thickness 1/2/3 … Authenticity Level 1/2/3 4 … Fitness 5 … Other
2	16	ASCII	Detector Description String (see Chapter 4.1 for encoding details)
18	5	ASCII	Detector Software Version (see Chapter 4.1 for encoding details)
23	1	…	Required Detector Position 0..Right/Top 1..Bottom/Left 2..don't care
24	1	…	Interface Setting Error: 0x00…No Error 0x01…Distance Machine Banknote Present to Judge not OK 0x02…Distance Machine Banknote Present to Detector not OK 0x04…Banknote Info not OK 0x80…Other Error Errors may be OR-ed
25	1	…	Selected Transport Clock Resolution 0x01……1 mm 0x02…1/2 mm All must be supported by BSM
26	2	…	Selected Distance Machine Banknote Present leading edge to nominal Detector position in mm
28	1	0-115	Number of Supplemental Data values
29	1	…	Type of Supplemental Data value #1
30	16	ASCII	Name of Supplemental Data value #1 (see Chapter 4.1 for encoding details)
46	1	…	Type of Supplemental Data value #2
47	16	ASCII	Name of Supplemental Data value #2
12+17*n	1	…	Type of Supplemental Data value #n
13+17*n	16	ASCII	Name of Supplemental Data value #n

Code	Type	Size
0x01	Signed char	1 Byte
0x02	Unsigned char	1 Byte
0x03	Signed Integer 16bit	2 Byte
0x04	Unsigned integer 16bit	2 Byte
0x05	Signed Long Integer 32bit	4 Byte
0x06	Unsigned Long Integer 32bit	4 Byte
0x07	Float single precision (IEEE-754)	4 Byte
0xA	Text1	1 Byte
0xB	Text4	4 Byte
0xC	Text8	8 Byte

Table 7: Supplemental Data types

See Chapter 4.1 for encoding details of values with type Text.

The BSM will check for the maximum amount of Supplemental Data bytes. It is the responsibility of the Detector to not exceed the maximum of 120 bytes of Supplemental Data in the Banknote Result.

The BSM has to recognise and store the length of the Supplemental Data because the data length is constant and will not be repeated in the Banknote Result message in case of transmission errors.

For the name of Supplemental Data values a meaningful intuitive name has to be used (e.g. UVIntensity1, SoilLevel2, MagLevelThread). Unused characters in the name of Supplemental Data values shall be filled with blanks (0x20).

4.6   Banknote Processing Phase

4.6.1   Banknote Processing Flow

Each banknote processing phase is announced by the BSM with the *Feed On Command 0x85* which is answered by the Detector with the *Feed On Answer Command 0x45*[5]. If the Feed On answer Message is not received or the Detector status is not set to OK the BSM shall repeat the *Feed On Command* once with one second delay. In case of no proper answer from the Detector is received, an understandable error message shall be shown to the BSM operator. The BSM shall not start feeding notes in this case.

At the end of a sorting phase the BSM sends a *Feed Off Message 0x84* to the Detector indicating the expected minimum pause length. This pause may be used by the Detector for internal calibration or self-testing and is answered by the *Feed Off answer 0x44*.

Between Feed On and Feed Off, banknotes are sorted and each banknote is announced by an active Banknote Present signal. This signal will be active a selectable distance before the banknote reaches the Detector (t_{BPL}) in order to give the Detector a Banknote ID belonging to this banknote.

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[5] It is at the discretion of the BSM manufacturer on when to send this Feed On command. E.g. it could also be sent with the start of the note transport.
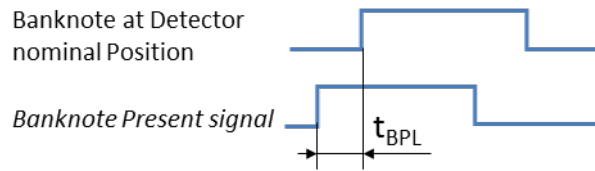
Figure 12: Timing of Banknote Present

In reference to the Banknote Present signal the BSM will send a Banknote ID to the Detector. To guarantee a correct assignment, the BanknoteID command has to be sent within 20mm after the leading edge of banknote present (t_{ID}).

All further communication (Banknote Info, Banknote Result) will refer to this Banknote ID. If the Detector does not receive a valid Banknote ID for any Banknote Present signal the Detector must not send any result. The BSM acts on this missing response of the Detector by rejecting this banknote. Denomination and Orientation of each banknote will be sent by the BSM via the command Banknote INFO or BanknoteIDandINFO.

If Denomination and Orientation is not available at the time the banknote approaches the Detector, BanknoteID will be sent in reference to the Banknote Present but BanknoteINFO will be sent later (t_{INF}), Late Banknote Info. (Maximum distance Banknote Present to Banknote Info is 2000 mm).
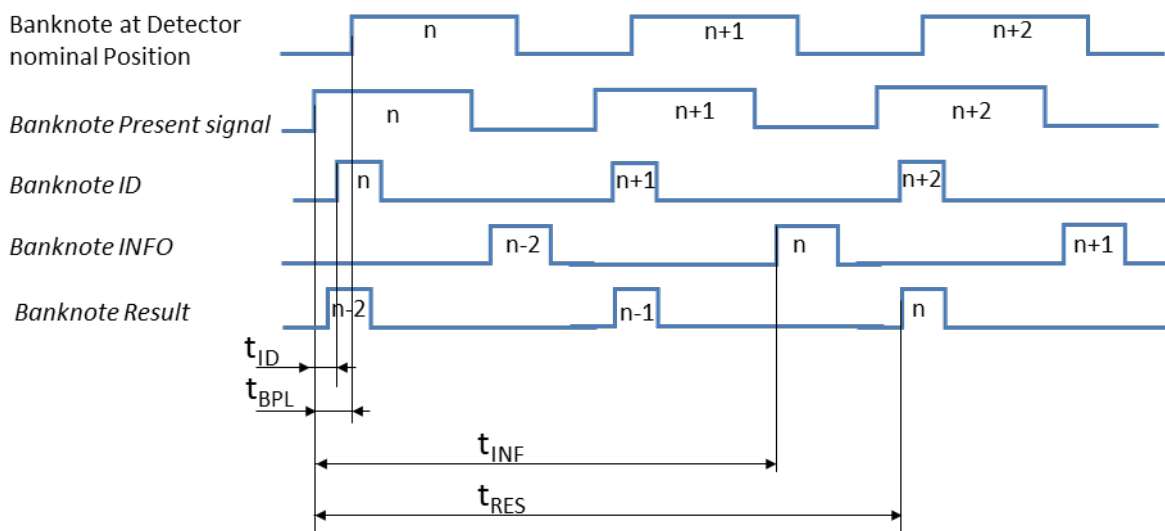

Figure 13: Signal schematics for Late Banknote Info

If Denomination and Orientation are available before a banknote approaches the Detector the BSM will use the combined Command BanknoteIDandINFO (Early Banknote Info) instead of BanknoteID and BanknoteINFO.
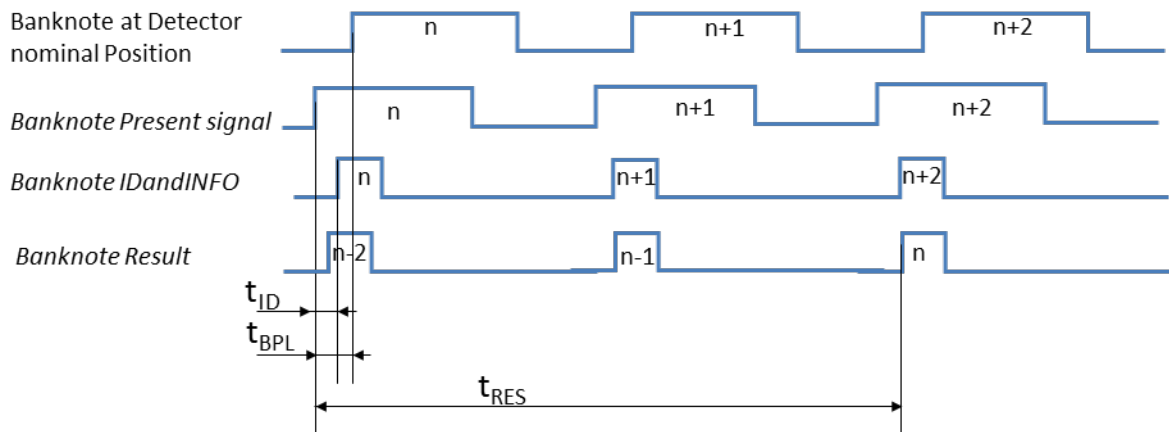
Figure 14: Signal Schematics for Early Banknote Info

Availability of late or early Banknote INFO is depending on the BSM and the mechanical position of the Detector in the BSM and will be announced by the BSM during the initialisation phase.

4.6.2 Banknote Processing Commands

4.6.2.1 Banknote ID 0x81

This message is sent to the Detector for every transported banknote. This command contains the Banknote ID, which is a unique number identifying the transported banknote for further communication.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x81	Command ID
1	4	…	Banknote ID

This Banknote ID will be used to identify this specific banknote for every further communication. (Banknote Info, Banknote Result)
Any measurement without an according Banknote ID shall be discarded by the Detector.
Furthermore the Detector shall send a result for every banknote with a Banknote ID.
The Banknote ID shall be increasing but does not need to be sequential.
The structure of the Banknote ID is 4 Bytes long, the definition is BSM manufacturer dependant, e.g.:
- Session number + 3 Byte sequential number → 0x05123456 (Session 5 with banknote sequential number 123456)
- Timestamp + sequential Number → 0x13375503 (13:37:55 Banknote 3 in this second)
- Byte sequential number → 12345678 (sequential number 12345678)

The Banknote ID may be reset after a power-off of the BSM.

4.6.2.2 Banknote Info 0x82

Banknote Info contains the denomination and orientation information for one banknote and is used for "Late Banknote Info".
Depending on the Detector slot this message can be sent later than the time the banknote passes the Detector

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x82	Command ID
1	4	…	Banknote ID
5	1	…	Banknote Series Codes
6	1	…	Denomination Code
7	1	…	Orientation Code

Banknote Series			Denomination		
Code	Name	Short Name	Code	Name	Short Name
0	Test / Calibration	Test	1	Blank Sheet	Blank
			2	Calibration	Calib
			…		
1	Euro Series 1	ES1	1	Euro 5	E5
			2	Euro 10	E10
			3	Euro 20	E20
			4	Euro 50	E50
			5	Euro 100	E100
			6	Euro 200	E200
			7	Euro 500	E500
2	Euro Series 2	ES2	1	Euro 5	E5
			2	Euro 10	E10
			3	Euro 20	E20
			4	Euro 50	E50
			5	Euro 100	E100
			6	Euro 200	E200
			7	Euro 500	E500
3-20	Reserved for future Euro Series				
21-254	Free to be used by other countries				
255	Undefined / error				

Table 8: Definition of banknote series / denomination codes

When the BSM is unable to recognise either the banknote Series, Denomination or Orientation it has to send the code 255 to the Detector for the unrecognised argument. In case the BSM does not assign a BanknoteID to the respective note, no Banknote Present signal and no information is sent to the Detector.

Orientation 1	FF – front side face forward	
Orientation 2	FR – front side reverse	
Orientation 3	BF – back side face forward	
Orientation 4	BR – back side reverse	

Table 9: Definition of orientation codes (as seen by the machine operator)

4.6.2.3 Banknote IDandInfo 0x83

This message is used for "Early Banknote Info". In this case Banknote Series, Denomination and Orientation are available before the banknote passes the Detector.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x83	Command ID
1	4	…	Banknote ID
5	1	…	Banknote Series Codes
6	1	…	Denomination Code
7	1	…	Orientation Code

4.6.2.4 Banknote Result 0x41

Banknote Result is the answer to each Banknote Info or Banknote IDandInfo Command. This message can be sent at any time after the Banknote Info respectively Banknote IDandInfo, but at the latest at the position communicated during the initialisation phase.
This result message must not be sent if no valid banknote ID was received by the Detector.
If the BSM does not receive a Banknote Result from the Detector the banknote must be sent to the reject stacker.

Direction: BSM in, DET out			
Offset	Length	Code / Data	Content
0	1	0x41	Command ID
1	4	…	Banknote ID
5	3	…	Series & Denomination & Orientation
8	1	…	Judgement (0=FIT, 1=UNFIT, 2=REJECT) + Result Code (e.g. Error Code, Reject cause…) <<2 0x80 - 0xF4 …Detector Specific Result Code
9	up to 120	…	Supplemental Data (Structure defined during start-up)

This message includes a Final Decision (Judgement), a result code (e.g. reject cause) and up to 120 bytes of Supplemental Data (the structure and length of the Supplemental Data is communicated during the initialisation phase, for details on the Supplemental Data see chapter 6).

Result Codes		
Value	Result Code	Meaning
0x04	1	No BN Info received
0x08	2	Calculation not finished
0x0C	3	Hardware error
0x10	4	Close feed
0x14	5	Denomination / orientation error
0x18	6	Feature intensity
0x1C	7	Feature shape
0x20	8	Feature presence
0x24 - 0x7C	9-31	Reserved
0x80 – 0xF4	32-61	Detector specific result code (Must be described in the Detector manual, if used)

Table 10: Banknote Result codes

Judgement examples:
FIT = 0x00 (no Result Code used)
REJECT because of Feature Intensity = 0x02+0x18=0x1A

4.6.2.5 Feed Off 0x84

This message is used to inform the Detector of a sorting pause (BSM stops sorting banknotes).

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x84	Command ID
1	1	…	Pause Length in 1/10 seconds

At the end of a sorting phase the BSM sends a *Feed Off Message 0x84* to the Detector indicating the expected minimum expected pause length. This pause may be used by the Detector for internal calibration or self-testing and shall be answered by the *Feed Off answer 0x44*.
The BSM is expected to know that it will take at least *Pause Length* seconds to speed up the transport and start feeding. If the transport is not stopped this expected time will be 0,2s.

4.6.2.6 Feed Off answer 0x44

Answer to Feed Off Command.

Direction: BSM in, DET out			
Offset	Length	Code / Data	Content
0	1	0x44	Command ID
1	1	…	Detector status (0..OK, 1-255 Error Code, see Table 5)
2	32	ASCII	Error message

A missing answer to a Feed Off command does not lead to an error state at the BSM but shall be given as a clear message to the operator screen of the BSM.

4.6.2.7 Feed On 0x85

This message informs the Detector of the end of a sorting pause and the sorting of banknotes starts.

Offset	Length	Code / Data	Content
Direction: BSM out, DET in			
0	1	0x85	Command ID

Each banknote processing phase is announced by the BSM with the *Feed On Command 0x85* which is answered by the Detector with the *Feed On answer Command 0x45*. If the Feed On answer Message is not received or the Detector status is not set to OK the BSM shall repeat the *Feed On Command* once with a 1 second delay. In case of no proper answer by the Detector an understandable error message shall be shown to the operator screen.

Upon receipt of the Feed On message, the Detector shall stop any on-going RawData transfer. The BSM shall not start feeding notes in case of improper answer by the Detector.

4.6.2.8 Feed On answer 0x45

 Answer to Feed On Command.

Offset	Length	Code / Data	Content
Direction: BSM in, DET out			
0	1	0x45	Command ID
1	1	…	Detector Status (0..OK, 1-255 Error Code see Table 5)
2	32	ASCII	Error Message

For each used Error Code a detailed description and approach for resolution shall be included in the Detector manual.

4.6.2.9 Raw Data request 0x86

Upon request of the BSM the Raw Data of the Detector is uploaded to the BSM. This may only be done by an authorised person during a sorting pause (Feed Off). The need for authorisation shall ideally be covered by the already available authorisation mechanisms on the BSM. The possibility to download Raw Data shall be made available to selected operator roles only (e.g. admin, supervisor or technician) defined by each NCB.

To start the upload a first Telegram with Start (10-19 selects the type of raw data, see table Raw data Type) is sent to the Detector. A privileged operator can select the type of Raw Data (10-19) via the BSM GUI. If no type is selected the BSM shall request all types of Raw Data consecutively. Each raw data type shall be written to a file named "DATE_SHIFT_MACHINEDESCR_DETECTORDESCR.rawXX" where XX describes the raw data type (10-19). Each file is limited to 100MByte by the Detector.

As an answer to each Raw Data Telegram an OK or Not OK is sent to the Detector.

An OK will lead to the transmission of the next Telegram whereas a Not OK will trigger a retransmission of the latest Raw Data Telegram. After two consecutive Not OK of the same Telegram a message is given to the operator on the BSM screen.

The BSM does not need to provide any visualisation of the Detector Raw Data. More details on the Raw Data handling are described in Chapter 6.

Direction: BSM out, DET in			
Offset	Length	Code / Data	Content
0	1	0x86	Command ID
1	1	…	0..OK 1..Not OK 10-19 Start Raw Data Type 10-19

Raw data Type	
Value	Meaning
10	Measurement data (e.g. line scans)
11	Statistics
12	Detection parameters
13	Diagnosis data
14-19	Detector specific, to be described in the manual

Table 11: List of Raw Data types

4.6.2.10 Raw Data answer 0x46

As an answer the Raw Data of the Detector is uploaded to the BSM.

The total amount of Raw Data is limited to the memory of the Detector, but must be at least 100 banknotes big. The amount of transmitted data in each Telegram is variable but may not exceed 1990 byte (2000 byte maximum message length including CRC, STX, ETX and Overhead as given in the below table).

Therefore the amount of data telegrams may vary depending on the total amount of data to transmit.

Preferably Raw Data shall be encrypted by the Detector before transmission.

Some Detectors need time to prepare the Raw Data. The waiting time for the BSM may however not be more than 30 seconds.

Direction: BSM in, DET out			
Offset	Length	Code / Data	Content
0	1	0x46	Command ID
1	1		0...OK 1…requested raw data not available
2	4	…	Length of remaining raw data (32Bit)
6	1	…	Data[0]
…	1	…	…
N+6	1	…	Data[N-1]

5   Mechanical Specification

5.1   Connector

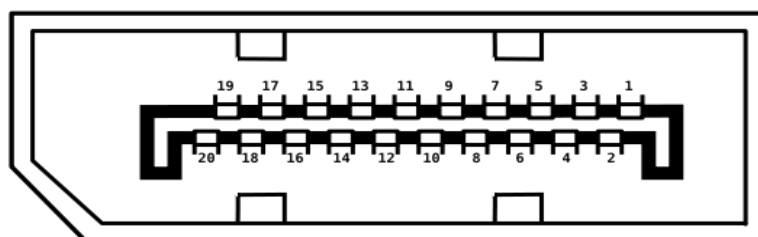The connector used will be a connector of the type Display Port.

Figure 15: Display Port female connector

CDI pinout DET side			
Pin	twist	signal	remark
1	12	RXD+	
2	11	GND_X	
3	10	RXD-	
4	9	CLK+	in
5	8	GND_X	
6	7	CLK-	in
7	6	BP-	in
8	5	GND_X	
9	4	BP+	in
10	3	TXD-	
11	2	GND_X	
12	1	TXD+	
13		NC	
14		NC	
15	15	READY	out
16	16	GND_X	isol. Supply (from BSM)
17	17	RESET	in
18	18	reserved	
19	19	+5V_X	isol. Supply IN (from BSM)
20	20	NC	

CDI pinout BSM side			
Pin	twist	signal	remark
1	12	RXD+	
2	11	GND	
3	10	RXD-	
4	9	BP+	out
5	8	GND	
6	7	BP-	out
7	6	CLK-	out
8	5	GND	
9	4	CLK+	out
10	3	TXD-	
11	2	GND	
12	1	TXD+	
13		NC	
14		NC	
15	15	READY	in
16	16	GND	
17	17	RESET	out
18	18	reserved	
19	19	+5V	
20	20	NC	
Frame		GND	

Table 12: CDI pinout

The CDI cable with the correct length for the respective CDI slot must be provided by the BSM manufacturer. The cable shall be a standard Display Port cable which is cheap, easily available up to 10m length and fully proven for high-speed data transmission.

The CDI connection on the Detector side is meant to connect the BSM to the Detector. In case the Detector consists of a measurement head and an external evaluation unit, the connection between these two parts of the Detector is up to the Detector supplier as long as the connection fits into the available space described in the Detector housing given in Chapter 5.2.

5.2   Detector

5.2.1   Detector Housing

Each Detector shall use a standard case according to the below specifications. The depth of the three M4 screwholes shown in Figure 17 shall be at least 5mm.
Each Detector shall provide a dedicated possibility to connect the Detector case to the BSM frame for grounding. This connector shall be on the back of the Detector via an at least 40cm long 1mm² cable with a 5mm lug.
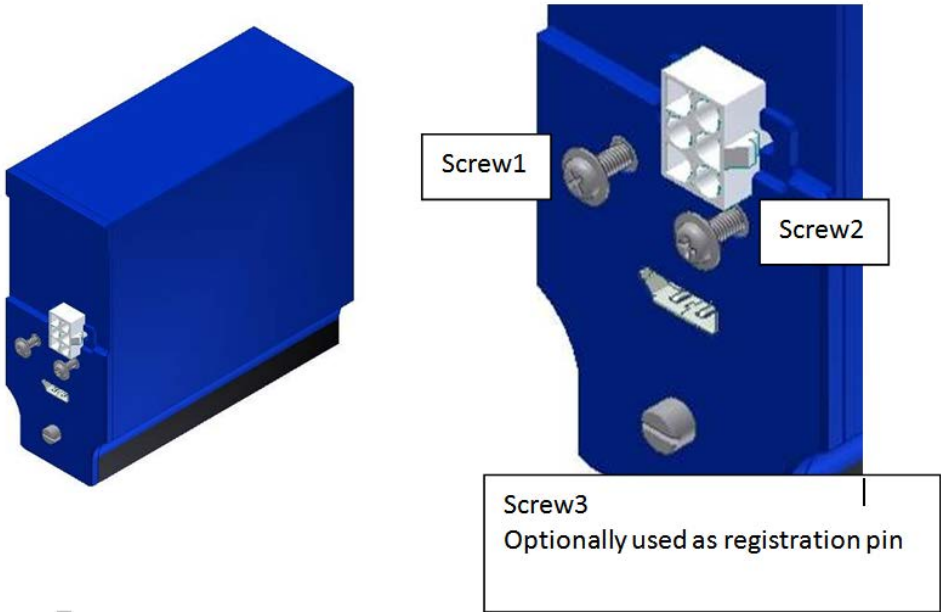
Figure 16: 3D View of the Detector[6]

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[6] The shown power supply connector (MateNLock) is not mandatory, only the available space for the connector is restricted according to Figure 18 below.
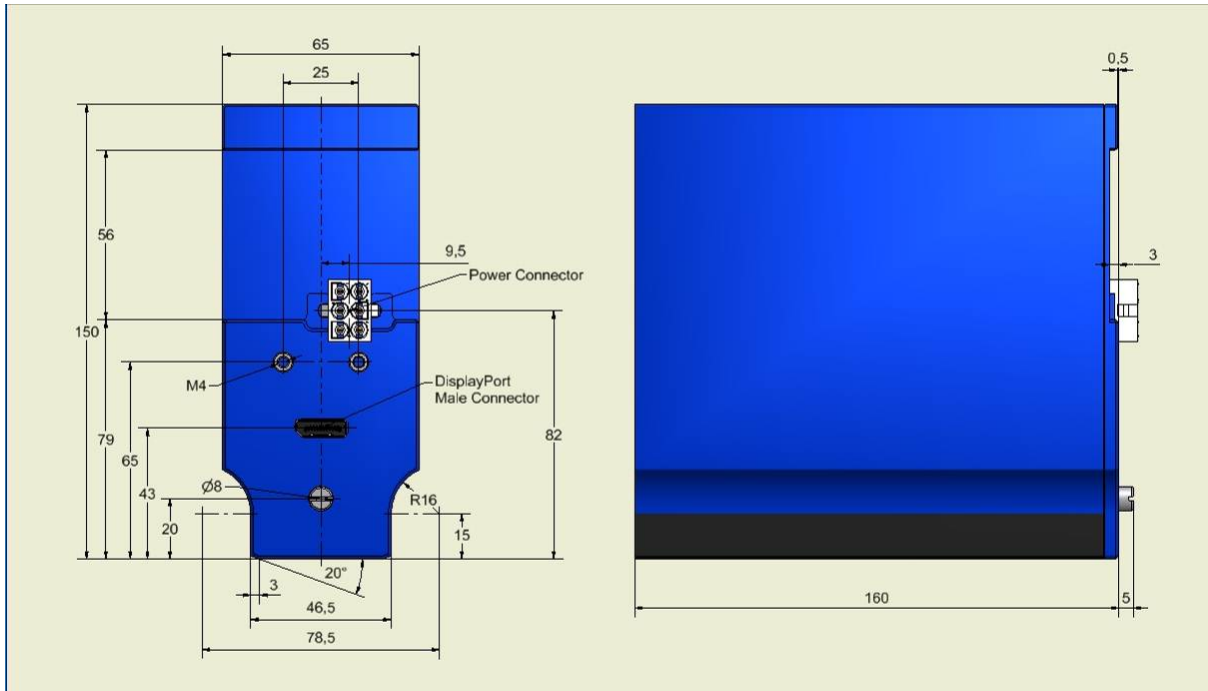
Figure 17: Detector backside (at base plate side) and side view

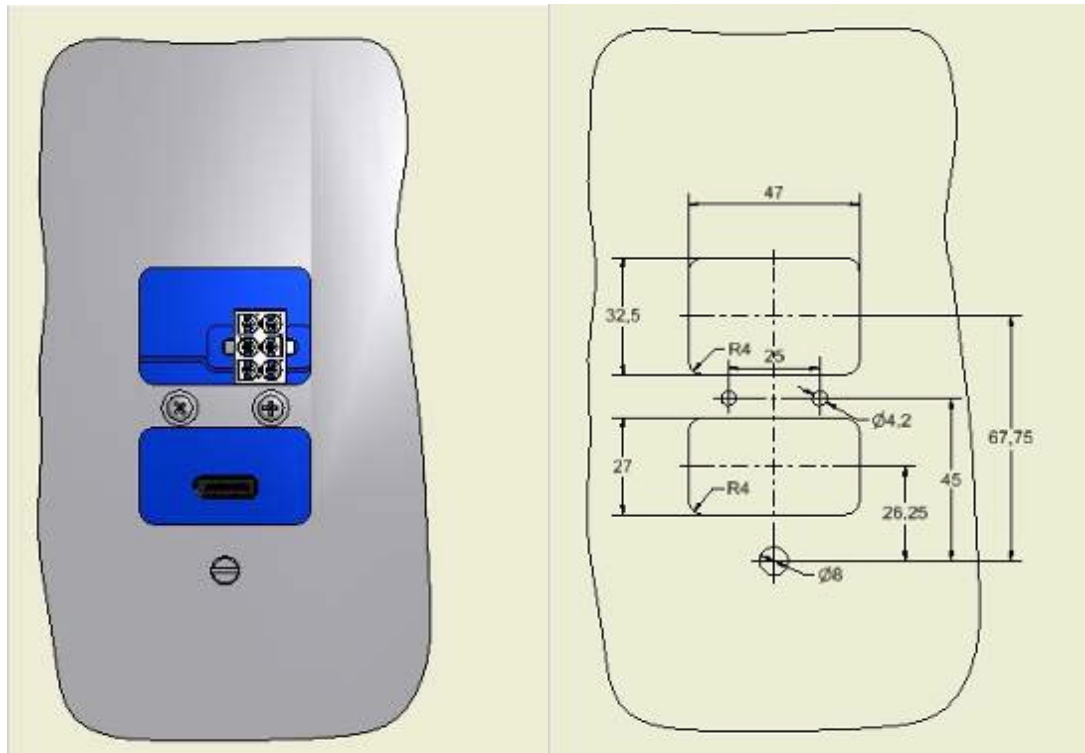The distance between Detector and banknote is not specified as this is dependent on the type of BSM.

Figure 18: Detector rear as seen through the mounting- / baseplate

5.2.2 Detector Shield Plate

The CDI specifications do not cover Detector specific shielding plates/arrangements. These would need to be agreed between the Detector and BSM supplier bilaterally if needed.

5.2.3 Information on current Banknote Sorting Machine adaptors

For mounting a Detector on an existing BSM that is not yet equipped with a CDI compliant mount, adaptors can be used to avoid impact on the BSM base plate design. In the following diagrams exemplary adaptors for current BSMs are shown.
It is the duty of the BSM supplier to supply CDI adaptors upon upgrade/delivery of any CDI compatible machine.
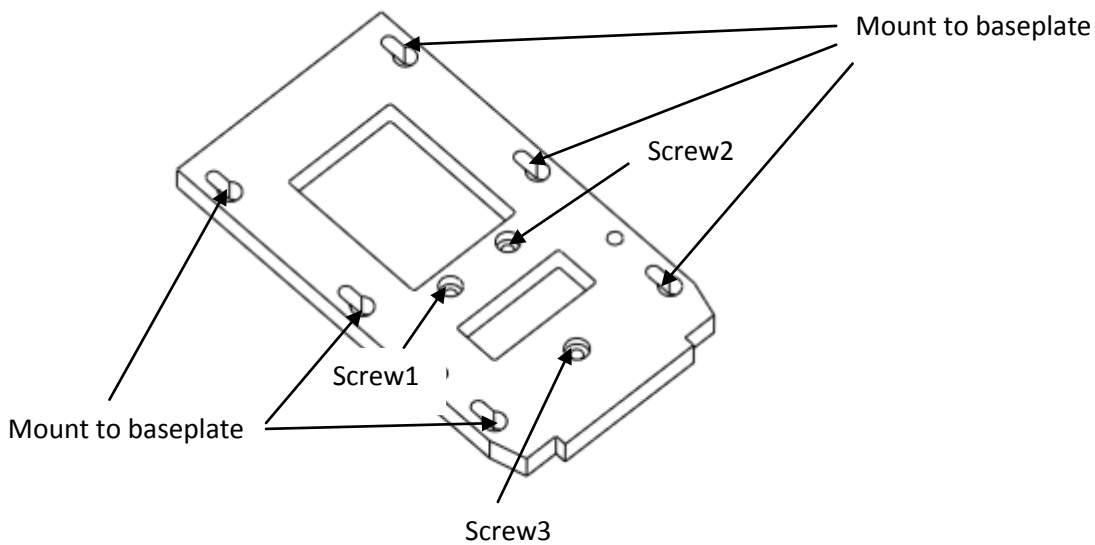
Figure 19: Mounting plate for De La Rue CPS2000
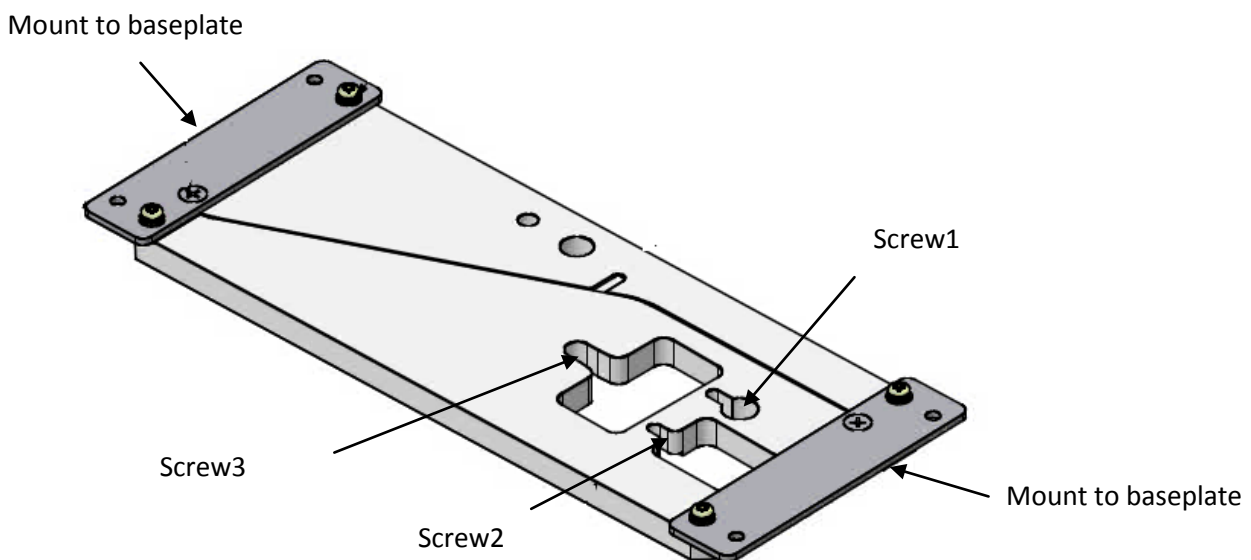
Figure 20: Mounting plate for Toshiba FS1200 and FS810
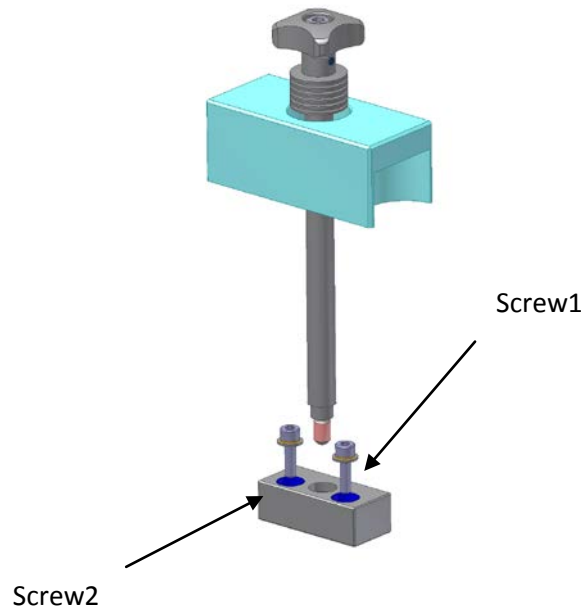
Figure 21: Clamping unit for Giesecke & Devrient BPS1000

6 Handling of Data on Banknote Sorting Machine

6.1 Handling of Supplemental Data

For further analysis the Supplemental Data shall be stored on the BSM. Additionally the BSM must provide a basic visualisation of this data and provide the possibility to export the data to an external drive or USB stick connected via USB 1.1 or higher.
The BSM does not need to keep the Supplemental Data in case of a power-off.

6.1.1 Supplemental Data storage

The BSM has to be able to store the Supplemental Data of a minimum of 1,000,000 banknotes.
For each banknote the amount of Supplemental Data and banknote specific information is limited to 128 Byte in total:

Supplemental Data		
Data size	**Name**	**Source**
4Byte	Banknote ID	Detector result
3Byte	Series & Denomination & Orientation	Detector result
1Byte	Detector Judgment + Result	Detector result
Up to 120Byte	Supplemental data	Detector result

Table 13: Supplemental Data structure

The structure of the up to 120 Bytes of Supplemental Data itself is defined by the Detector during the initialisation phase within the DetectorInfo message.

The BSM must provide a dedicated menu item/option in the GUI of the BSM including the following functions:
- clear the Supplemental Data stored in the BSM
- send a (software or hardware) Reset to the Detector

6.1.2 Supplemental Data Visualisation

During the Feed Off state the BSM shall provide the following data presentation for each numerical Supplemental Data value:
- Min Value
- Max Value
- Mean value
- Standard Deviation
- Histogram view

Additionally there shall be possibilities to filter the above visualisation of the processed data by:
- Banknote Series / Denomination / Orientation
- Detector Judgment (show only notes judged FIT/UNFIT/REJECT from this Detector)
- Amount of banknotes (all, first 1000, last 1000, from banknote XXXXX to banknote YYYYY)

Further analysis can be provided by the BSM, but is not mandatory for CDI compatibility.

The BSM shall supply the above mentioned statistics without in-depth knowledge about the meaning of each value.

6.1.3   Supplemental Data Storage Format

The data export shall be organised as a "text/csv" File (Comma-Separated Values, detailed description in RFC4180).

The exported file has to be named "DATE_TIME_SHIFT_MACHINEDESCR_DETECTORDESCR.csv" (e.g. "2011-05-21_14-02-56_5_AT-VIE#3_featurereader123.csv"). The time stated in the filename shall be the current time when the export was started. The shift stated in the filename shall be the current shift when the export was started.

The first line of the generated CSV file includes the Date, Time, Machine Description String and Detector Description String without the leading and terminating blank characters[7]. Additionally a remark whether the CSV was exported via the BSM ("CDI") or the Detector ("ESP") must be included. The second line consists of the column headers (name of Supplemental Data value as defined in the Detector Info messages.
Starting with the third line, each line describes one banknote with the following information:

- Banknote ID
- Banknote Series
- Denomination
- Orientation
- Detector Judgment
- Detector Result
- Supplemental value #1
- Supplemental value #2
- …
- Supplemental value #n

The BSM shall store Supplemental Data for every banknote processed. In case no Detector judgement was received for a banknote the BSM shall store the BanknoteID followed by zeroes in the remaining data fields (text data fields may also be represented as empty strings). Alternatively the BanknoteID can be skipped.

Format definitions

Date:	DD.MM.YYYY (European format)
Time:	hh:mm:ss (hours in 24h format)
BnID:	plain number (decimal or hexadecimal)
BN Series:	Text (Short name as described in the series / denomination Table 7)[8]
Denomination:	Text (Short name as described in the series / denomination Table 7)
Orientation:	1/2/3/4
Judgment:	Text: FIT/UNF/REJ
Other Values:	as defined during initialisation (Detector Info 0x22)

---

[7] The Detector description string "TEST 123" would be changed to "TEST 123"
[8] In case no text is available for the code provided by the Detector the code itself shall be stored in the Supplemental Data file.

6.1.3.1 Supplemental Data Export file example

Detector "featurereader123" has the following Supplemental Data:

Name	Type
Intensity	Float single precision (IEEE-754)
Shape	Signed Integer 16bit
Level	Unsigned Long Integer 32bit
Code	Text4

Detector "featurereader123" on BSM "AT-VIE#3" sent the following results:

BNID	Series	Denom	Orion	Judgement	Result	Int	Shape	Level	Code
123456	ES1=1	Euro50=4	FF=1	FIT=0	0	50.7	100	50000	1234
123457	ES2=2	Euro2=1	BF=3	REJECT=2	32	-0.9	-1	4294967295	none

Resulting Supplemental Data file:

21.05.2012, 14:02:56, AT-VIE#3, featurereader123, via CDI
"BnID","Series","Denom","Ori","Det Judge","Det Res.","Intensity","Shape","Level","Code"
123456,"ES1","E50",1,"FIT",0,50.7,100,50000,"1234"
123457,"ES2","E5",3,"REJ",32,-0.9,-1,4294967295,"none"

6.1.4 Supplemental Data Export

Data transfer of the complete Supplemental Data to an attached USB device shall be via a dedicated menu item/option in the GUI of the BSM. Again, also this option may only be available to users with sufficient privileges (e.g. admin, supervisor or technician).

6.2 Handling of Raw Data

For in-depth analysis of the Detector results, the option of uploading Raw Data to the BSM must be available.
This Raw Data can be used for further analysis with Detector specific software supplied by the Detector supplier. This analysis will typically be done on a separate PC.

6.2.1 Raw Data storage

On request of the BSM operator with sufficient privileges the Raw Data is uploaded to the BSM during a Feed Off.
Each Raw Data type shall be written to a file named.
"DATE_TIME_SHIFT_MACHINEDESCR_DETECTORDESCR.rawXX" where XX describes the raw data type (10-19) and is limited to 100MByte each. The BSM shall reserve an overall storage space of 1Gb for the Raw Data values.
The format of the Raw Data depends on the type of the Detector. The BSM shall store all bytes fully transparent to the Raw Data file and may not apply any data conversion.

6.2.2 Raw Data export

Raw data export shall be identical to the Supplemental Data export as described in the last paragraph of 6.1.3 above.

7 Handling of Data on Detector

As a general measure, the Detector shall purge all Supplemental Data and all measurement-specific Raw Data when receiving a Hardware- or Software Reset from the BSM.

7.1 Handling of Supplemental Data

For further analysis a lower amount of the Supplemental Data shall also be stored on the Detector. The Detector shall be able to export these stored Supplemental Data via the ESP to a PC. The Detector supplier has to provide all necessary parts needed to connect to the ESP of its Detector together with the Detector shipment, such as:

- USB cable
- Software driver
- Communication software
- Data interpretation software

The communication protocol of the ESP is not restricted.

7.1.1 Supplemental Data Storage

The Detector has to be able to store the Supplemental Data of at least the last 10,000 banknotes, preferably the last 1,000,000 notes shall be available on the Detector. For each Banknote the amount of Supplemental Data is limited to 128 byte:

Supplemental Data		
Data size	**Name**	**Source**
4Byte	Banknote ID	Detector result
3Byte	Series & Denomination & Orientation	Detector result
1Byte	Detector Judgment + Result	Detector result
Up to 120Byte	Supplemental data	Detector result

Table 14: Supplemental Data structure

7.1.2 Supplemental Data Visualisation

During Feed Off state the data presentation, providing identical functionalities as described in 6.1.2 above for each Supplemental Data value, shall be possible on a PC connected to the Detector via the ESP.

7.1.3   Supplemental Data Storage Format

The data format shall be identical to the one on the BSM side (see Chapter 6.1.3).
The exported file has to be named "DATE_TIME_MACHINEDESCR_DETECTORDESCR.csv" (e.g. "2011-05-21_14-02-56_AT-VIE#3_featurereader123.csv"). The time stated in the filename shall be the current time when the export was started.

7.1.4   Supplemental Data Export

Data transfer of the complete Supplemental data to the connected PC shall be via a dedicated menu item/option in the GUI of the Detector software for users with sufficient privileges (e.g. admin, technician or supervisor)

7.2   Handling of Raw Data

For in-depth analysis of the Detector the Raw Data must be also available via the ESP.

7.2.1   Raw Data storage

The Detector shall be able to export the stored Raw Data via the ESP to a PC when no banknotes are being sorted (Feed Off). The Detector supplier has to provide all necessary parts needed to connect a standard PC to the ESP of its Detector such as:

- USB or network cable
- Software driver
- Communication software
- Data interpretation software

The Detector must have at least the last 100 banknotes available in its memory to be accessible via its ESP.

7.2.2   Raw Data export

The format of the Raw Data depends on the type of the Detector. To avoid conversion issues the raw bytes are saved. It is up to the user of this Raw Data to change it in the right formats.
Each Raw Data type is written to a file named
"DATE_TIME_MACHINEDESCR_DETECTORDESCR.rawXX" where XX describes the raw data type (10-19). Data transfer of the complete Raw Data to the attached PC shall be via a dedicated menu item/option in the GUI of the Detector software for users with sufficient privileges (e.g. admin, technician or supervisor).

8   Table of Figures

9   Table of Tables

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