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TECHNICAL NOTE

USER INTERFACE TO THE BEAM INTERLOCK SYSTEM

Abstract

This note describes the functionality and the requirements of any User System's connection to the Beam Interlock System via the User Interface; this connection is critical for machine safety and must be implemented in a very specific manner to provide safe and reliable interlocking. The same unit is provided for all of the different applications of the Beam Interlock System; LHC ring, LHC injection, SPS ring and SPS Extraction & Transfer Lines.

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Table of Contents

List of Figures

List of Tables

1. OVERVIEW

1.1 INTRODUCTION

The Beam Interlock System (***BIS***) was originally conceived and designed for the LHC, providing a fast, reliable and dependable mechanism for safe operation of the accelerator. During the design development it was always foreseen that the BIS would be capable of providing a robust modular solution for any other Beam Interlock System required by CERN. The BIS is expected to be deployed in four distinct, yet related environments:

1. The LHC ring
2. The SPS ring
3. The SPS Extraction channels and Transfer Lines: (LSS4, TT40, TT41 & TI8) and (LSS6, TT60 & TI2).
4. The LHC Injection

In all four cases, the same hardware is used to connect any **User System**[i] to the Beam Interlock System. Therefore, a unique User Interface (***CIBU***)[ii] is provided, fulfilling all the requirements of any of the three implementations.

The main priority in the development of the Beam Interlock System has been *safety*: it will respond when requested to with a very high level of safety, in fact, the BIS meets the IEC 61508 Safety Integrity Level 3 (***SIL 3***) that is to say the chances of the Beam Interlock System failing and not being able to respond to a User request are less than 10^{-7}/h. The CIBU is intended to be installed in the User System's rack, giving a safe and reliable connection from User to BIS which is independent of User hardware, and of distance from User to BIS Rack.

1.2 PURPOSE OF THIS DOCUMENT

The purpose of this document is to provide a detailed description of the interconnection from User System to BIS, in any of the three environments listed above. However it must also be understood that this document is only a ***technical note***, complementing other engineering specifications ([1], [2], [3] and [4]) describing in detail the functionality and implementation of the BIS.

1.2.1 REFERENCES

[1] The Beam Interlock System, Engineering Specification.
LHC-CIB-ES-0001-00-10 (EDMS Document No. 567256)
This document describes the functionality, architecture and performance requirements of the Beam Interlock System. In addition it defines the interfaces of the LHC BIS with the other systems

[i] Any equipment interconnected to the BIS with the purpose of interlocking is designated a **User System**
[ii] Following the LHC naming convention, this hardware is designated as **CIBU** (**C**ontrols-**I**nterlocks-**B**eam-**U**ser)
The CIBU is available in 2 versions: CIBU**S** (**single** type for one beam connection) and CIBU**D** (**double** type for beam1/beam2 connections)

[2] The Beam Interlock System Realisation, Engineering Specification (in preparation). Describing the LHC BIS implementation, explaining the design and realisation of the different hardware parts that compose the BIS, also covering the reliability, safety, availability and maintainability of the LHC BIS.

[3] The SPS Beam Interlock System, Engineering Specification
(in preparation).
Describing the purpose and architecture of the SPS BIS, its functions, its interfaces with other systems, and its implementation based on the LHC BIS.

[4] Interlocking between SPS, CNGS, LHC transfer lines and LHC injection, Engineering Specification, LHC-CI-ES-0002 (EDMS Document No. 602470).
Describing the SPS Extraction Lines BIS layout, discussing the implementation based on the LHC BIS. Also lists the expected Extraction Line Users.

1.3 AN IMPORTANT NOTE ABOUT REDUNDANCY

To meet the stringent SIL 3 requirements, and for CERN's accelerator complex to be suitably protected against beam related damage, the Beam Interlock System is completely redundant. This redundancy is performed using 2 separated channels (named **'A'** and **'B'**) from User System through to the Kicker systems. It is for this reason that two separate BEAM_PERMIT inputs are required from the User System, labelled as **USER_PERMIT 'A'** and **USER_PERMIT 'B'**; ideally these two links should connect to two completely isolated pieces of hardware in the User System.

It has to be noted that ***joining the redundant links together creates a single-mode failure in the interconnection, circumventing all BIS redundancy and thus having a huge impact on LHC safety. Explicit justification*** is needed for any User System that will not provide a redundant USER_PERMIT signal to the BIS.

1.4 STRUCTURE OF THIS DOCUMENT

The Beam Interlock System consists of identical modular hardware, however the end function carried out differs according to the scenario in which it is used. This document begins by briefly describing the functions and differences of each of the four main applications of the BIS.

The role of the User Interface for:

- ***LHC Interlock*** is described in s*ection 2.1.*
- ***SPS Interlock*** is described in *section 2.2.*
- ***SPS Extraction Interlock*** is described in *section 2.3.*
- ***LHC Injection Interlock*** is described in *section 2.4.*

Section 3 describes the CIBU function, showing diagrams with connector and LED locations.

Section 4 specifies the electronic interface required by the User System, with its requirements and implementation.

Section 5 details other user requirements and the document concludes with complete diagrams of the preferred implementation of the interface.

2. THE ROLE OF THE USER INTERFACE

2.1 INTERLOCKING THE LHC

The aim of the Beam Interlock System is to generate BEAM_PERMIT signals for the two circulating LHC Beams.

When BEAM_PERMIT is TRUE

» The related beam is allowed to circulate.

When BEAM_PERMIT is FALSE

» A beam dump is requested (when BEAM_PERMIT *changes* to FALSE).

More information is given in the dedicated engineering specification [1].

In LHC, the role of the CIBU is to take the two USER_PERMIT signals and transmit them to the nearest Beam Interlock Controller in a safe and reliable manner. In return the Users receive a BEAM_INFO giving an indication of the availability of the whole LHC machine for beam operation.

Two different families of User System are connected to the BIS:

1. Those interlocking Beam-1 and Beam-2 **independently**
   » User connects twice, with Beam-1 and Beam-2 via a CIBUD (see 3.2.1).
2. Those interlocking Beam-1 and Beam-2 **simultaneously**
   » User connects once, with Both-Beam via a CIBUS (see 3.2.2).

CIBU type & User Connection	USER_PERMIT		BEAM_INFO	
	TRUE	FALSE	TRUE	FALSE
CIBUD (Beam-1)	Beam-1 allowed to circulate	Beam operation NOT permitted **OR** dump request for Beam-1	All required Beam-1 User Systems are available	At least one required Beam-1 User System is unavailable
CIBUD (Beam-2)	Beam-2 allowed to circulate	Beam operation NOT permitted **OR** dump request for Beam-2	All required Beam-2 User Systems are available	At least one required Beam-2 User System is unavailable
CIBUS (Both-Beam)	Beam-1 & Beam-2 allowed to circulate	Beam operation NOT permitted **OR** dump request for Beam-1 & Beam-2	All required User Systems for Beam-1 **OR** Beam-2 operation are available	At least one required Beam-1 **AND** At least one required Beam-2 User System is unavailable

Table 1: USER_PERMIT and BEAM_INFO Descriptions for LHC

N.B The safety requirements of the BIS dictate the internal architecture for the transmission of information from the User System to the LHC Beam Dumping System. This action meets at least *SIL 3* of the *IEC 61508* standard. However, it must be noted that the BEAM_INFO signal provided by the CIBU has ***no such safety requirement***.

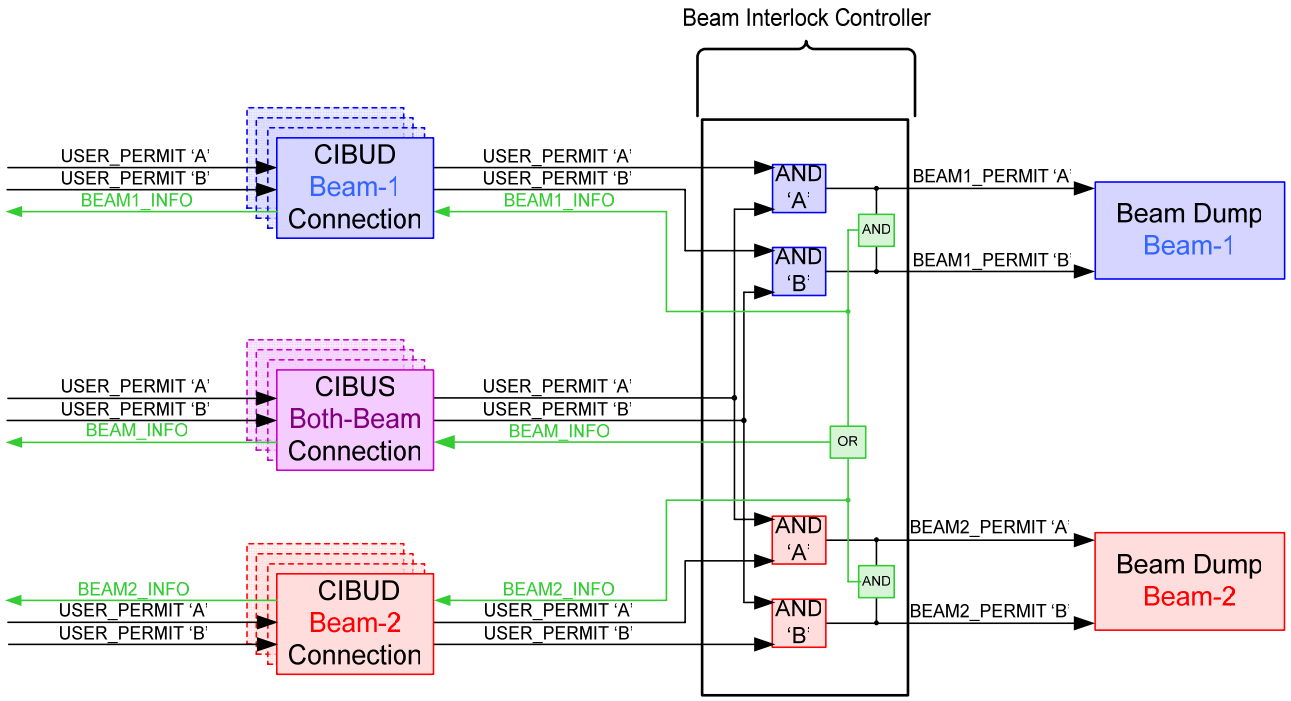

Figure 1: Simplified Internal Architecture of the LHC Beam Interlock System

The role of the CIBU is simply to transmit the USER_PERMIT signals to the nearest Beam Interlock Controller in a safe and reliable manner, the redundant channels are labelled as **'A'** and **'B'** in the diagram. Connections to the LHC Injection System are not shown for simplicity.

The LHC BIS is made from 16 *Beam Interlock Controllers* (***BICs***) distributed around LHC. Each one performs the logical 'AND' of USER_PERMIT signals from the connected User Systems. A very simplified version with only three connected systems is shown above, the BIC is able to connect with many more.

2.2 INTERLOCKING THE SPS RING

In the SPS, the Beam Interlock System generates a single BEAM_PERMIT signal:

When BEAM_PERMIT is TRUE

» SPS Beam is allowed to circulate, and SPS injection is permitted.

When BEAM_PERMIT is FALSE

» An SPS beam dump is requested (when BEAM_PERMIT *changes* to FALSE)

More information is given in the dedicated engineering specification [3].

The SPS CIBU transmits the USER_PERMIT signals in a reliable and safe manner to the nearest Beam Interlock Controller to produce the SPS BEAM_PERMIT signal. In return it provides Users with the BEAM_INFO giving an indication of the availability of the SPS ring for beam operation:

CIBU Type	USER_PERMIT		BEAM_INFO	
	TRUE	FALSE	TRUE	FALSE
CIBUS	SPS-Beam allowed to circulate	Beam operation NOT permitted **OR** SPS-Beam dump request	All required SPS-Beam User Systems are available	At least one required SPS-Beam User System is unavailable

Table 2: USER_PERMIT and BEAM_INFO Descriptions for SPS

The SPS BIS has a simplified architecture, but the same safety level as the LHC BIS. A single connected system is shown in the drawing below

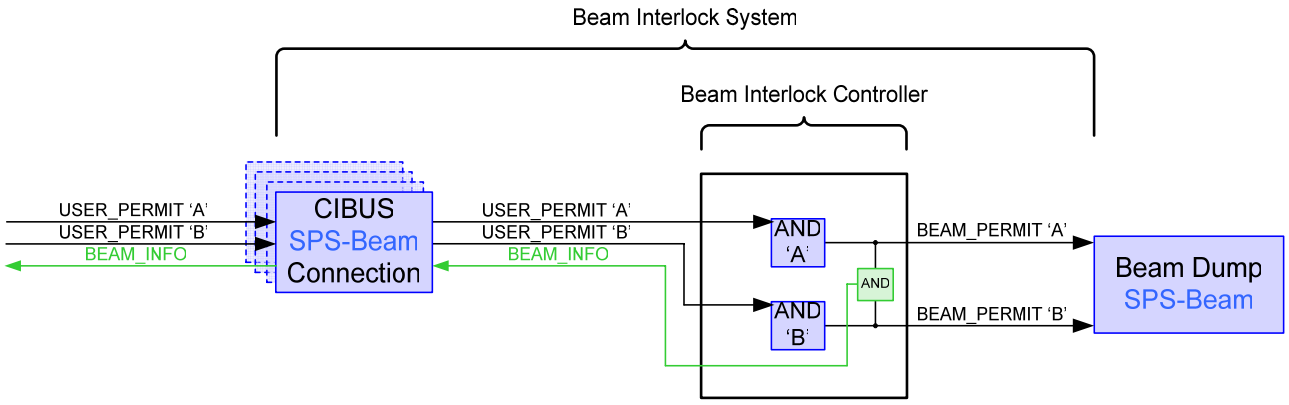

Figure 2: Simplified Internal Architecture of the SPS Beam Interlock System

The SPS BIS is composed of 6 *Beam Interlock Controllers* (***BICs***) one installed in each BA building. Each controller performs the logical 'AND' of USER_PERMIT signals from the locally connected User Systems.

This is exactly the same hardware as the other Beam Interlock Systems, simply without the Beam-2 modules, as SPS has only one Beam. As a result, the function of the SPS BIS is identical to the LHC BIS: when any USER_PERMIT is removed, the Beam Dump is fired and the Beam is extracted.

2.3 INTERLOCKING THE SPS EXTRACTION AND TRANSFER LINES

The role of the SPS Extraction Lines BIS is to enable beam extraction when all of the Extraction Line systems are ready. SPS Extraction is blocked if at least one system is not available. The same system is used for both SPS Extraction zones.

The BIS managing the SPS Extraction and Transfer Lines is based on a different architecture than the others:

- Several "slave" BICs, each interlocking a transfer line or part of one.

Connected to

- One "Master" BIC receiving the signal from the "slave" BICs and generating a BEAM_PERMIT signal for the dedicated Extraction Kicker system:

When BEAM_PERMIT is TRUE

» SPS Extraction is permitted.

When BEAM_PERMIT is FALSE

» SPS Extraction is not permitted.

More information is given in the dedicated engineering specification [4].

The Role of the CIBU in this case is to safely and reliably transmit the USER_PERMIT information to the nearest "slave" Beam Interlock Controller:

CIBU Type	USER_PERMIT		BEAM_INFO	
	TRUE	FALSE	TRUE	FALSE
CIBUS	SPS-Extraction is allowed	SPS-Extraction is NOT allowed	See note below	See note below

Table 3 : USER_PERMIT and BEAM_INFO Descriptions for SPS Extraction Lines

Note: The SPS Extraction Line BIS is based on hierarchy and its function is based on a windowed approach, with long periods of BEAM_PERMIT = FALSE followed by millisecond bursts of BEAM_PERMIT = TRUE when extraction is being made.

For these reasons BEAM_INFO is maintained in the SPS Extraction and Transfer Lines solely for hardware compatibility reasons.

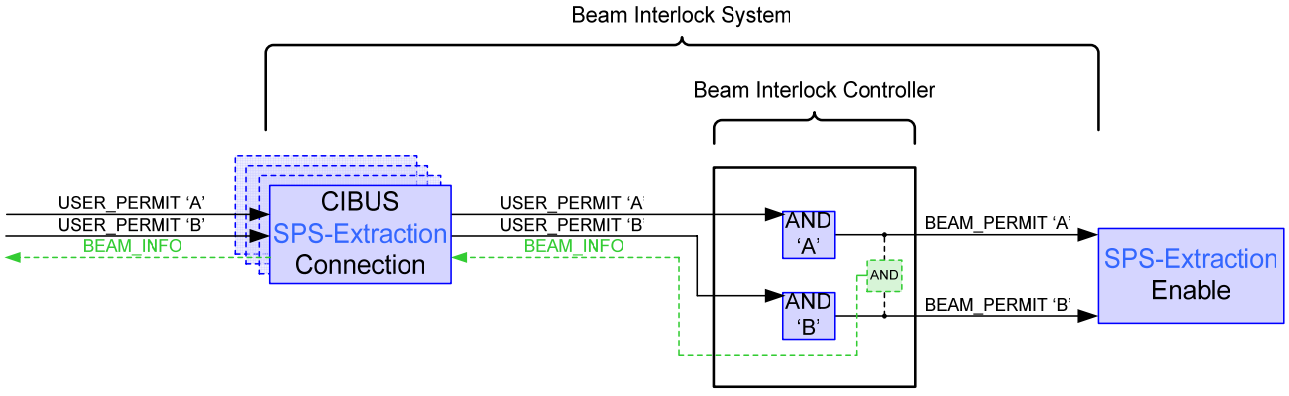

Figure 3: Simplified Architecture of SPS Extraction and Transfer Lines Interlock System

The BIS managing the SPS Extraction and Transfer Lines is using the same hardware as all other Beam Interlock Systems.

2.4 INTERLOCKING THE LHC INJECTION

For the LHC Injection zones, the Beam Interlock System generates a single BEAM_PERMIT signal:

When BEAM_PERMIT is TRUE

» LHC injection is permitted.

When BEAM_PERMIT is FALSE

» LHC Injection is blocked.

More information is given in the dedicated engineering specification [3].

The CIBU transmits the USER_PERMIT signals in a reliable and safe manner to the nearest Beam Interlock Controller to produce the INJECTION BEAM_PERMIT signal. In return it provides Users with the BEAM_INFO giving an indication of the availability of the injection operation:

CIBU Type	USER_PERMIT		BEAM_INFO	
	TRUE	FALSE	TRUE	FALSE
CIBUS	LHC-Injection is allowed	LHC-Injection is NOT allowed	See note below	See note below

Table 4: USER_PERMIT and BEAM_INFO Descriptions for LHC Injection

The LHC Injection BIS has same safety level as the LHC BIS, the Injection BIS gives a windowed BEAM_PERMIT, with long periods of BEAM_PERMIT = FALSE followed by millisecond bursts of BEAM_PERMIT = TRUE when injection is being made.

For these reasons BEAM_INFO has little real meaning in the injection controllers. It is maintained only for compatibility.

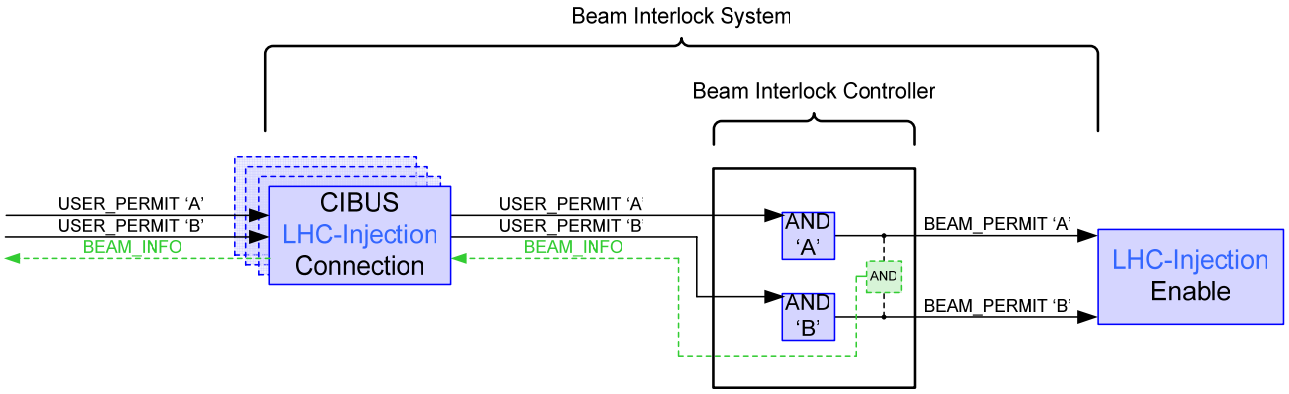

Figure 4 : Simplified Internal Architecture of the LHC Injection Interlock system

The LHC Injection BIS is composed of only one *Beam Interlock Controller* (***BIC***) installed in each LHC injection region (SR2 and SR8). Each controller performs the logical 'AND' of USER_PERMIT signals from the locally connected User Systems.

As a result, when any USER_PERMIT is FALSE, the corresponding LHC Beam Injection is blocked.

3. DESCRIPTION OF THE USER CONNECTION

To maintain the safety requirements of the Beam Interlock System, the method of connection of User Systems is very particular. Effort has been made to create a simple, reliable and versatile input structure: taking into consideration the variety amongst equipments and the times of response required by the whole system.

3.1 THE DIFFERENT TYPES OF USER SYSTEMS

There are many different types of hardware platform that will be connected directly to the BIS, equipment ranges from standard VME based approaches through Compact PCI, operating with TTL logic at around 5V, to PLC based systems where the common output voltage is 24V or a current loop. Overall the User Systems can be generalised into the following two categories:

Main Hardware	**Operating Voltage** *(Volts)*	**Speed Of Response** *(relative)*	**Permit Change Time**
PLC System	24	Slow	~1-10ms
VME System	5	Fast	~0-5µs

Table 5: Basic Types of User System

The input circuit of the User Interface accommodates these systems with the same interface.

3.2 HARDWARE INTERFACE SUPPLIED TO THE USER SYSTEMS

The User Interface (***CIBU***) hardware is provided to all Users who need to connect to any Beam Interlock System. It consists of a *19" rack mounted* board, having a height of *2U*.

It will be mounted at the front of the Users Rack, with all electrical connections made at the rear of the CIBU panel, only status LEDs are visible from the front.

The CIBU variants completely serve all different types of User: LHC ring, LHC Injection, SPS ring and SPS Extraction Lines.

Therefore, the User Interface is available under 2 versions:

- CIBU**S**: **single** connection for interlocking a single Beam or Both-Beam.
- CIBU**D: double** connections for interlocking Beam-1 or Beam-2.

Note: The CIBUD and the CIBUS use exactly the same internal hardware. As the CIBUS has single connection, it has simply half of the components (the Beam-2 part is not assembled).

In both cases, the CIBU contains fully redundant power supplies and the hardware within the panel can be tested and monitored at distance.

3.2.1 THE CIBUD

The CIBU type **D** (i.e. CIBUD) is only used in the LHC. It permits to connect LHC User System that is interlocking Beam-1 and Beam-2 independently.

The User connects to the BIS *twice*, once for each Beam. This connection is made in the **same CIBUD** but via a separate cable with a different gender connector and socket.

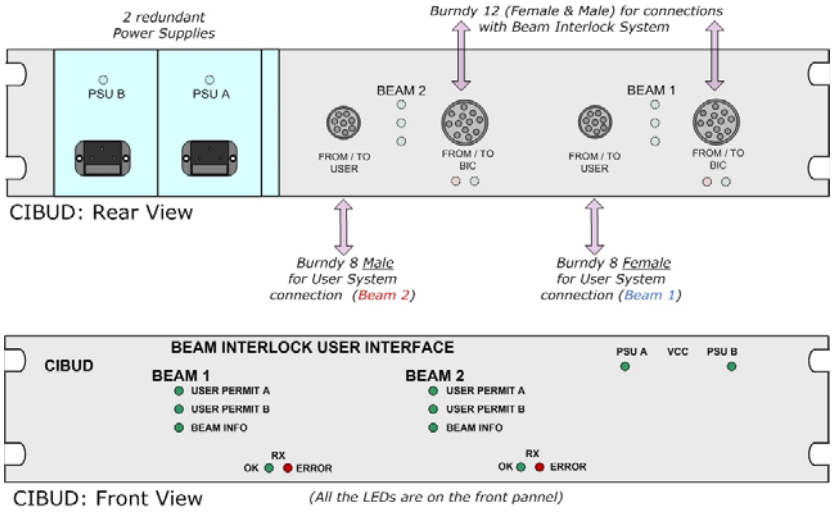

Figure 5: Rear View and Front View of the CIBU type D

3.2.2 THE CIBUS

The CIBU type **S** (i.e. CIBUS) is used for SPS ring, for LHC Injection and for Extraction and Transfer Lines between SPS and LHC/CNGS. In all cases, there is only one beam.

The CIBUS is also used in the LHC for those Users that are interlocking Beam-1 and Beam-2 simultaneously. The User connects once, with a Both-Beam link. In case of USER_PERMIT = FALSE, both beams would be extracted.

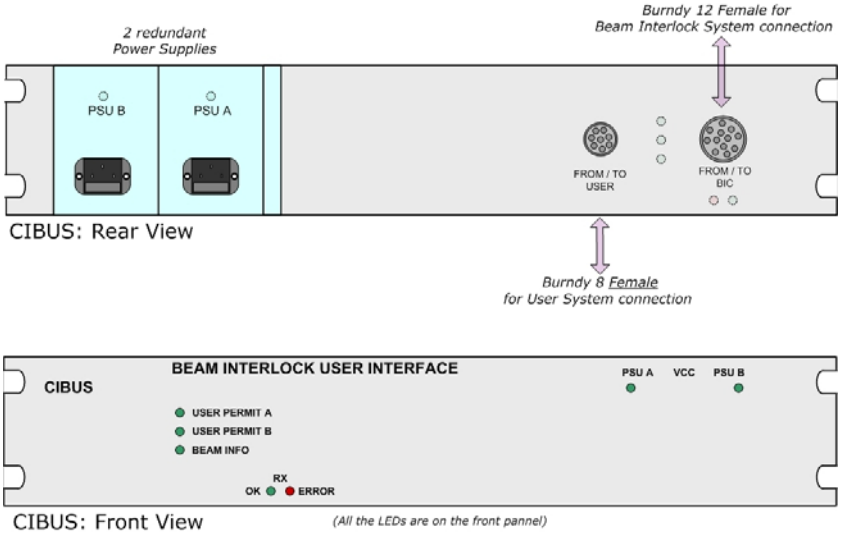

Figure 6: Rear View and Front View of the CIBU type S

The *socket* genders are noted on the two Figures on this page.

Figure 7: CIBUD Rear View

When viewed from the rear, the Beam-2 sockets are on the left hand-side, Beam-1 on the right.

3.2.3 THE CIBU LEDS

Various CIBU Light-Emitting Diodes are visible on the front panel. The important LEDs to note are those representing USER_PERMIT 'A', USER_PERMIT 'B' and BEAM_INFO. These are Tri-Colour LEDs having the functions shown in the following diagram:

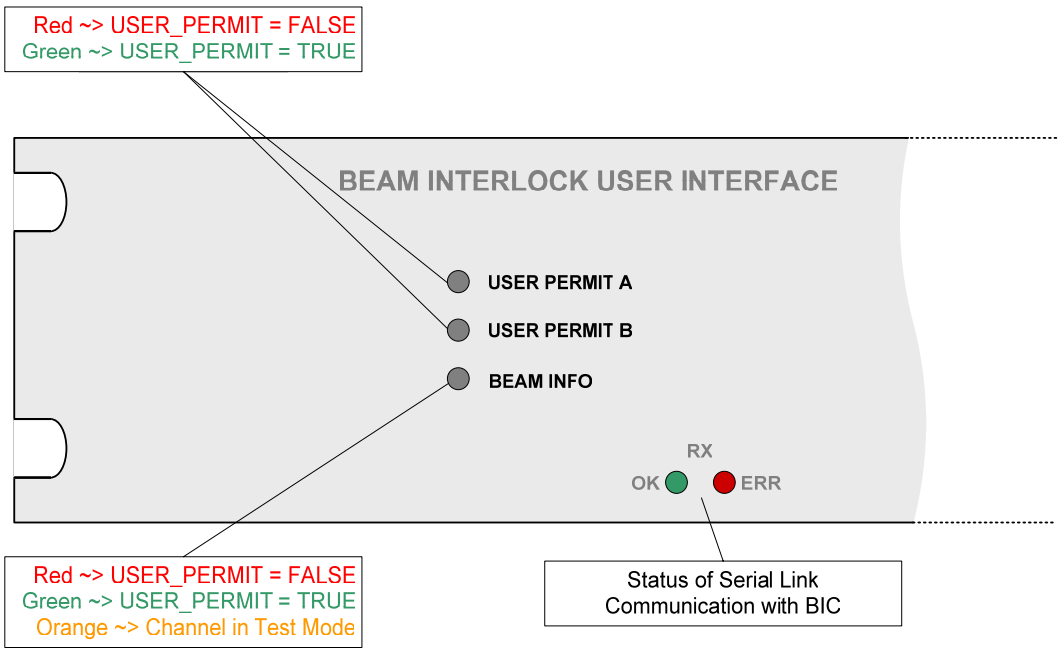

Figure 8: CIBU Tri-Colour Light-Emitting Diode Function

4. ELECTRONIC INTERFACE REQUIRED WITH THE USER SYSTEMS

4.1 GIVING USER_PERMIT

As the safety and reliability requirements of the BIS are strict, there are many rules to follow concerning the interface to the User System. The redundant USER_PERMIT signals **'A'** and **'B'** are generated by two separate current loops from the User System, for each of the two current loops the following applies:

Input Loop Current[iii] *(mA)*	USER_PERMIT *(Boolean)*
< 1	FALSE (user **DOES NOT** give permission for beam)
≥ 9	TRUE (user gives permission for beam)

Table 6: Function of the Input Current Loops for USER_PERMIT

Note that between the values of 1 and 9 milliamps, the value of USER_PERMIT is either TRUE or FALSE, depending on the age of the installed equipment. A newer optocoupler will react to lower levels of current, whereas an ageing device will have a higher threshold of current.

Essentially USER_PERMIT is guaranteed FALSE when the current is less than one milliamp, it is guaranteed TRUE when the current is greater than nine milliamps.

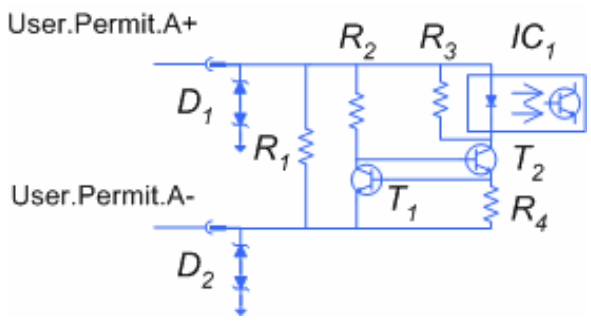

Figure 9: Current Loop for USER_PERMIT

Component Name	Value	Type
D_1	33V (Bi)	TVS +/-33V (BD)
D_2	33V (Bi)	TVS +/-33V (BD)
R_1	18kΩ	125mW
R_2	20kΩ	125mW
R_3	1k2Ω	125mW
R_4	56Ω	125mW
T_1	-	BC847
T_2	-	PZT2222
IC_1	-	HCPL-2601

Table 7 : Component List for USER_PERMIT

The User System needs to provide sufficient voltage across *USER.PERMIT.A+* and *USER.PERMIT.A-*. Around 12mA will be drawn through the optocoupler, this is regulated by the transistor T_1 in conjunction with R_4, which turns off T_2 when the voltage drop across R_4 is too high. R_3 forces the optocoupler off in low current situations, as the optocoupler requires around 1.2V across its diode before switching.

R_1 ensures that floating inputs cannot cause USER_PERMIT to change value. Note also that a pair of Transient Voltage Suppressors (D_1 and D_2) is used to protect the input of the circuit. These activate when the line voltage is outside of the range +/-33V.

Circuit USER_PERMIT 'B' is identical.

[iii] No tolerance is given for the current level, it is resulated by a transistor pair

4.2 READING BEAM_INFO

The BEAM_INFO is returned to the User in the form of an optocoupler which is driven by the CIBU:

Transistor Status	BEAM_INFO *(Boolean)*
Open	TRUE (beam is allowed to circulate)
Closed	FALSE (beam is **NOT** allowed to circulate)

Table 8: Function of the Output Transistor for BEAM_INFO

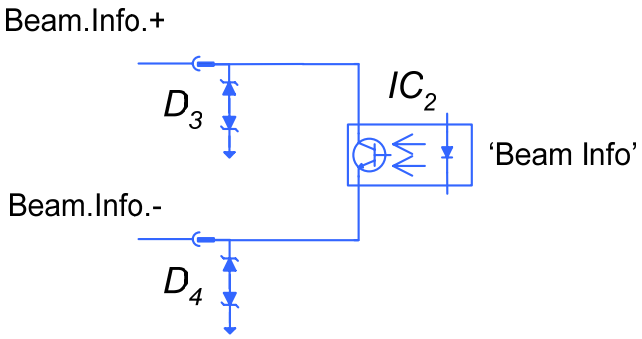

Figure 10: Optocoupler for BEAM_INFO

Component Name	**Value**	**Type**
D_3	33V (Bi)	TVS +/-33V (BD)
D_4	33V (Bi)	TVS +/-33V (BD)
IC_2	-	SFH 618A-5

Table 9: Component List for BEAM_INFO

When the CIBU allows current to flow in the optocoupler, the transistor is activated, giving an indication to the user of the status of the Beam Permit within the BIS.

The failure modes of this circuit mean that this signal cannot be used for safety critical operations. If a User wants to be sure that no beam circulates in the LHC, the USER_PERMIT must be set to FALSE.

This circuit is also protected by Transient Voltage Suppressor Diodes that activate when the signal exceeds +/-33V.

4.3 PINOLOGY OF CIBU SOCKETS

The socket on the *User Interface* (*CIBU*) for the connection from/to the *User System* is a **Burndy 8-Pin UT07**. The pinology of the socket is shown in the table directly below, with the schematic on the right:

PIN	Schematic Name	Function
1	GND	EMC improvement by ground proximity
2	GND	EMC improvement by ground proximity
3	User.Permit.A+	Current Loop + for USER_PERMIT 'A'
4	User.Permit.A-	Current Loop – for USER_PERMIT 'A'
5	User.Permit.B+	Current Loop + for USER_PERMIT 'B'
6	User.Permit.B-	Current Loop – for USER_PERMIT 'B'
7	Beam.Info.+	BEAM_INFO + collector
8	Beam.Info.-	BEAM_INFO - emitter
Shield	GND	EMC improvement by enclosure

Table 10: Pinology of CIBU User Connection

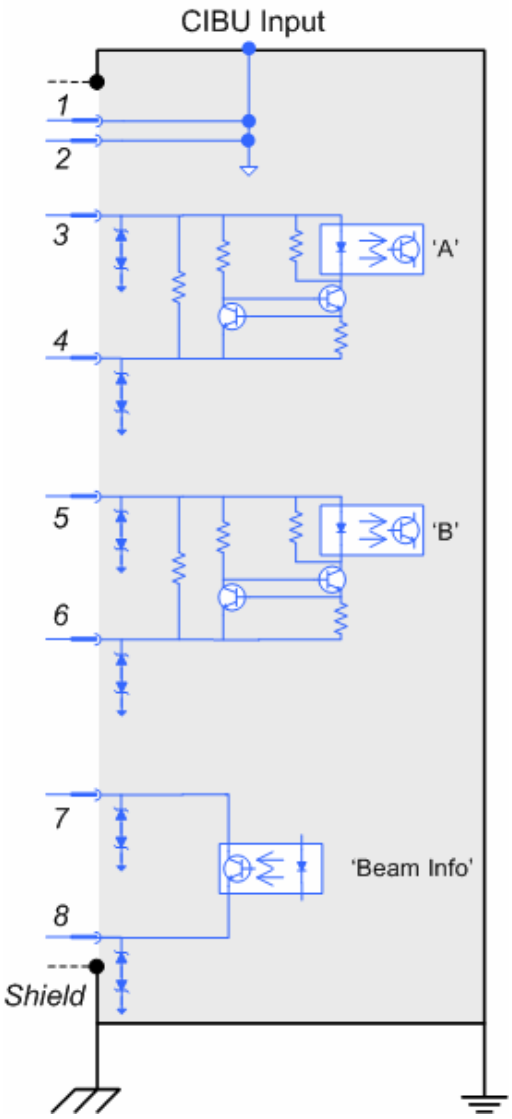

Figure 11: CIBU Input Circuit Schematic

For the CIBUS, the above socket is always a Burndy 8-Pin **female**.

For the CIBUD, it's either a Burndy 8-Pin **female** (Beam-1) or Burndy 8-Pin **male** (Beam-2). This is intentional so that User Systems capable of dumping the LHC beams individually cannot misconnect the Beam-1 and Beam-2 signals.

4.4 USER SYTEM TO BIS INPUT/OUTPUT SPECIFICATIONS

The circuit on the previous page shows the complete interface, care must be taken not to exceed the specification of any of the components used, in particular the optocouplers for the user permit signals.

4.4.1 GUARANTEED INPUT SPECIFICATIONS

Name	Description	Value
V_{ins} (max)	Maximum voltage allowed on a single USER.PERMIT.+ or .- line	33 V
V_{in} (max)	Maximum Voltage allowed from USER.PERMIT.+ to USER.PERMIT.-	~25V
V_{in} (min)	Minimum voltage needed across circuit for USER_PERMIT = TRUE	~3 V
V_{in} (rev)	Maximum negative Voltage allowed from USER.PERMIT.+ to USER.PERMIT.-	5V
dV_{in}/dt (max)	Maximum rate of change of V_{in} with respect to time	5000 V/µs
I_{intrue} (min)	Minimum current from USER.PERMIT.+ to .- for USER_PERMIT = TRUE	9 mA
I_{intrue} (max)	Maximum current from USER.PERMIT.+ to .- for USER_PERMIT = TRUE	~15mA
$I_{infalse}$ (max)	Maximum current from USER.PERMIT.+ to .- for USER_PERMIT = FALSE	1mA
I_{in} (reverse)	Maximum negative current from USER.PERMIT.+ to .-	10 µA[iv]
Δt (min)	Minimum signal length to change USER_PERMIT from TRUE to FALSE	2 µs
SAFETY	Combined Safety of USER_PERMIT 'A' and 'B'	SIL 3

Table 11: CIBU Input Specifications

The current in the input stage is internally regulated by the CIBU; the guaranteed values of current are shown in the table above. Note that a digital filter is applied to the USER_PERMIT signal, removing 2µs of state change from TRUE to FALSE.

A Note for PLC Users:

1. The dV/dt maximum means the use of mechanical relays for driving the input circuits should be avoided.

2. Applying a reverse voltage of 24V to the input circuit (for example swapping pins 3 and 4 by accident) will damage the CIBU.

4.4.2 GUARANTEED OUTPUT SPECIFICATIONS

Name	Description	Value
V_{out} (max)	Maximum voltage from BEAM.INFO.+ to .-	27 V
V_{out} (max reverse)	Maximum negative voltage from BEAM.INFO.+ to .-	6 V
I_{out} (max)	Maximum current BEAM.INFO.+ to .-	50 mA
Δt_{on} (max)	Maximum time for BEAM_INFO to change to TRUE from FALSE	140 µs
Δt_{off} (max)	Maximum time for BEAM_INFO to change to FALSE from TRUE	120 µs
SAFETY	Combined Safety of BEAM_INFO	< SIL 1

Table 12: CIBU Output Specifications

Note that **BEAM_INFO does not meet ANY of the Safety Integrity Levels of the IEC-61508**, it should be used for information only and in no case must BEAM_INFO be solely used to influence either USER_PERMIT signal.

[iv] Through optocoupler, I = V/18000 will also flow through R_1

5. USER REQUIREMENTS

5.1 POWERING THE CIBU

The User must provide **two 230V mains supply sockets** within a distance of approximately **1.5m** of the rear of the CIBU, for the redundant Power Supply Units.

5.2 USER SYSTEM TEST ON DEMAND

For the commissioning, installation and cold check-out of the CIBU, the User System must also be able to change the state of USER_PERMIT 'A' and USER_PERMIT 'B' from TRUE to FALSE on demand. This will verify the complete link from User System to BIS.

The reverse transition should not be possible[v] via any form of test mode; i.e. **Users should not be able to *force* both USER_PERMIT = TRUE** if their system is not ready for beam operation.

In order to facilitate testing of the entire interlock chain, Users are permitted to set USER_PERMIT 'A' = TRUE, but only when USER_PERMIT 'B' is guaranteed to be FALSE.

Note that upon entering a Test Mode, User Systems should toggle USER_PERMIT 'A' and USER_PERMIT 'B' to FALSE to guarantee that the machine is without beam.

5.3 USER SYSTEM SPECIFICATIONS OF INTERCONNECTION

The interconnection also dictates some of User System parameters:

Firstly, the User System must be capable of sourcing *~80mA* to drive the input stages of the USER_PERMIT signals and the BEAM_INFO, Users should take care to restrict the current that can flow through the USER_PERMIT lines, as a connector fault could drive one of these signals to ground during installation.

Secondly, the User should take care to add *Transient Voltage Suppressors* in the signal lines as transient voltage spikes could destroy unprotected User circuits.

5.4 EMC COMPLIANCE OF INTERCONNECTION

In order to avoid EMC problems, the connection from CIBU to User System must be correctly implemented. The connection is to be realised as follows:

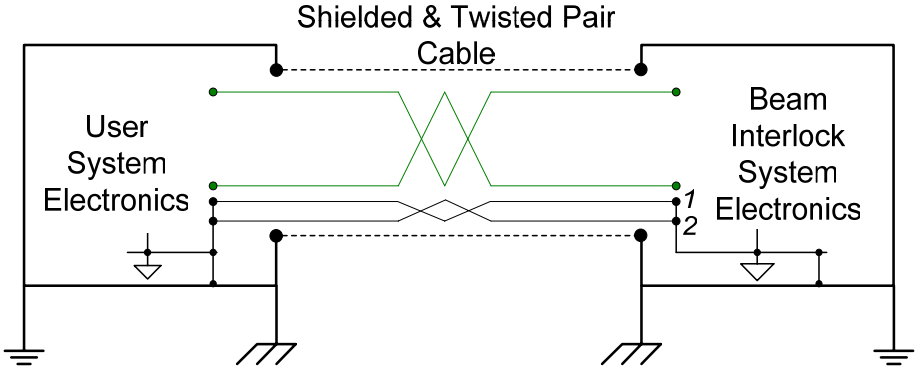

Figure 12: Principle of Interconnection for Complete EMC Compliance

[v] This constraint is NOT applicable for User Systems that are interlocking the Extraction lines

5.4.1 THE INTERCONNECTING CABLE

The interconnecting cable needs to be a **shielded-twisted-pair** (NE 8 is a good example) passing in a sensible route from User System to Beam Interlock System. The cable should be stowed in cable-racks if the distance to travel exceeds around 1m. As a rule of thumb it should be no longer than **4m** as the CIBU should be as close as practically possible to the User System. Care should be taken **not to allow the cable to run in parallel to power cables**, as they will interfere. It should also be noted that the cable should **not run in parallel to conductors carrying very low voltage signals**, as the cable can be a source of interference, as well as a receptor.

5.4.2 THE CONNECTORS

Conductive **metal connectors** are needed, which should mate with an electrically conductive chassis **without anodisation**. Whereevr possible a treatment such as alodine should be applied to make the metalwork more conductive. Note that standard front panels are NOT conductive. The shield of the cable should be connected **360°** around the connector, surrounding all the signal wires completely; **pig-tail connections for the shield are expressly forbidden**.

5.4.3 THE EARTHING

The shield of the cable should be electrically connected to the chassis, which itself should form a protective box around the user equipment. The chassis should be connected to Earth with the shortest stubs possible, and in many places. The electronic ground of the User System should also be joined to Earth in many places, with short stubs. Internal connections are provided that link the ground of the Beam Interlock System with the User System. **The electrical grounds of the Beam Interlock System and the User System should be connected together in all circumstances**.

5.5 RECOMMENDED INTERCONNECT

The interconnection from User System to CIBU should ideally be as shown in the following diagrams, change the Beam Status **4k7Ω** pull-up to suit V+ if desired.

The following diagram (Figure 13) is recommended for:

- for Both-Beam / Single Beam connection (CIBUS)
- for Beam-1 connection (CIBUD)

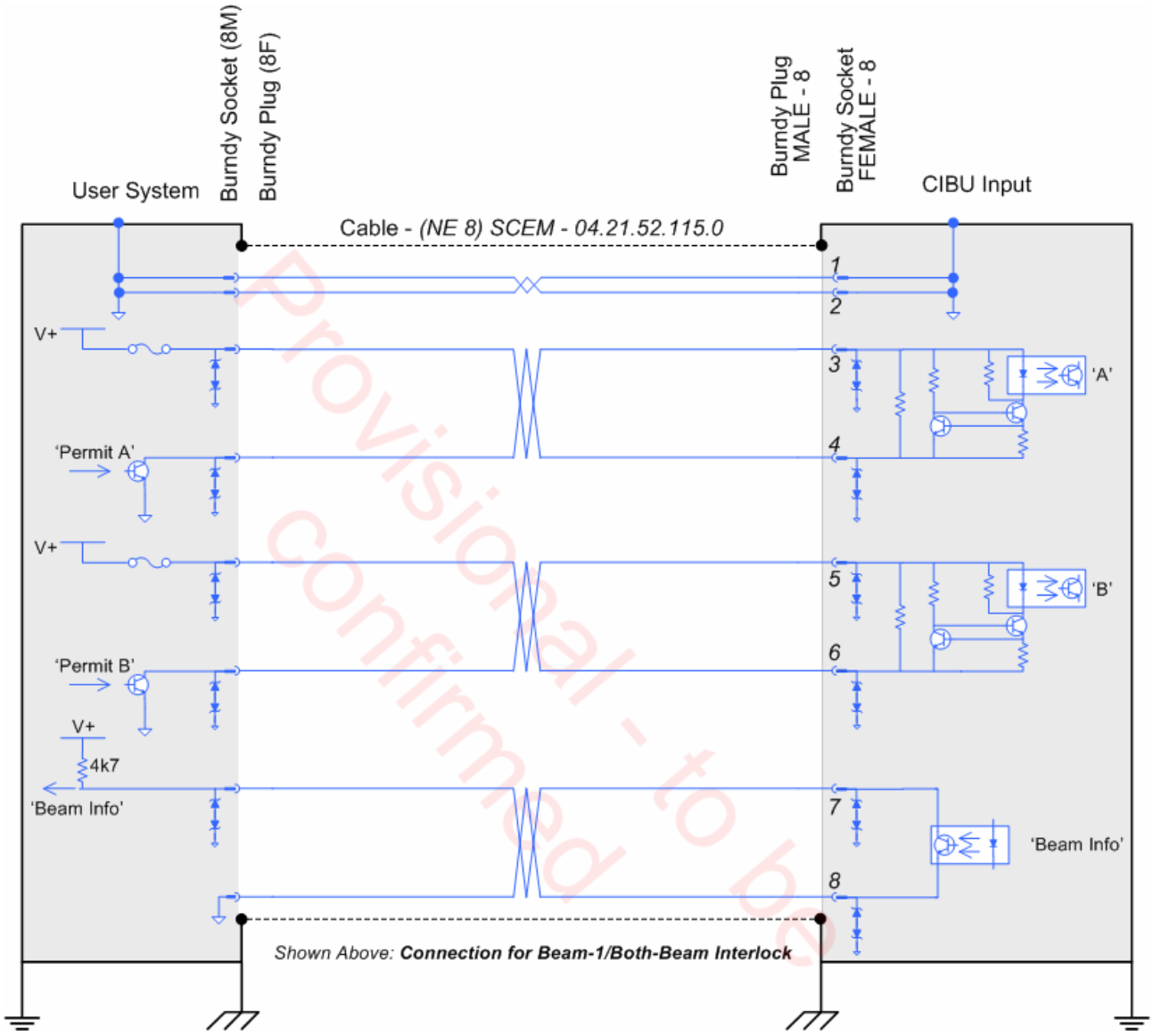

Figure 13: Recommended User interconnect for CIBUS and for CIBUD Beam-1

The following diagram (Figure 14) is used for CIBUD Beam-2 connection.

It will be used in a very small number of cases, where Independent Beam Interlock Users operate on LHC Beam-2. The type differs only very slightly in the gender of the connectors on the CIBUD.

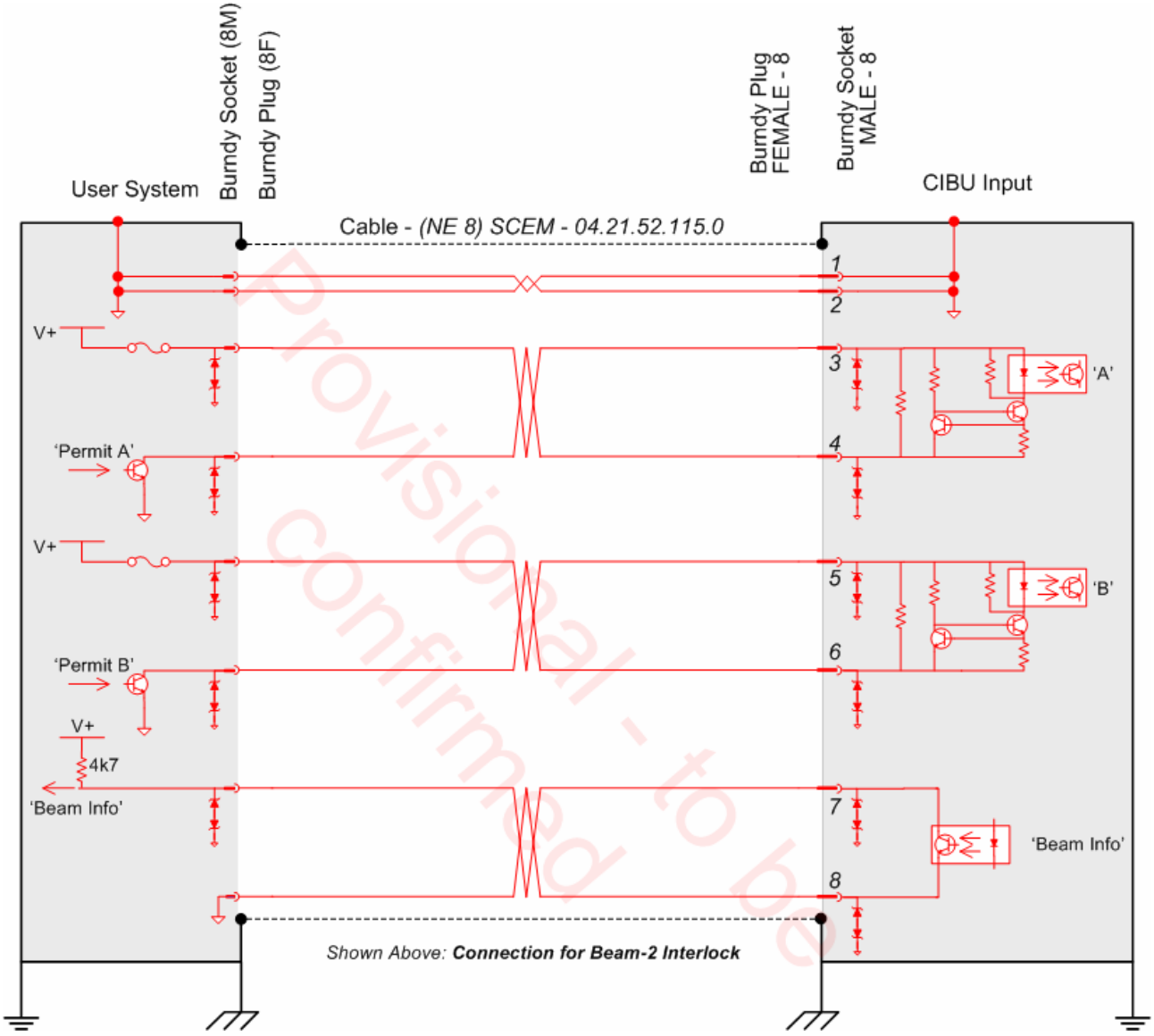

Figure 14: Recommended interconnect for CIBUD Beam-2

N.B.

The CIBU socket of a Beam-1 / Both-Beam User Connection is **FEMALE**

The CIBU socket of a Beam-2 User Connection is **MALE**

For the SPS, CNGS and Transfer Line applications User Systems should prepare a cable which ends in a Burndy 8 MALE plug, as shown in Figure 13.