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TECHNICAL SPECIFICATION

**Access, Terminals, Transmission and Multiplexing (ATTM);
European Requirements for Reverse Powering
of Remote Access Equipment;
Part 1: Twisted pair networks**

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RTS/ATTM-0636

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

The present document is part 1 of a multi-part deliverable covering the European requirements for reverse powering of remote access equipment, as identified below:

Part 1: "Twisted pair networks";

Part 2: "Coaxial cable networks".

Modal verbs terminology

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Introduction

As various Operators consider the deployment of fibre-fed remote nodes that contain xDSL DSLAM equipment, it is necessary to consider the means of powering such remotely located equipment. One such method, known as "reverse power feed", transmits the power from the customer premises to the fibre-fed remote node using the distribution-side copper network. The present document defines a reverse power feed transmission standard which allows Operators to source suitably compliant equipment for inclusion in their networks. The reverse power feed methodology can be used to power a remote node hosting any metallic transmission system (e.g. G.fast [i.4], VDSL2 [i.3], etc.).

1 Scope

The present document defines architectures and specifications for reverse powering of remote network nodes from one or multiple CPEs over twisted pair networks. The architectures describe how to combine reverse power feed with the data only, VoIP and POTS line services. Start-up protocols are defined to ensure proper interaction between the line services and the reverse power system. Operations and maintenance requirements for managing the reverse power feed and power combining within the remote network node are specified. The present document also identifies power splitter and POTS Adapter requirements.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

- [1] ETSI ES 202 971: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics of a 2-wire analogue interface for short line interface".
- [2] CENELEC EN 60950-1: "Information Technology Equipment - Safety - Part 1: General requirements (IEC 60950-1:2005 + Cor.:2006 + A1:2009, modified)".
- [3] ETSI ES 203 021: "Access and Terminals (AT); Harmonized basic attachment requirements for Terminals for connection to analogue interfaces of the Telephone Networks; Update of the technical contents of TBR 021, EN 301 437, TBR 015, TBR 017".
- [4] Broadband Forum TR-301: "Architecture and Requirements for Fiber to the Distribution Point", Issue 1.
- [5] Broadband Forum TR-286: "Testing of Metallic Line Testing (MELT) functionality on xDSL Ports".
- [6] IEC 61000-4-11: "Electromagnetic compatibility (EMC) - Part 4-11: Testing and measuring techniques - Voltage dips, short interruptions and voltage variations immunity tests".
- [7] ETSI TS 101 952-1: "Access network xDSL splitters for European deployment; Part 1: Generic specification of xDSL over POTS splitters".
- [8] ETSI ES 203 021-3: "Access and Terminals (AT); Harmonized basic attachment requirements for Terminals for connection to analogue interfaces of the Telephone Networks; Update of the technical contents of TBR 021, EN 301 437, TBR 015, TBR 017; Part 3: Basic Interworking with the Public Telephone Networks".
- [9] CENELEC EN 62368-1: "Audio/video, information and communication technology equipment - Part 1: Safety requirements".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Void.

[i.2] NICC ND 1645 (V1.1.2) (2011-06): "NGA Telephony; Architecture and requirements".

NOTE: Available at <https://nicstandards.org.uk/wp-content/uploads/2019/03/ND1645v1.1.2.pdf>.

[i.3] Recommendation ITU-T G.993.2: "Very high speed digital subscriber line transceivers 2 (VDSL2)".

[i.4] Recommendation ITU-T G.9700: "Fast access to subscriber terminals (G.fast) - Power spectral density specification".

[i.5] Recommendation ITU-T G.9701: "Fast access to subscriber terminals (G.fast) - Physical layer specification".

[i.6] ETSI TS 101 271 (V1.2.1): "Access, Terminals, Transmission and Multiplexing (ATTM); Access transmission systems on metallic access cables; Very High Speed digital subscriber line system (VDSL2) [Recommendation ITU-T G.993.2 modified]".

[i.7] Recommendation ITU-T G.998.4, Annex E: "Low Power Mode operation with ITU-T G.993.2 and G.993.5".

[i.8] Recommendation ITU-T G.9701, Amendment 1 (2014): "Support of Low power operation and all functionality necessary to allow transceivers to be deployed as part of reverse powered (and possibly battery operated) network equipment".

[i.9] Recommendation ITU-T G.992.5: "Asymmetric digital subscriber line 2 transceivers (ADSL2) Extended bandwidth ADSL2 (ADSL2plus)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

broadband bypass: scenario whereby the DPU supports "Reverse Power Feed Architecture - No POTS with Broadband Bypass" (RPFA NOP-BB) as defined in clause 5.8

NOTE: The scenario whereby the DPU supports ZT-RCR defined in clause 7.4 whereby exchange POTS is not present on the line, but where there is an overlay DSL service (i.e. "naked" or "dry" DSL).

bypass mode: operational state of the POTS adapters or power splitter where there is a metallic connection to the exchange or to an ATA

NOTE: This also refers to the operational state of the stateless Switching Function (SF) specifically for the RPFA-NOPBB architecture option, where the xTU-R of the CPE is connected to the xTU-O of the CO/cabinet.

metallic connection: physical connectivity providing a DC path between two points, typically provided via a pair of twisted copper (or aluminium) wires

normal mode: operational state of the POTS adapters or power splitter where there is no metallic connection to the exchange or to an ATA

NOTE: This also refers to the operational state of the stateless Switching Function (SF), specifically for the RPFA-NOPBB architecture option, where the xTU-R of the CPE is connected to the xTU-O of the DPU.

normal operation: state of a system (i.e. a DPU reversely powered by a PSE) reached after the start-up procedure has been completed

POTS adapter: device that provides DC isolation between reverse power feed and POTS DC feed to allow a POTS service to share the same wires as those used by reverse power feed

POTS DC feed: DC current presented at a POTS adapter to power a plain old telephone

POTS Remote Copper Reconfiguration (RCR): scenario where POTS from the exchange may be provided to the subscriber and shall be disconnected by the DPU, prior to start-up of the DPU

power splitter: device that performs a frequency splitting/combining function between the AC part of the services being carried (which can include POTS and xDSL based services) and the injected DC electrical power

NOTE: The power splitter does not include a DC-blocking high-pass function.

RING: other leg of a twisted pair

service splitter: low pass filter that separates baseband POTS from xDSL frequencies

NOTE: The relevant specifications for the service splitter can be found in ETSI TS 101 952-1 [7].

start-up mode: start-up procedure of a system (powering part of a DPU and PSE)

TIP: one leg of a twisted pair

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Ω	Ohm
μF	micro Farad
nF	nano Farad
R	2-wire analogue presented interface
U-R	Reference point at CPE containing both DC power and service data
U-R2	Reference point at CPE containing the filtered service data
U-R2P	Reference point at CPE containing the injected DC power
U-R2S	Reference point at CPE containing the baseband POTS and the converted POTS signalling
U-O	Reference point at DPU containing both DC power and service data
U-O2	Reference point at DPU containing the filtered service data
U-O2O	Reference point at DPU containing the baseband POTS and the converted POTS signalling
U-O2P	Reference point at DPU containing the extracted DC power

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Alternating Current
ACM	Alternating Current Mains
ADSL	Asymmetric Digital Subscriber Line
ATA	Analogue Telephone Adapter
BAT	Battery
BBA	Battery Back-up Available
CO	Central Office
CP	Customer Premises
CPE	Customer Premises Equipment
CPE ME	CPE's Management Entity

CPF	Common Power Feed
DC	Direct Current
DGL	Dying Gasp Loss
DN	Distribution Network
DP	Distribution Point
DPU	Distribution Point Unit
DPU ME	DPU's Management Entity
DR	Diode/Resistor
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
ELC	Error Line Condition
EXPSW	Exchange Sharing the in-premises Wiring
FSK	Frequency Shift Keying
FTTdp	Fibre To The distribution point
FTU	G.fast Transceiver Unit

NOTE: See Recommendation ITU-T G.9701 [i.5].

FTU-O	FTU at the DPU
FTU-R	FTU at the remote site
HON	Higher Order Node
IFN	Intensity of current Feed Now
LPF	Low Pass Filter
LR	Long Range
LSU	Last Start Up
MDSU	Metallic Detection based Start-Up protocol
ME	Management Entity
MELT	Metallic Loop Test
NMS	Network Management System
NT	Network Termination
NTE	Network Termination Equipment
OAM	Operations And Maintenance
OHP	Off-Hook Phone
PC	Power Class
PE	Power Extractor
PHY	Physical (layer)
PMA	Persistent Management Agent
PME-C	CPE's Power Management Entity
PME-D	DPU's Power Management Entity
PMT	Power Management Transceiver
POTS	Plain Old Telephony Service
PRP	POTS Remote Copper Reconfiguration (RCR) Protocol
PS	Power Splitter
PSD	Power Spectral Density
PSE	Power Source Equipment
PSU	Power Supply Unit (including the combiner function if multiple lines are active)
PT	PRP Trigger
PTID	PRP Trigger IDentification
RBW	Resolution Bandwidth
RC	Resistor/Capacitor
RCR	Remote Copper Reconfiguration
RPCE	Reverse Power Control Entity
RPF	Reverse Power Feed
RPFA	Reverse Power Feed Architecture
RPFA-DRP	Reverse Power Feed Architecture - DeRived POTS
RPFA-DRPSW	Reverse Power Feed Architecture - DeRived POTS Sharing in-Premises Wiring
RPFA-EXP	Reverse Power Feed Architecture - EXchange POTS
RPFA-EXPSW	Reverse Power Feed Architecture - EXchange POTS Sharing in-Premises Wiring
RPFA-NOP	Reverse Power Feed Architecture - No POTS
RPFA-NOPBB	Reverse Power Feed Architecture - No POTS with Broadband Bypass
R _{SIG}	Signature Resistor
SCF	Switch Control Function

SF	Switching Function
SG	Service Gateway
SIG	SIGNature
SR	Short Range
SS	Service Splitter
TNV	Telecommunication Network Voltage
UPS	Uninterrupted Power Supply
VA	Volt Ampere
VDSL	Very high speed Digital Subscriber Line
VoIP	Voice over Internet Protocol
VPSE	steady state Voltage from PSE
xDSL	unspecified DSL variant
xTU-O	FTU-O or VTU-O
xTU-R	FTU-R or VTU-R
ZRC	Zener/Resistor/Capacitor
ZT-LAC	Zero Touch Link Auto Configuration
ZT-RCR	Zero Touch Remote Copper Reconfiguration

4 Introduction to Reverse Power Feed

The basic architecture of a fibre-fed remote node with reverse power feed is shown in Figure 1.

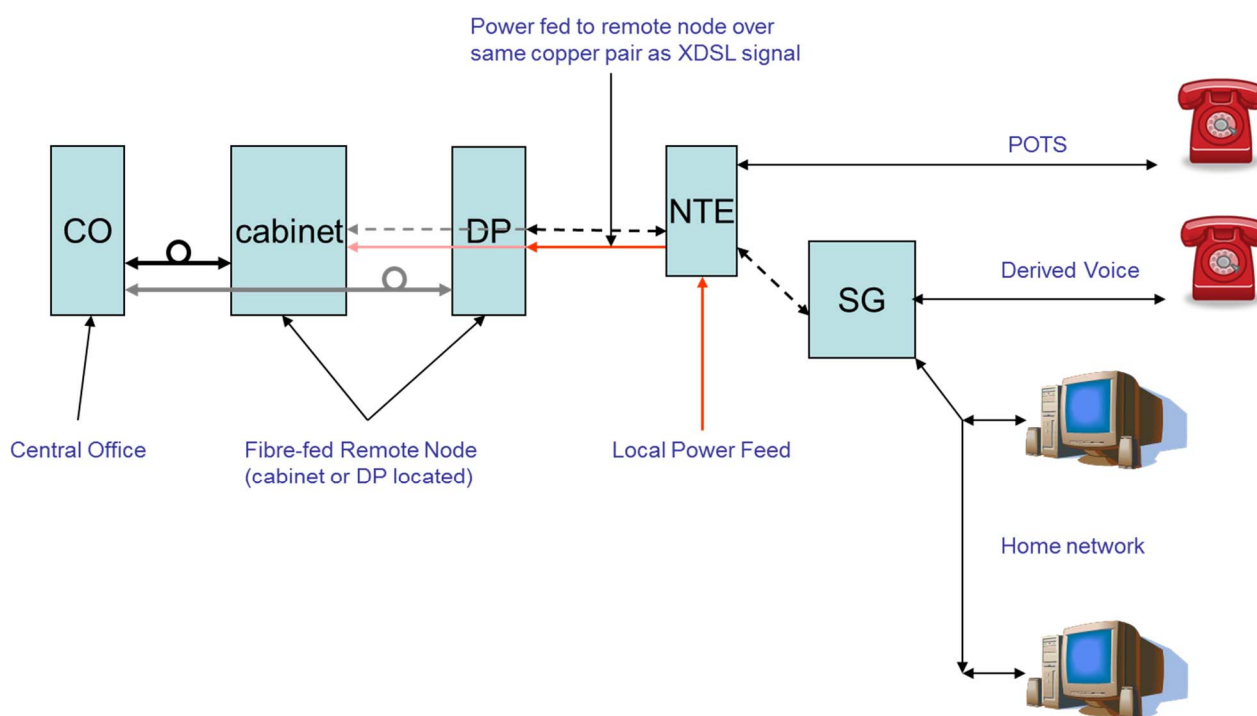


Figure 1: Generic Fibre-fed Remote Node Architecture with reverse power feed

Figure 1 shows power being injected at the NTE from a local power source (located within the home and/or building) which traverses the local loop to power a fibre-fed remote node which can be located at either the Distribution Point (DP) or street cabinet using the same copper pair cable that is used to transmit the xDSL to/from the home/fibre-fed remote node. A metallic POTS service is shown at the NTE. Voice services can also be implemented as a derived service from the Service Gateway (SG).

An issue with regards to reverse powered fibre-fed nodes is that of who or what is responsible for the powering of common circuitry contained within the node. It is easy to envisage that an individual user should be responsible for the powering of the remote line terminating/driver electronics corresponding to his particular circuit. However, it is not so easy to determine who or what is responsible for powering of say the DPU that terminates the fibre link.

There may be occasions where only a single user is providing power to the remote node but this may not be sufficient to power all of the remote node electronics for proper operation.

It is recognized that one single (i.e. generic) specification cannot consider all possible architectural variants, therefore the present document has been organized as a series of architecture options and equipment shall adhere to one or more of these options.

In the present document, two different implementations of Power Source Equipment (PSE) for Customer Premises are considered: standalone (i.e. a two box model where the PSE and NTE are separate) or integrated (i.e. a single box model where the PSE and NTE are integrated). In these implementations, the Power Splitter (PS) may either be integrated or stand alone.

5 Reverse Power Feed Architecture

5.1 Basics of RPF

Reverse power feed is one of three DPU powering methods defined in TR-301 [4]. Here, the DPU draws its power from the customer premises via the copper lines between those premises and the DPU. The reverse power feed capacity and DPU power consumption need to be such that the DPU can be fully operational when only a single customer is connected. Any back-up battery would be located in the customer premises.

The other two methods are:

- Forward Power from a Network Power Node. In this case, any back-up battery would be located at the network power node.
- Local Power from AC mains source. In this case, any back-up battery would be located at the DPU location.

The combination of reverse powering with one or both of the other two methods is outside the scope of the present document.

Reverse powering shall have two power splitters (one located at the customer premises and another at the remote node) to enable power to be inserted at the customer end of a link and extracted at the remote node. Each power splitter performs a frequency splitting and combining function between the services being carried (which can include POTS and xDSL based services) and the injected DC electrical power.

Within the remote node, if it operates with multiple power-fed lines then there shall be a power extraction and combiner unit. The purpose of this unit is to combine the multiple power feed inputs to produce a single power source output. The power load should be shared amongst the input power sources.

The technical specifications in the present document shall apply to each architecture described below as one of the six options shown in Table 1. The optional reverse power battery backup at the customer premises is illustrated in block BAT for each reference model.

Table 1: Architecture Options for Reverse Power Feed

Option	Name	Description
1	RPFA-NOP	Reverse Power Feed Architecture - No POTS
2	RPFA-EXP	Reverse Power Feed Architecture - Exchange POTS
3	RPFA-EXPSW	Reverse Power Feed Architecture - Exchange POTS Sharing in-premises Wiring
4	RPFA-DRP	Reverse Power Feed Architecture - Derived POTS
5	RPFA-DRPSW	Reverse Power Feed Architecture - Derived POTS Sharing in-premises Wiring
6	RPFA-NOPBB	Reverse Power Feed Architecture - No POTS with Broadband Bypass

5.2 Reverse Power Feed and POTS Co-Existence

5.2.1 Overview

Table 1, option 2 to option 5 involve reverse power feed co-existing with POTS - whether this is exchange based POTS (RPFA-EXP, RPFA-EXPSW) or derived POTS (RPFA-DRP, RPFA-DRPSW).

When a POTS service is present on the same wire pair as reverse power feed (option 2, option 3 and option 5) the POTS DC feed will be removed and the DC signalling/low frequency signalling will be translated so that it uses another part of the baseband spectrum, but the basic analogue voice signal remains essentially untouched. At the CP, DC feed and the signalling are restored and POTS is presented as normal.

When POTS is provided by derived voice service (option 4 and option 5), low power (L2) modes [i.7] and [i.8] may be used to provide the voice service even when the entire payload is not required by other services.

In order to achieve co-existence between reverse power feed and POTS, various adapters are required as described in clause 5.2.2 for use in the reverse power feed reference models.

5.2.2 POTS Adapters

5.2.2.1 General

The following three different types of POTS Adapter are specified for use in the reverse power feed reference models:

- 1) POTS Adapter - E (POTSA-E).
- 2) POTS Adapter - C (POTSA-C).
- 3) POTS Adapter - D (POTSA-D).

Where reverse power feed and POTS signals traverse the same copper wires, a signalling system shall be implemented to allow the signalling at the POTS interface based on off-hook/on-hook DC impedance, presence/absence of ringing signal, and in those jurisdictions requiring it, line reversal for Calling Number ID alerting to be communicated across the copper pair from the DPU to the POTS terminals. This functionality can be provided by the various POTS Adapters described in clauses 5.2.2.2, 5.2.2.3 and 5.2.2.4.

5.2.2.2 POTS Adapter - E (POTSA-E)

POTSA-E is the single adapter located at the DPU and this adapter shall perform the following functions:

- 1) Translate the downstream DC feed and low frequency POTS signalling into an in-band or out-of-band signalling system.
- 2) Translate the signals from the upstream in-band or out-of-band signalling system into DC and low frequency POTS signalling.

POTSA-E may provide a relay by-pass when un-powered (for life-line operation) or when signalled to provide direct access to the exchange to allow operations such as line-test to be performed.

5.2.2.3 POTS Adapter - C (POTSA-C)

POTSA-C is the single adapter located at the NT module and this adapter shall perform the following functions:

- 1) Translate the upstream DC and low frequency POTS signalling from the POTS Terminal into an in-band or out-of-band signalling system.
- 2) Translate the downstream in-band or out-of-band signalling system into POTS signalling towards the POTS Terminal.
- 3) Restore the downstream DC feed while providing sufficient current limit and DC voltage to supply one or more phone devices.

- 4) Provide a pre-defined rate of change of current increase when a phone device goes off-hook to allow for the detection of phone devices going off-hook that do not have the correct POTS Adapter fitted.

POTSA-C may provide relay by-pass when un-powered (for lifeline operation) or when signalled to provide direct access to the exchange to allow operations such as line-test to be performed.

5.2.2.4 POTS Adapter - D (POTSA-D)

POTS Adapter - D is the adapter that can be attached to every phone device connected to the in-premises wiring on the home network. This adapter operates in the presence of reverse powering. This adapter shall perform the following functions:

- 1) Translate the signals from the upstream DC and low frequency POTS signalling from the POTS Terminal into an in-band or out-of-band signalling system.
- 2) Translate the signals from the downstream in-band or out-of-band signalling system into POTS signalling towards the POTS Terminal.
- 3) Restore the downstream DC feed while providing sufficient current limit and DC voltage to supply a single phone device.
- 4) Provide a pre-defined rate of change of current increase when a phone device goes off-hook to allow for the detection of phone devices going off-hook that do not have the correct POTS Adapter fitted.

5.3 Reverse Power Feed Architecture without POTS on the same pair (RPFA-NOP)

The functional reference model of the reverse power feed architecture without POTS on the same pair (RPFA-NOP) is shown in Figure 2 and the associated reference points are detailed in Table 2. In this option, the reference model illustrates the RPF architecture with the broadband service only and no underlying narrowband service, neither exchange-based POTS nor derived POTS.

The xTU-O is located inside the Distribution Point Unit (DPU) at the network side of the wire pair (U-O reference point). The xTU-R is located inside the Network Termination (NT) at the customer premises side of the wire pair (U-R reference point). Each DPU is located at a distribution point and can contain one or more xTU-O transceivers (xTU-O-I, $I = 1 \dots N$), with each transceiver connected to a NT.

At the backhaul link termination, the PHY blocks represent the physical layer of the xTU-O module towards the access network and of the NT towards the Customer Premises (CP). These blocks are shown for completeness of the data flow but are out of scope of the present document. The L2+ blocks represent the Layer 2 and above functionalities contained in the xTU-O module and the NT. These blocks are shown for completeness of the data flow but are out of scope of the present document.

The traffic from all DPUs is aggregated by a backhaul transmission system operating over the Distribution Network (DN) and Higher Order Node (HON) up to the V reference point. The type of transmission system is out of scope of the present document.

The management of a DPU is performed by the Network Management System (NMS), passing management information to the DPU's Management Entity (DPU ME) over a management communications channel that is provided over the backhaul transmission system. The details of the management communications channel and most of the management functionality required for the DPU are out of scope of the present document.

As there is a need for management transactions between the DPU and the CPE for controlling the start-up of reverse powering to the DPU when mains power is applied to the CPE and for monitoring powering in normal operations, Power Management Transceivers (PMT) are connected to the copper drop in the DPU (PMT-I, $I = 1 \dots N$) and the customer premises to support a management protocol. The management information is exchanged between the PMT-I and DPU ME through the power management entity PME-D. At the customer premises, the information flow takes place between the PMT and CPE ME through the power management entity PME-C.

The power is inserted on the line (i.e. copper pair) by the Power Source Equipment (PSE) located in the customer premises and extracted from the line by the Power Extractor (PE-I, $I = 1 \dots N$) located in the DPU. Power is extracted from each active port and combined in the Power Supply Unit (PSU) and coordinated over all lines by the Reverse Power Control Entity (RPCE). The PE and PSU are separated from the broadband signal on the line (at reference point U-O and U-R) by a Power Splitter (PS).

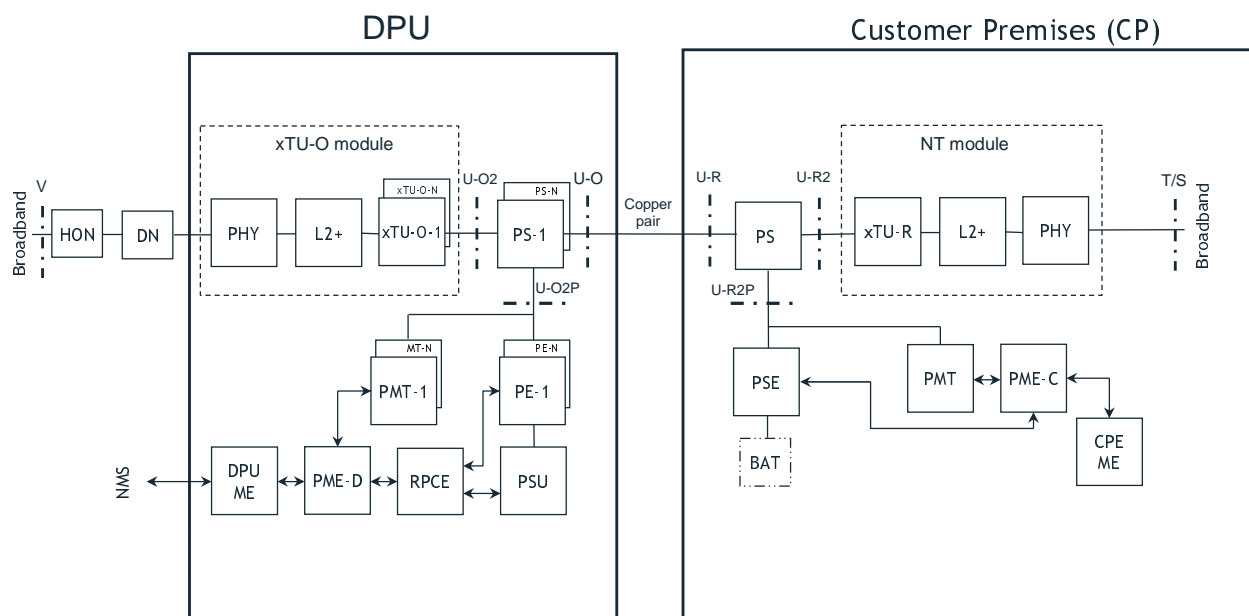


Figure 2: RPFA-NOP Reference Model

Table 2: RPFA-NOP Reference Points

Reference Point	Broadband Signals	Reverse Power Feeding	Analogue Voice Signals	Out of band POTS Signalling
U-O2	Yes	Yes	No	No
U-O2P	No	Yes	No	No
U-O/U-R	Yes	Yes	No	No
U-R2P	No	Yes	No	No
U-R2	Yes	No	No	No

5.4 Reverse Power Feed Architecture with Baseband POTS from the Exchange (RPFA-EXP)

The functional reference model of the reverse power feed architecture with baseband POTS from the exchange (RPFA-EXP) is shown in Figure 3 and Figure 4 and the associated reference points are detailed in Table 3.

This option includes two different variants. Figure 3 illustrates the case where a dedicated POTS port is used to connect a single POTS device while the remaining customer premises equipment CPE (Power Splitter (PS), Service Splitter (SS), Power Source Equipment (PSE) and NT module) may be located anywhere on the in-premises wiring. The single POTS Adapter (POTSA-C) is also located at the same place as the rest of the CPE.

The second variant shown in Figure 4, illustrates the case where the CPE (Power Splitter (PS), Service Splitter (SS), Power Source Equipment (PSE) and NT module) and the POTSA-C adapter are installed at the master-socket location while multiple POTS devices are connected to the existing in-premises wiring.

In both cases it is expected that baseband voice is transmitted between the DPU and the customer premises and the function of the POTS Adapter in the DPU (POTSA-E) and POTS Adapter in the customer premises (POTSA-C) is concerned with the POTS signalling translation. Also in both cases, there is no requirement for an individual POTSA-D to be attached to each individual phone device within the customer premises.

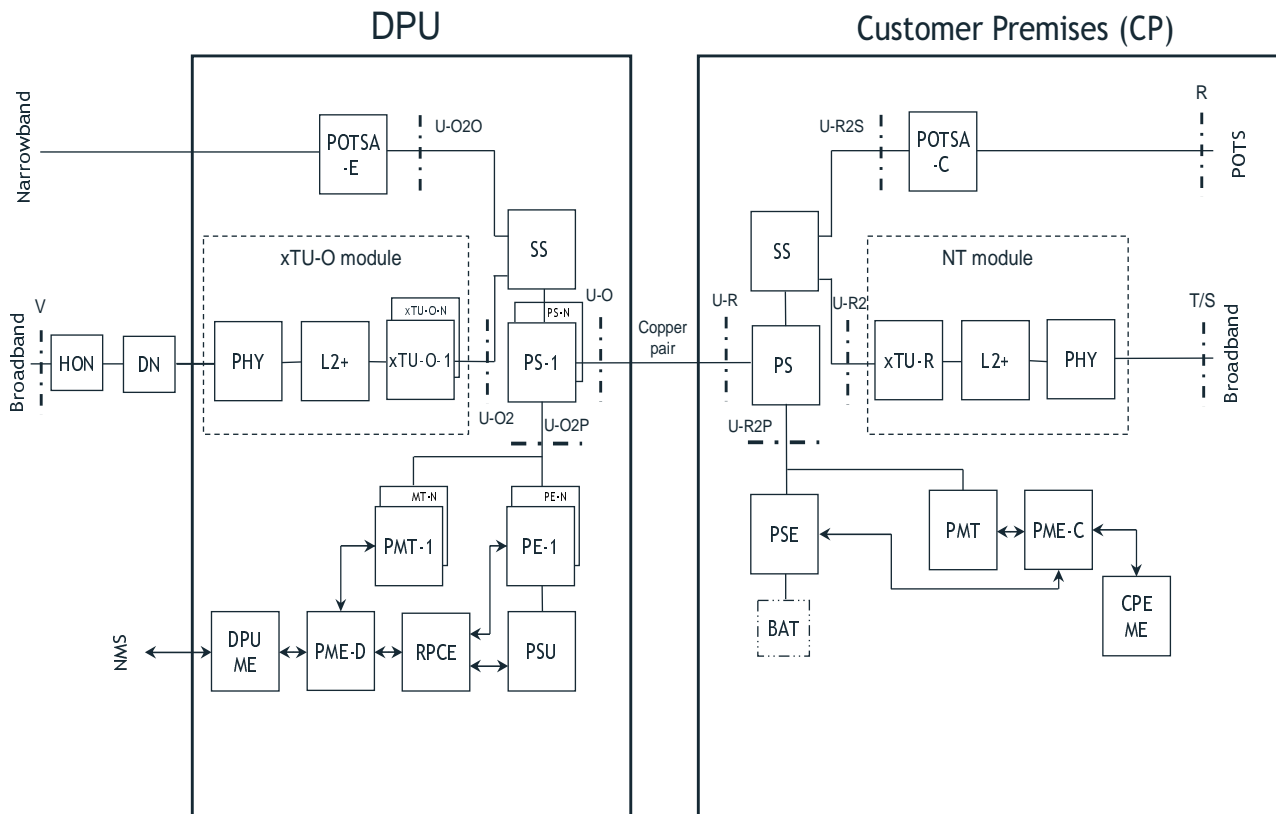


Figure 3: RPFA-EXP Reference Model

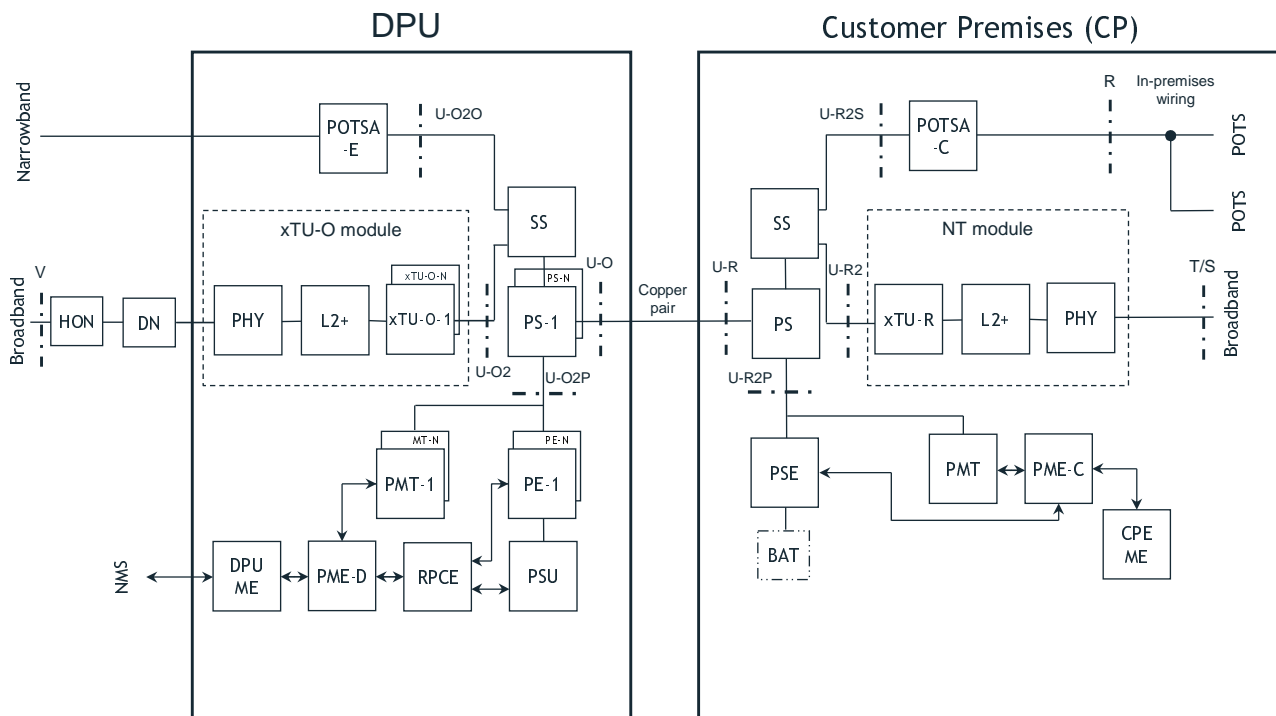


Figure 4: RPFA-EXP Reference Model with multiple POTS distributed over In-Premises Wiring

Table 3: RPFA-EXP Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analog Voice Signals	Out of band POTS Signalling
U-O2	Yes	Yes	No	No
U-O2O	No	Yes	Yes	Yes
U-O2P	No	Yes	No	No
U-O/U-R	Yes	Yes	Yes	Yes
U-R2P	No	Yes	No	No
U-R2S	No	Yes (see note)	Yes	Yes
U-R2	Yes	No	No	No

NOTE: The POTSA-C adapter needs power for signalling conversion and will usually be locally powered if it is collocated with the PSE, but it needs access to RPF to detect its presence and may optionally be powered by RPF.

5.5 Reverse Power Feed Architecture with Baseband POTS from the Exchange Sharing the in-premises Wiring (RPFA-EXPSW)

The functional reference model of the reverse power feed architecture with baseband POTS from the exchange sharing the in-premises wiring (RPFA-EXPSW) is shown in Figure 5 and the associated reference points are detailed in Table 4. In this application, each POTS device connected to the in-premises network is connected to an individual POTSA-D which provides POTS signalling translation. This reference model is used when a traditional voice solution is utilized but an analogue POTS presentation is required over the in-premises wiring including all extension wiring.

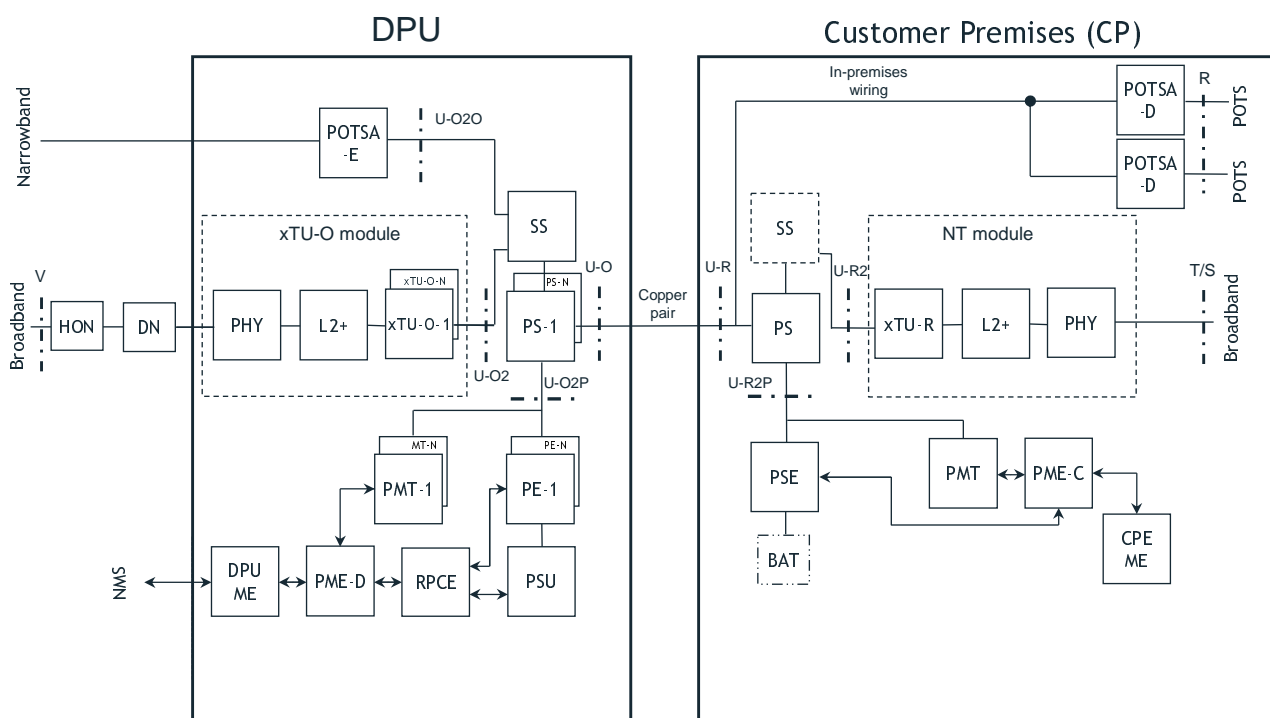


Figure 5: RPFA-EXPSW Reference Model

Table 4: RPFA-EXPSW Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analog Voice Signals	Out of band POTS Signalling
U-O2	Yes	Yes	No	No
U-O2O	No	Yes	Yes	Yes
U-O2P	No	Yes	No	No
U-O/U-R	Yes	Yes (see note)	Yes	Yes
U-R2P	No	Yes	No	No
U-R2	Yes	No	No	No

NOTE: RPF provides power for signalling conversion.

It should be noted that the use cases for RPFA-EXP and RPFA-EXPSW may be combined so that POTSA-C and POTSA-D may both be present.

5.6 Reverse Power Feed Architecture with Derived POTS (RPFA-DRP)

The functional reference model of the reverse power feed architecture with derived POTS (RPFA-DRP) is shown in Figure 6 and Figure 7 and the associated reference points are detailed in Table 5.

Similar to the RPFA-EXP architecture defined in clause 5.4, this option includes two different variants. Figure 6 illustrates the case when the CPE (Power Splitter (PS), Power Source Equipment (PSE) and NT module) may be located anywhere on the in-premises wiring while a single analogue POTS interface is available on the dedicated line (i.e. POTS service uses one wire pair while the DSL service uses another wire pair). The second variant is shown in Figure 7. This illustrates the case where the CPE is installed at the master-socket location and multiple POTS interfaces are distributed over the in-premises wiring. In this architecture, an analogue presentation of a VoIP service is provided at the CPE via an Analogue Terminal Adapter (ATA). Other application models are possible, for example where the ATA is connected to a cordless phone or a wireless phone device. The ATA can be integrated with the router in the same physical box NT1, or with the NT module. Such a scheme is inherently simpler than the POTS solutions described in clause 5.4 because there is no requirement for service splitter and POTS Adapters. However, this solution proves to be the most difficult to arrange for POTS failover during power outages at the CPE. Such a solution is dependent upon local battery power at the CPE being able to also power the remote node (albeit the remote node may be operating in a low-power mode).

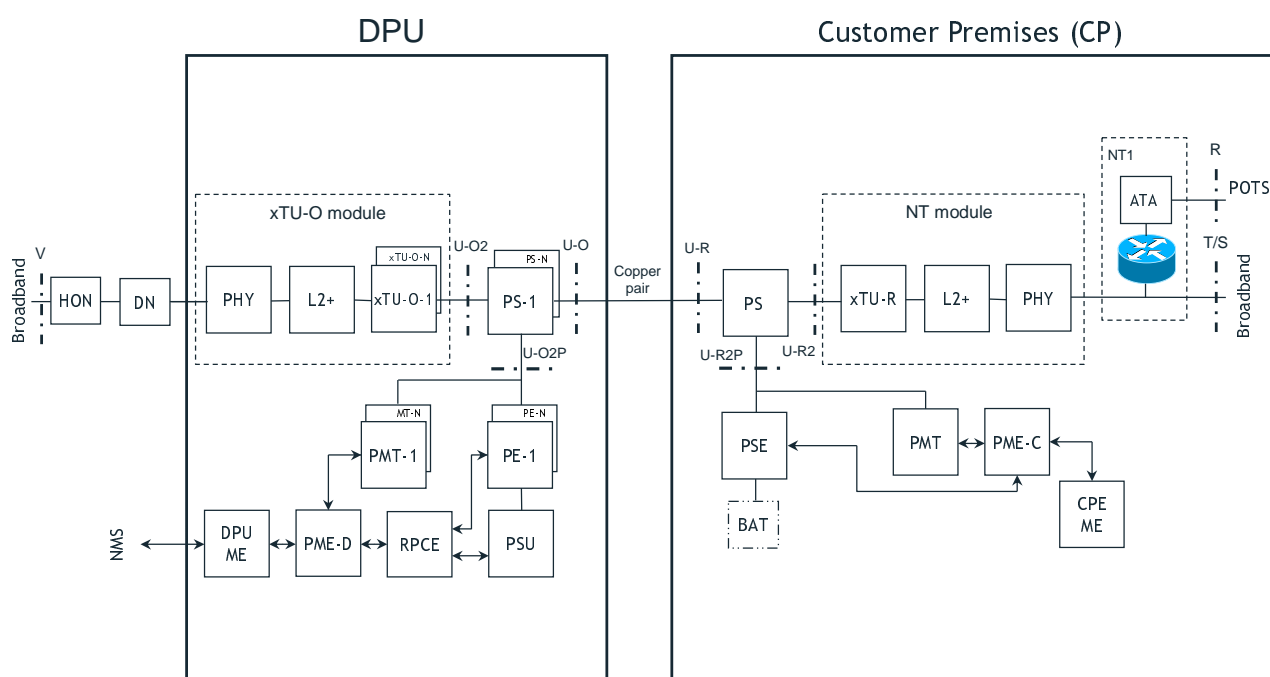


Figure 6: RPFA-DRP Reference Model with derived POTS and a single POTS port

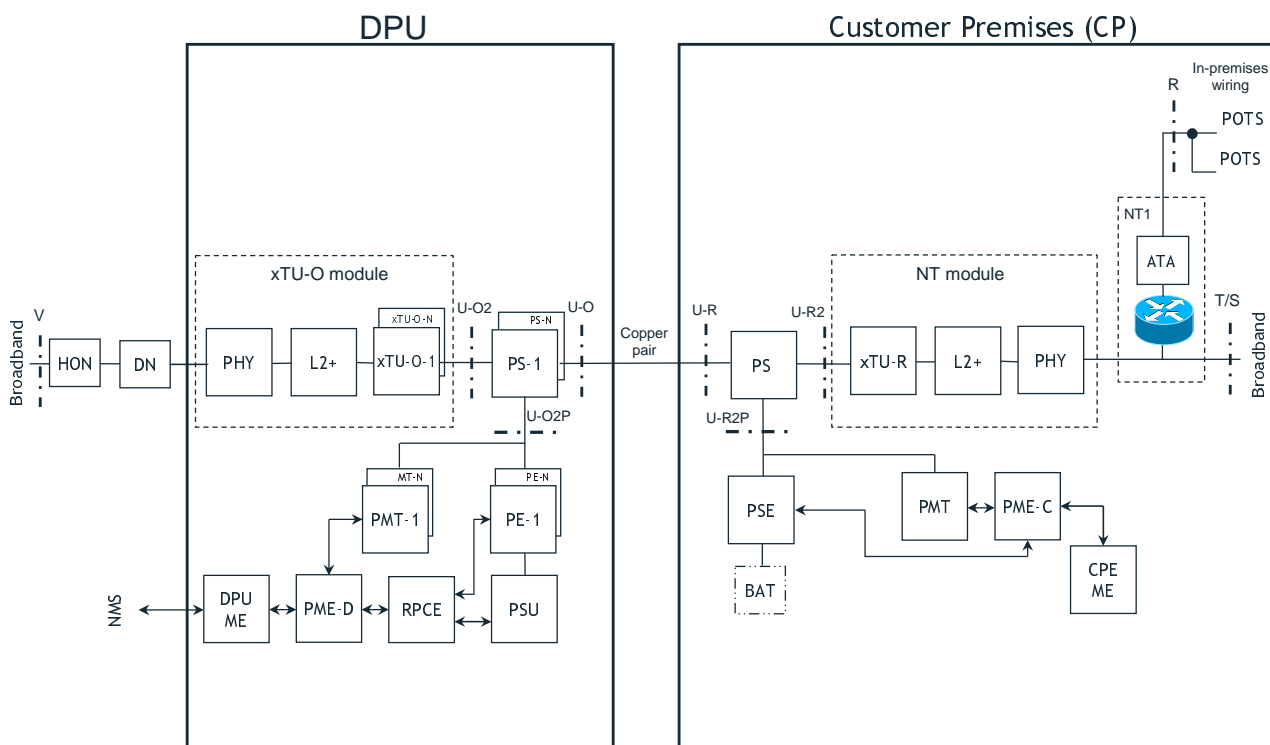


Figure 7: RPFA-DRP Reference Model with derived POTS distributed over In-Premises Wiring

Table 5: RPFA-DRP Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analogue Voice Signals
U-O2	Yes	Yes	No
U-O2P	No	Yes	No
U-O/U-R	Yes	Yes	No
U-R2P	No	Yes	No
U-R2	Yes	No	No

5.7 Reverse Power Feed Architecture with Derived POTS Sharing the in-premises Wiring (RPFA-DRPSW)

The functional reference model of the reverse power feed architecture with derived POTS sharing the in-premises wiring (RPFA-DRPSW) is shown in Figure 8 and the associated reference points are detailed in Table 6. In this application, POTS is carried as a derived voice stream within the broadband data. The voice stream is extracted via a router and then presented to a POTS Adapter via an ATA. The voiceband POTS signal is injected onto the in-premises wiring via the voice-frequency path through the Service Splitter (SS). Because there is DC powering present on the in-premises wiring, it is not possible to include DC POTS signalling and therefore a POTSA-D is required for every POTS device that is not collocated with the NT module.

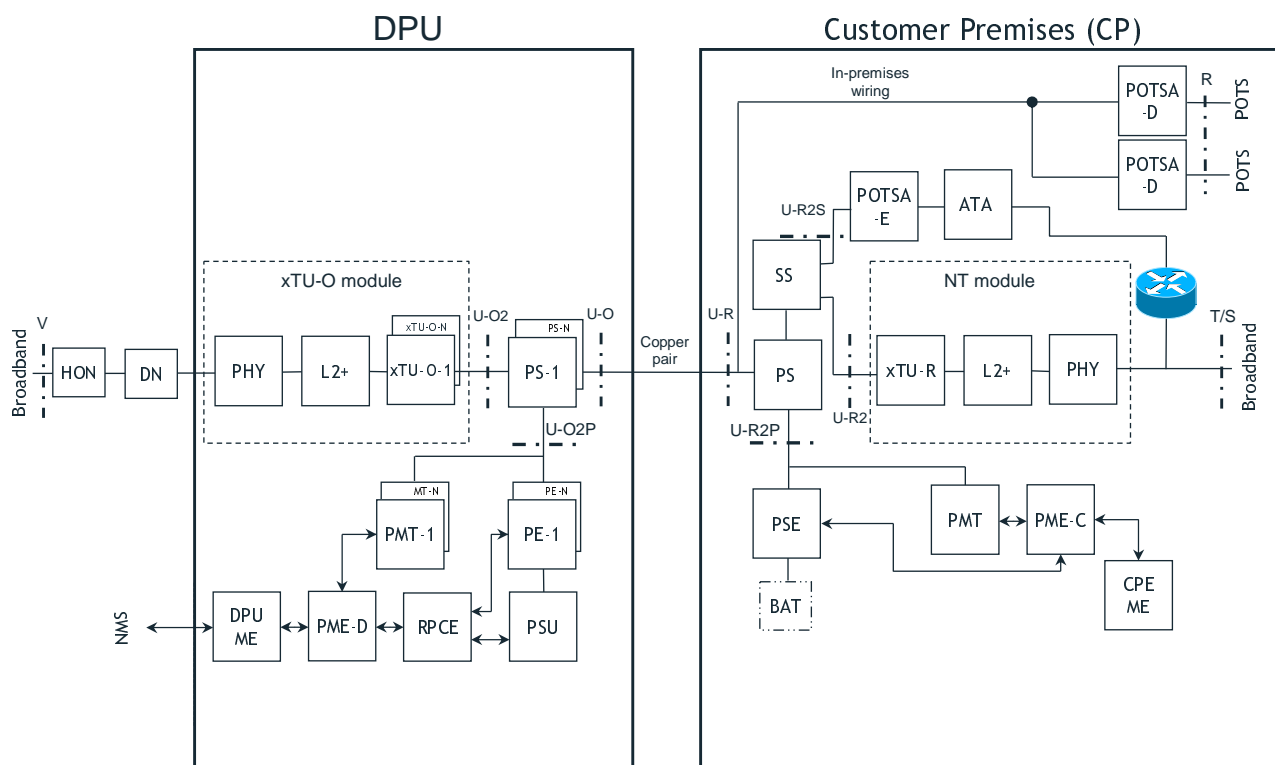


Figure 8: RPFA-DRPSW Reference Model

Table 6: RPFA-DRPSW Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analogue Voice Signals	Out Of Band POTS Signalling
U-O2	Yes	Yes	No	No
U-O2P	No	Yes	No	No
U-O/U-R	Yes	Yes (see note 1)	Yes	Yes
U-R2P	No	Yes	No	No
U-R2S	No	Yes (see note 2)	Yes	Yes
U-R2	Yes	No	No	No

NOTE 1: RPF provides power for signalling conversion.
NOTE 2: The POTSA-E adapter needs power for signalling conversion and is usually locally powered if it is collocated with the PSE, but it needs access to RPF to detect its presence and may optionally be powered by RPF.

It should be noted that the use cases for RPFA-DRP and RPFA-DPRSW may be combined so that a POTS port and POTSA-D may both be present.

5.8 Reverse Power Feed Architecture without POTS and with Broadband Bypass (RPFA-NOPBB)

The functional reference model of the reverse power feed architecture without POTS on the same pair and with Broadband Bypass (RPFA-NOPBB) is shown in Figure 9 and the associated reference points are detailed in Table 7. This scenario is based on the reference model RPFA-NOP without POTS.

A stateless switching function SF in the DPU connects the xTU-R in the CPE either with the xTU in the CO/cabinet or with the xTU-O in the DPU. The SF may include filter and impedance adapting means to prevent the leakage of noise into and from the U-O2 interface and impedance changes impacting the crosstalk characteristics by changing the switch positions. Stateless means that the NMS does not control the states of the switch. In the default position, the switch connects the xTU in the CO/cabinet with the xTU-R. When a PSE is connected and reverse power feeding starts, the power management in the DPU sends a signal to the Switch Control Function (SCF). The Switch Control Function triggers the switch in order to switch over from the xTU in the CO/cabinet to the xTU-O in the DPU. Then, the xTU-R is connected with the xTU-O in the DPU. The behaviour of the switch when the PSE is not present for a time period T, shall be defined by the operator.

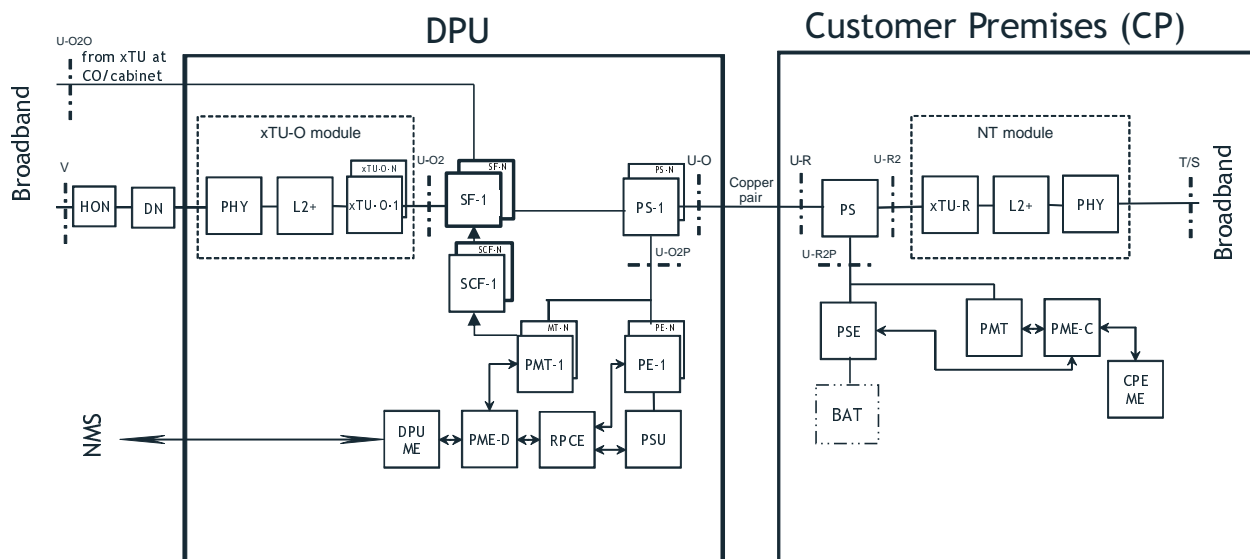


Figure 9: RPFA-NOPBB Reference Model

Table 7: RPFA-NOPBB Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analog Voice Signals	Out of band POTS Signalling
U-O2	Yes	Yes	No	No
U-O2O	Yes	No	No	No
U-O2P	No	Yes	No	No
U-O/U-R	Yes	Yes	No	No
U-R2P	No	Yes	No	No
U-R2	Yes	No	No	No

6 Reverse Power Feed Start-Up Protocol

6.1 Introduction

6.1.1 General

As shown in clause 5, Reverse Power Feed can be applied either in conjunction with a baseband POTS service from a CO, or with a derived POTS service, or without any POTS service.

In any scenario, a procedure shall be followed to guarantee proper interaction between the elements of the RPF system (DPU - PSE - POTS Adapters in the in-premises network). The procedure shall allow a proper start-up of RPF, and should cover all further states of the RPF system (operation, shut down, error conditions).

Powering DPUs over copper lines implies additional requirements because the power source is remote and the power feeding may co-exist with the POTS service, whether this is exchange based POTS (RPFA-EXP, RPFA-EXPSW) or derived POTS (RPFA-DRP, RPFA-DRPSW). For example, if reverse powering is present on the in-premises network it is important to detect directly connected off-hook phones and prevent them from becoming a safety hazard. If a directly connected off-hook telephone is detected, a back-off mechanism shall be initiated for the reverse powering.

The following power source requirements apply (clause 8.2 of TR-301 [4]):

- 1) The PSE of a single active line shall be able to power its DPU in both mains-powered and battery-powered (when available) operation.
- 2) The PSE shall send a Dying Gasp indication to the DPU after it has lost both mains and battery power (if available) and before it removes power from the line.
- 3) The PSE shall remove power from a line upon the detection of a fault condition.
- 4) During normal operation, if any of these fault conditions occur, the PSE shall remove power and return to the startup procedure:
 - a) Presence of an open circuit.
 - b) Presence of a short circuit.
 - c) Presence of an off-hook phone.
- 5) In the case where the PSE detects a fault condition, the PSE shall not inject full power on the line.
- 6) The PSE shall verify that all of the following conditions are met, before injecting full power:
 - a) Absence of an open circuit.
 - b) Absence of a short circuit.
 - c) Absence of a POTS Exchange (foreign) DC voltage on the line.
 - d) Absence of an off-hook phone.
 - e) Detection of a DPU that supports reverse powering.
 - f) Correct matching of the PSE RPF Class with the DPU RPF Class.
- 7) The PSE shall power the DPU independent of the polarity on the line.

The equivalent network model of the above line related fault conditions (further referred to as the Error Line Conditions ELC 0 to ELC 3) is shown in Figure 10.

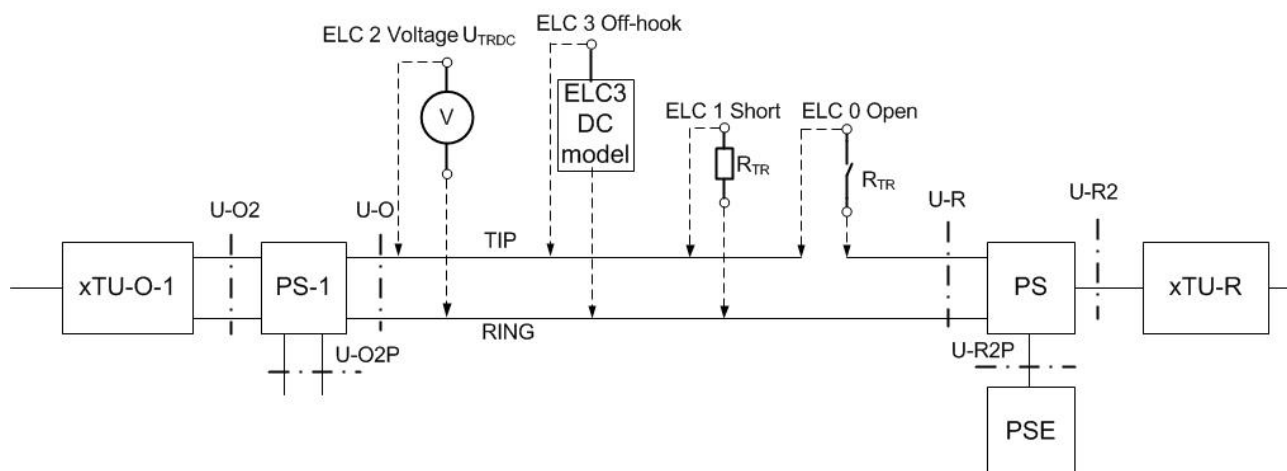


Figure 10: Illustration of an Error Line Conditions network model

The Error Line Condition parameters and detection criteria for the ELC network model are defined in Table 8.

Table 8: Error Line Condition Parameters and Detection Criteria

Error Line Condition	Description	Parameter	Detection Criteria
ELC 0	Open tip-to-ring	$R_{Emin} = 1 \text{ M}\Omega$ $C_{Emax} = 100 \text{ nF}$	$R_{TR} \geq R_{Emin}$ for a duration exceeding 300 ms (see note) $C_{TR} \leq C_{Emax}$
ELC 1	Short tip-to-ring	$R_{Emax} = 140 \text{ }\Omega$	$R_{TR} \leq R_{Emax}$
ELC 2	POTS Exchange (foreign) DC voltage	$U_{TRDCEmax} = 3 \text{ V}$	$ U_{TRDC} \geq U_{TRDCEmax}$
ELC 3	Off-hook phone	Measured voltage and current in the range below the upper limit of the DC characteristics defined in Table 9	
NOTE:	This duration is set such that the definition of ELC 0 does not overlap with the Maintain Power Signature definition as defined in note 4 of Table 41.		

NOTE: Due to the definition of parameters, definite detection of ELC 1 or ELC 3 may be ambiguous.

The RPF start-up protocol shall use the detection criteria listed in Table 8 to ensure detection of Error Line Conditions (ELC).

The upper limits of the off-hook phone DC characteristics are specified in Table 9 according to clause 4.7.1 of ETSI ES 203 021-3 [8].

Table 9: Upper limits of the Off-hook phone DC voltage/current characteristics

Point	Voltage (V)	Current (mA)
A	9	0
B	9	20
C	14,5	42
D	40	50
E	60	56
NOTE:	Linear interpolation of voltage in function of current shall be used to obtain values between points A-E.	




6.1.2 Start-up in presence of MELT signature

The RPF start-up protocol shall operate irrespective of the presence of MELT signatures located at the CPE side.

Table 10 defines the MELT signatures located at the U-R interface for which the operability of the RPF start-up protocols shall be provided.

- A PSE that supports the Metallic Detection based Start-Up protocol (MDSU) shall start up with the RC type MELT signature, defined in Table 10, having time constant $t = R \times C \leq 49 \text{ ms}$.
- A PSE supporting POTS Remote copper reconfiguration Protocol (PRP), an optional extension of the MDSU defined in clause 6.2.5, shall start up with the RC type MELT signature, defined in Table 10, having time constant $t = R \times C \leq 49 \text{ ms}$ and a resistive part exceeding 4 k Ω .

Table 10: MELT SIGNATURES

##	MELT signatures	Comments										
1	<p style="text-align: center;">D R</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Component</th> <th>Nominal value</th> </tr> </thead> <tbody> <tr> <td>R</td> <td>470 kΩ ± 1 %</td> </tr> <tr> <td>U_{F(D)}</td> <td>0,7 V (at I_f = 10 mA) ± 0,1 V</td> </tr> </tbody> </table>	Component	Nominal value	R	470 kΩ ± 1 %	U _{F(D)}	0,7 V (at I _f = 10 mA) ± 0,1 V	DR type Specified in TR-286 [5]				
Component	Nominal value											
R	470 kΩ ± 1 %											
U _{F(D)}	0,7 V (at I _f = 10 mA) ± 0,1 V											
2	<p style="text-align: center;">D1 D2 R C</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Component</th> <th>Nominal value</th> </tr> </thead> <tbody> <tr> <td>R</td> <td>100 kΩ ± 1 %</td> </tr> <tr> <td>C</td> <td>470 nF ± 1 %</td> </tr> <tr> <td>U_{Z(D1)}</td> <td>6,8 V ± 5 % @ 50 μA</td> </tr> <tr> <td>U_{Z(D2)}</td> <td>6,8 V ± 5 % @ 50 μA</td> </tr> </tbody> </table>	Component	Nominal value	R	100 kΩ ± 1 %	C	470 nF ± 1 %	U _{Z(D1)}	6,8 V ± 5 % @ 50 μA	U _{Z(D2)}	6,8 V ± 5 % @ 50 μA	ZRC type Specified in TR-286 [5]
Component	Nominal value											
R	100 kΩ ± 1 %											
C	470 nF ± 1 %											
U _{Z(D1)}	6,8 V ± 5 % @ 50 μA											
U _{Z(D2)}	6,8 V ± 5 % @ 50 μA											
3	<p style="text-align: center;">R C</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Component</th> <th>Nominal value</th> </tr> </thead> <tbody> <tr> <td>R</td> <td>20 kΩ ± 1 %</td> </tr> <tr> <td>C</td> <td>2,2 μF ± 10 %</td> </tr> </tbody> </table>	Component	Nominal value	R	20 kΩ ± 1 %	C	2,2 μF ± 10 %	RC type				
Component	Nominal value											
R	20 kΩ ± 1 %											
C	2,2 μF ± 10 %											

6.2 Metallic Detection based Start-Up (MDSU) Protocol

6.2.1 Signature detection

The Metallic Detection based Start-Up (MDSU) protocol is applicable to three architecture scenarios defined in clause 5, Table 1; "without POTS" (RPFA-NOP), "with derived POTS" (RPFA-DRP) and "without POTS and with Broadband Bypass" (RPFA-NOPBB). After checking for the absence of typical POTS line conditions (off-hook, foreign DC voltage from the POTS Exchange) and the short and open line condition (a tip-to-ring short and open), the procedure allows for a proper start-up of the RPF.

A metallic detection based start-up method provides a convenient and reliable way to prevent supplying power to off-hook phones since it inherently tests line signature resistance which is much larger than the resistance of any off-hook phones.

The MDSU protocol is based on detection of a resistive signature located in the DPU, that is a 25 kΩ resistor R_{SIG} bridged across the tip- and ring-wire. The detection signature is part of the functional block SIG, as shown in Figure 11, Figure 12 and Figure 13. The PSE, located in the customer premises, probes the DPU in order to detect a valid DPU detection signature and applies the power to the DPU after successful verification of the line conditions listed under requirement 6) in clause 6.1 and classification of the classification signature. After the DPU is powered up, the detection and classification signatures may be disconnected to save the PSE power.

The class verification function provides an additional level of confidence in correct DPU and PSE mutual identification. In addition to a valid detection signature, the DPU shall provide a signature classification which is represented by a specific current level.

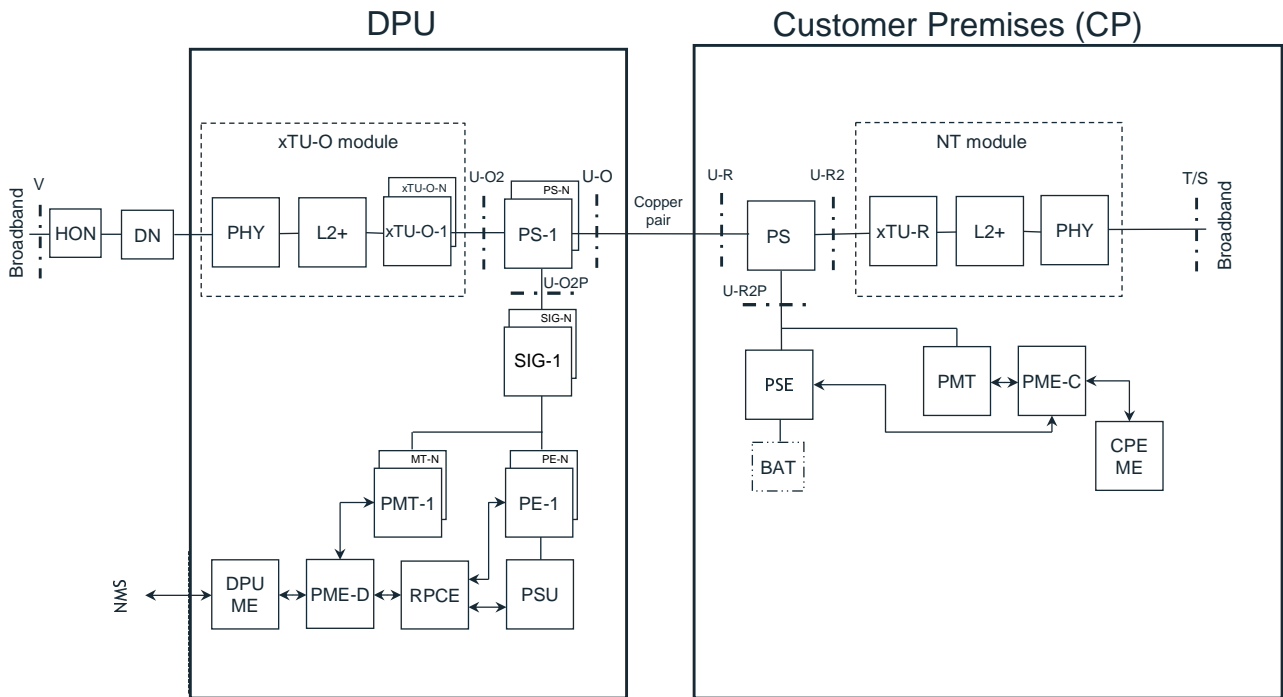


Figure 11: RPFA-NOP reference model with the DPU signature

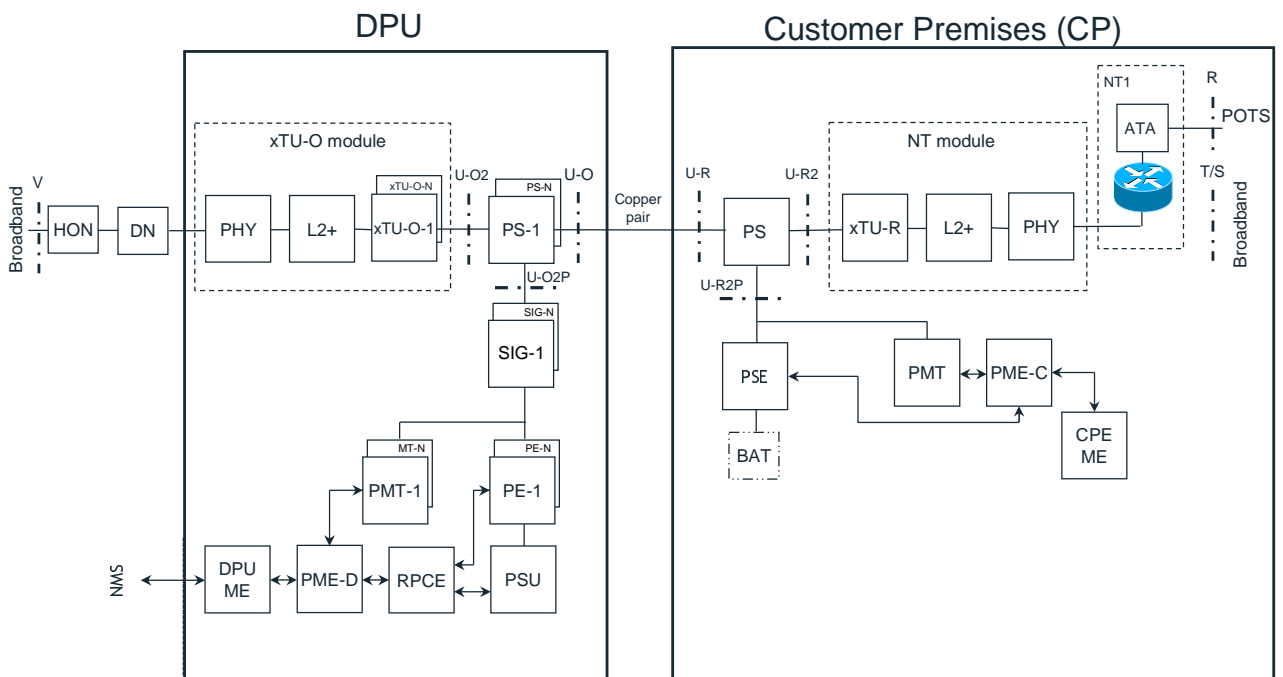


Figure 12: RPFA-DRP reference model with the DPU signature

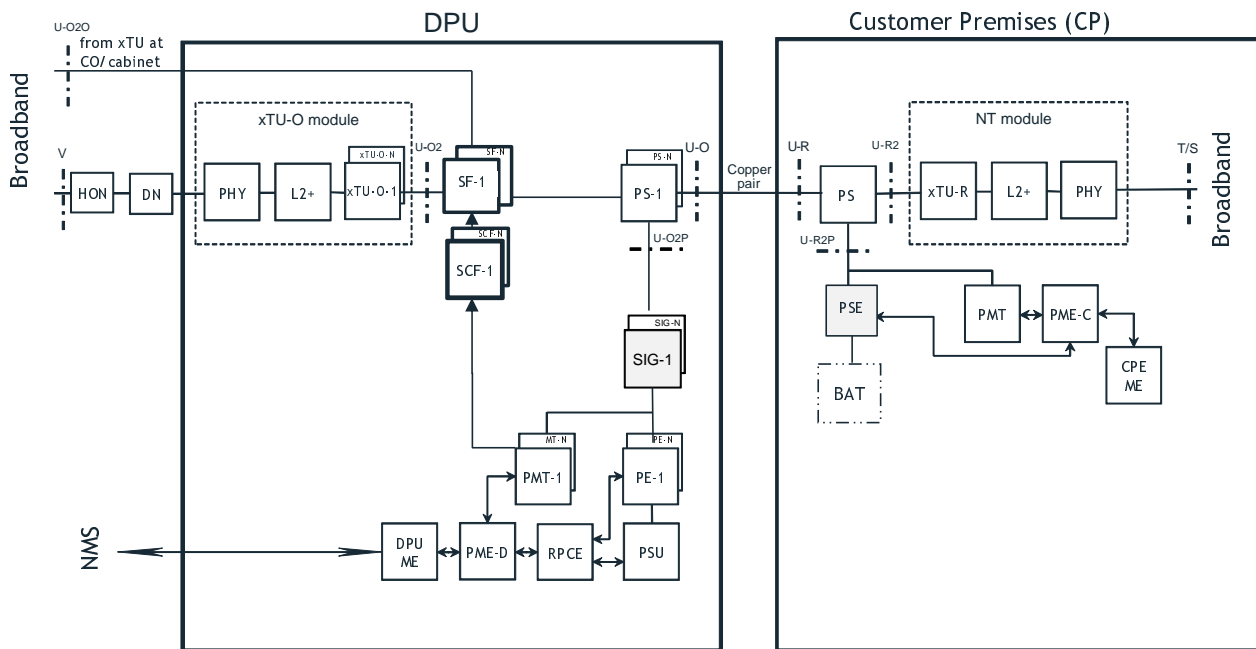


Figure 13: RPFA-NOPBB reference model with the DPU signature

The signature detection process is performed by applying a small current-limited voltage to the device between tip and ring, while measuring the tip-ring DC resistance (R_{TR}) and capacitance (C_{TR}), applied by the DPU device. The method to measure resistance R_{TR} and capacitance C_{TR} is vendor discretionary. The measurement method shall not violate the electrical specifications listed in Table 11.

NOTE: One possible approach is shown below. In evaluating the presence of a valid DPU signature, the PSE should make at least two measurements with voltage values at the PSE (V_{PSE}) that create at least a 1 V difference between test points. The detection voltage measured at the PSE (V_{PSE}) should typically be between 2,8 V and 10 V with a valid DPU detection signature connected.

The resistance is calculated as:

$$R_{SIG} = \frac{V_{PSE2} - V_{PSE1}}{I_{PSE2} - I_{PSE1}}$$

where:

- V_{PSE1} and V_{PSE2} are the first and second voltage measurements made by the PSE, respectively.
- I_{PSE1} and I_{PSE2} are the first and second current measurements made by the PSE, respectively.

The PSE should control the slew rate of the probing detection voltage when switching between detection voltages to be less than 0,1 V/ μ s. The voltage or current measurement should be taken after V_{PSE} has settled to within 1 % of its steady state condition.

The signature detection process also includes measuring a foreign DC voltage (U_{TRDC}) between TIP and RING.

Table 11: Measurement signals for measuring R_{TR} and C_{TR}

Measured parameter	Measurement Voltage, V_{MEAS} , at U-R (PSE with integrated PS) / U-R2P (PSE with external PS)	Measurement current, I_{MEAS} , through U-R2P interface
R_{TR} and C_{TR}	$0 < V_{MEAS} \leq 30$ V	$0 < I_{MEAS} \leq 5$ mA

The PSE shall apply power to the DPU if the following condition is satisfied:

- A valid DPU signature is detected and none of the error line conditions ELC 0 to ELC 3 defined in Table 8 occur.

The PSE shall not apply power to the DPU if the following condition is satisfied:

- Non-valid DPU signature is detected or at least one of the error line conditions ELC 0 to ELC 3 defined in Table 8 occur.

Note that the PSE may accept or reject a signature resistance in the band between R_{NVlow} and R_{Vmin} , and in the band between R_{Vmax} and R_{NVhigh} (see Table 12).

In normal operation, the PSE shall remove power and return to the startup procedure if any of the following error line conditions occur:

- Presence of an open circuit
- Presence of a short circuit
- Presence of an off-hook phone

These are listed in Requirement 5) of clause 6.1.

The PSE detection criteria for the DPU signature is defined in Table 12.

Table 12: PSE Detection criteria for the DPU signature

DPU signature	Parameter	Detection Criteria
Valid	$R_{Vmin} = 19 \text{ k}\Omega$; $R_{Vmax} = 26,5 \text{ k}\Omega$ $C_{Vmax} = 150 \text{ nF}$	$R_{Vmin} \leq R_{TR} \leq R_{Vmax}$ $C_{TR} \leq C_{Vmax}$
Non-valid	$R_{NVhigh} = 33 \text{ k}\Omega$; $R_{NVlow} = 15 \text{ k}\Omega$ $C_{NV} = 10 \text{ }\mu\text{F}$	$R_{TR} < R_{NVlow}$, OR $R_{TR} > R_{NVhigh}$, OR $C_{TR} \geq C_{NV}$

The electrical characteristics of the DPU signature shall comply with Table 13.

Table 13: Electrical characteristics of DPU signature

Parameter	Symbol	Units	Min	Max
Resistor	R_{SIG}	$\text{k}\Omega$	23,7	25,5
Capacitor (in parallel with signature resistor)	C_{SIG}	μF	0,05	0,12
Input voltage at which the DPU removes the signature resistance	$V_{Disconnect}$	V	10,1	12,8

6.2.2 DPU classification using MDSU protocol

The key objectives of the DPU classification are:

- To establish mutual identification of PSE and DPU as an enhanced validation mechanism on top of the detection mechanism. This addresses the scenario in which a combination of connected equipment (phones, fax machines, etc.) would have the same signature as those of a valid DPU.
- To provide power level interoperability criteria between PSE power classes and DPU power consumption.

In addition to a valid detection signature, the DPU shall provide the characteristics of a classification signature as specified in Table 14. A DPU shall present one, and only one, classification signature during classification.

Table 14: DPU classification signature

DPU class	Conditions	Class min current	Class max current
Class SR1	Voltage from 14,5 V to 20,5 V at U-O interface	9 mA	12 mA
Class SR2		17 mA	20 mA
Class SR3		26 mA	30 mA

The circuit of the classification current sink in the DPU shall only operate between certain applied voltage levels to prevent interference with the resistor detection process and not to sink any current after the classification process is finished. The voltage range should be measured across the classification circuit and should be in accordance with Table 15.

Table 15: Classification Circuit Turn On Threshold Range

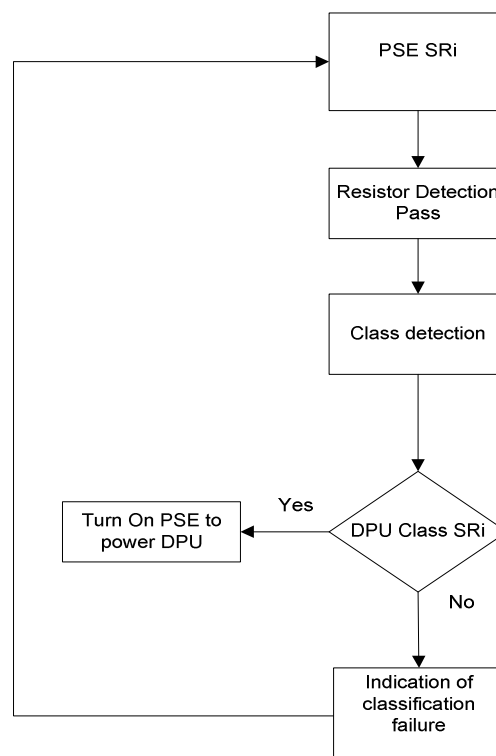
Parameter	Test condition	Min	Max	Units
Classification circuit Turn ON threshold range	Measured across classification circuit in DPU (see note). Turn on for any I_{CLASS} while the voltage across classification circuit increases.	11	14	V
Classification circuit Turn OFF threshold range	Measured across classification circuit in DPU (see note). Turn off while the voltage across classification circuit increases.	20,7	24	V
NOTE: The classification circuit is an internal circuit within the DPU and is not accessible via the U-O line interface.				

The PSE shall apply a voltage between 16,5 V and 20,5 V at the U-R interface for a PSE with an internal power splitter and at the U-R2P interface for PSEs with an external power splitter, to detect I_{CLASS} and to make a decision according to Table 16 and the flow chart in Figure 14.

Table 16: RPF Classifications Current Range

PSE Measured I_{CLASS}	RPF Class
8 mA to 13 mA	SR1
16 mA to 21 mA	SR2
25 mA to 31 mA	SR3

RPF classes SR1, SR2 and SR3 are defined in clause 7.2.



NOTE: Where index $i = 1, 2, 3$.

Figure 14: PSE Classification Flow Diagram

If a class SRi PSE identifies a class SRi DPU signature it shall turn on power (assuming no other fault conditions are identified).

If a class SRi PSE does not identify a class SRi DPU signature, it shall not turn on power and shall provide indication of classification failure. This could be done locally on PSE, e.g. by using a light emitting diode.

6.2.3 Start-up Sequence diagram

The start-up sequence diagram is shown in Figure 15.

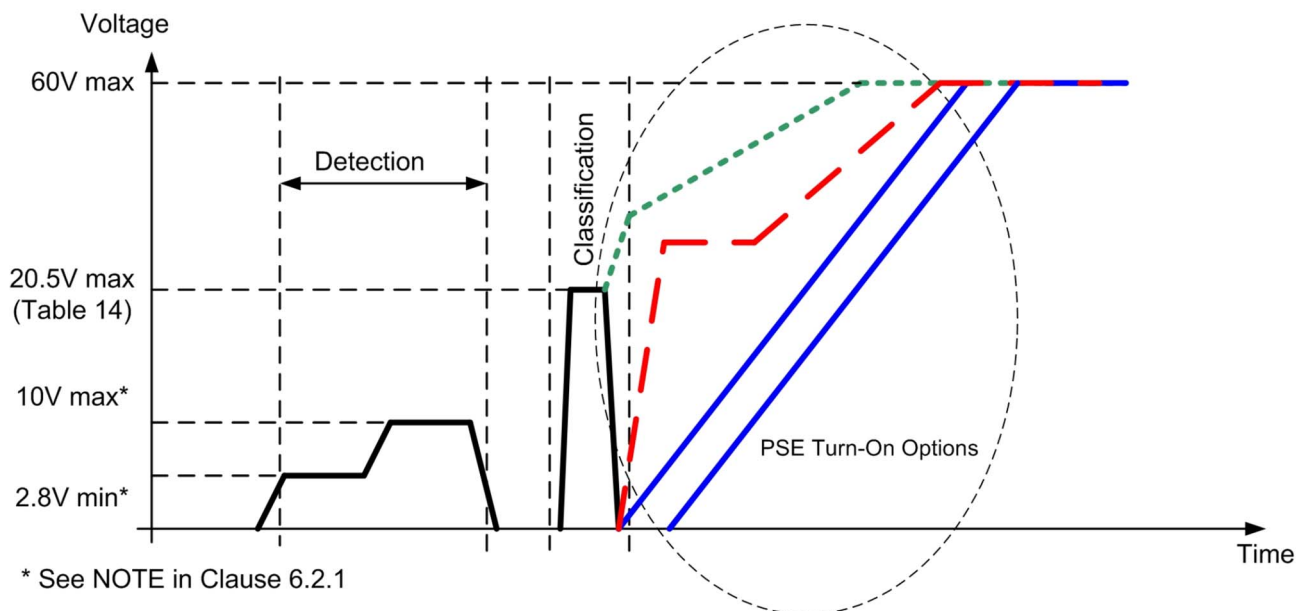


Figure 15: Start-up Sequence Diagram

The present document does not impose any special requirements on the PSE turn-on voltage curve, instead it requires that the off-hook phone detection is ensured during this process.

6.2.4 Start-up flow chart

The start-up flow chart is shown in Figure 16.

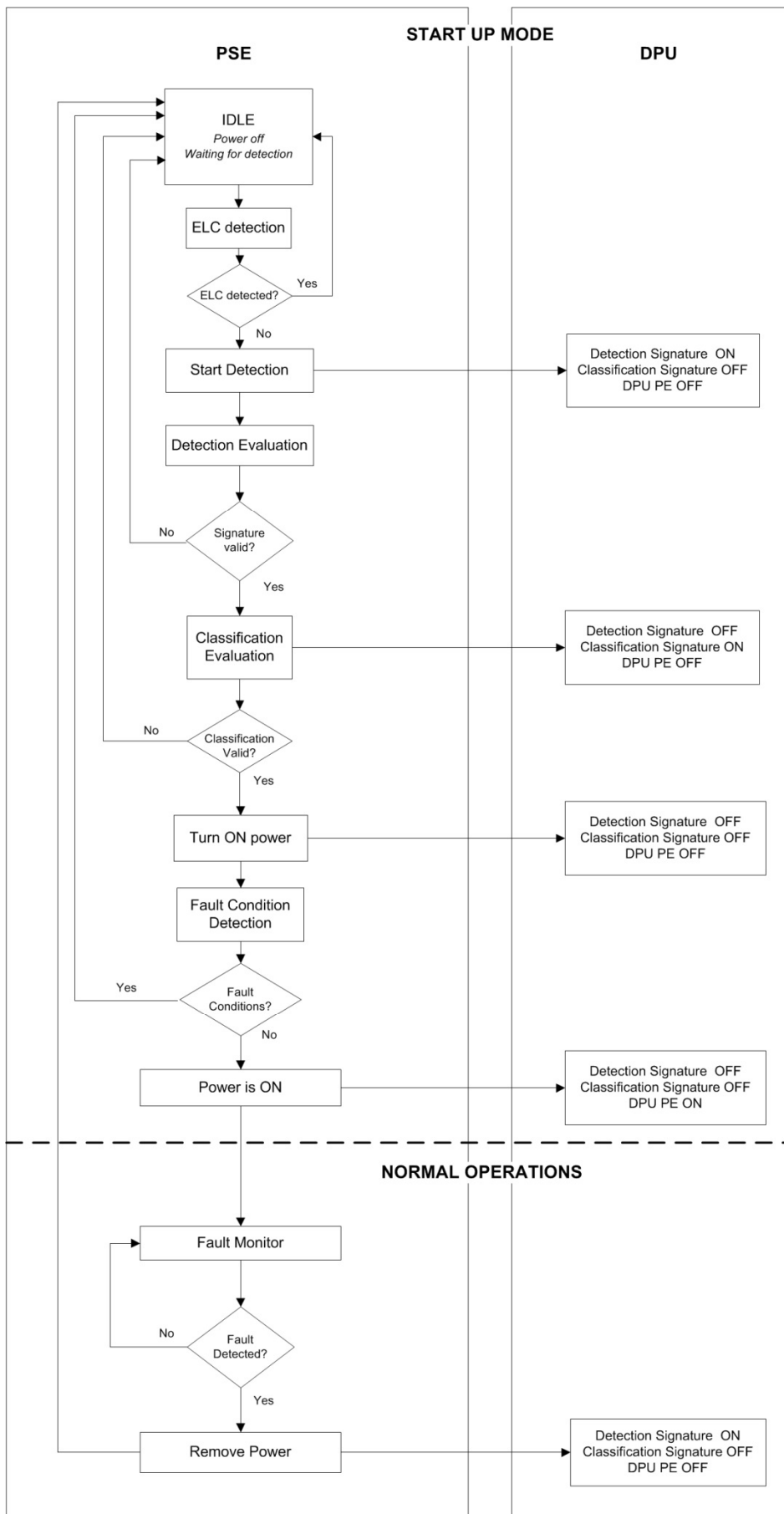


Figure 16: Start-up Flow Chart

6.2.5 POTS RCR Protocol (PRP) - Optional extension of MDSU

6.2.5.1 PRP definition

POTS Remote Copper Reconfiguration (RCR) Protocol (PRP) is an optional extension of the MDSU protocol on lines where POTS may be present. Its purpose is detection, classification and start-up of a DPU for scenarios where POTS from the exchange may be provided to the subscriber and shall be disconnected by the DPU, prior to start-up of the DPU. This scenario is referred to as POTS Remote Copper Reconfiguration (RCR).

PRP is intended for use in the following scenarios:

- 1) Exchange POTS is present on the line combined with an overlay DSL service.
- 2) Exchange POTS is present on the line with no overlay DSL service.

PRP will also work in the following additional scenarios:

- 1) Exchange POTS is not present on the line but where there is an overlay DSL service (i.e. "naked" or "dry" DSL).
- 2) Exchange POTS is not present on the line (e.g. through a break in the line between exchange and DPU or where there is a decommissioned line) and no overlay DSL service.

PRP is applicable to the architecture options defined in clause 5, Table 1.

PRP uses an AC signal, referred to as the PRP trigger, providing simultaneously power and messages to the DPU to disconnect or reconnect POTS from the exchange. Once POTS has been removed from the copper pair the MDSU protocol will be applied, as defined in clause 6.2.1 to clause 6.2.4.

PRP supports exchanges of signalling messages from the PSE to the DPU and from the PSE to POTSA-C/POTSA-D. The modulation scheme for the PRP messages shall be Frequency-Shift Keying (FSK). A mark (binary "1") shall be modulated at 1 500 Hz, a space (binary "0") at 2 100 Hz. Messages shall always be sent back-to-back. To support the exchange of signalling messages, three functional blocks are needed. These are defined in Table 17.

Table 17: Functional Blocks For Exchanging Signalling Messages

Functional Block	Function	Location
PSE PRP generator	Generates PRP messages. Sends power (AC signal) and PRP messages simultaneously to the DPU and POTS Adapter(s) if present.	CPE side
POTS Adapter PRP receiver	Extracts power (AC) from the PRP trigger. Receives PRP messages from the PSE. Instructs the POTS Adapter to start-up and to disconnect or reconnect POTS.	CPE side
DPU PRP receiver	Extracts power (AC) from the PRP trigger. Receives PRP messages from the PSE. Enables/disables or connects/disconnects SIG/PE.	DPU side

A signalling message shall consist of the following segments: a flag (FLAG), a PRP Trigger Identification (PTID) byte, Last Start Up (LSU) bits and a Power State Bit (PSB); as shown in Figure 17. FLAG indicates the start of message; the PTID byte identifies the PRP trigger from the PSE towards the DPU or the POTSA-C/POTSA-D. The LSU bits reflect the state of the last start-up of the PSE. The Power State bit indicates whether the PSE is trying to start up the DPU on either battery or mains power. The FLAG, PTID byte, LSU bits and Power State bit are defined in Table 18, Table 19, Table 20 and Table 21 respectively. All the bit values are chosen such that:

- Hamming distance between all PTID bytes is 4.
- Hamming distance between all PTID bytes and FLAG is 4.
- Hamming distance between all LSU bits is 2.
- Hamming distance to a false flag followed by a falsely valid PTID byte is 3.

The intent of the protocol is to prevent detection of false triggers as these can be service impacting. Although the chosen bit values could allow a receiver to implement error correction, it should not be performed. Furthermore to increase the robustness of the protocol the receiver may consider any information carried by the PRP trigger valid, if the receiver has detected it multiple times back to back.

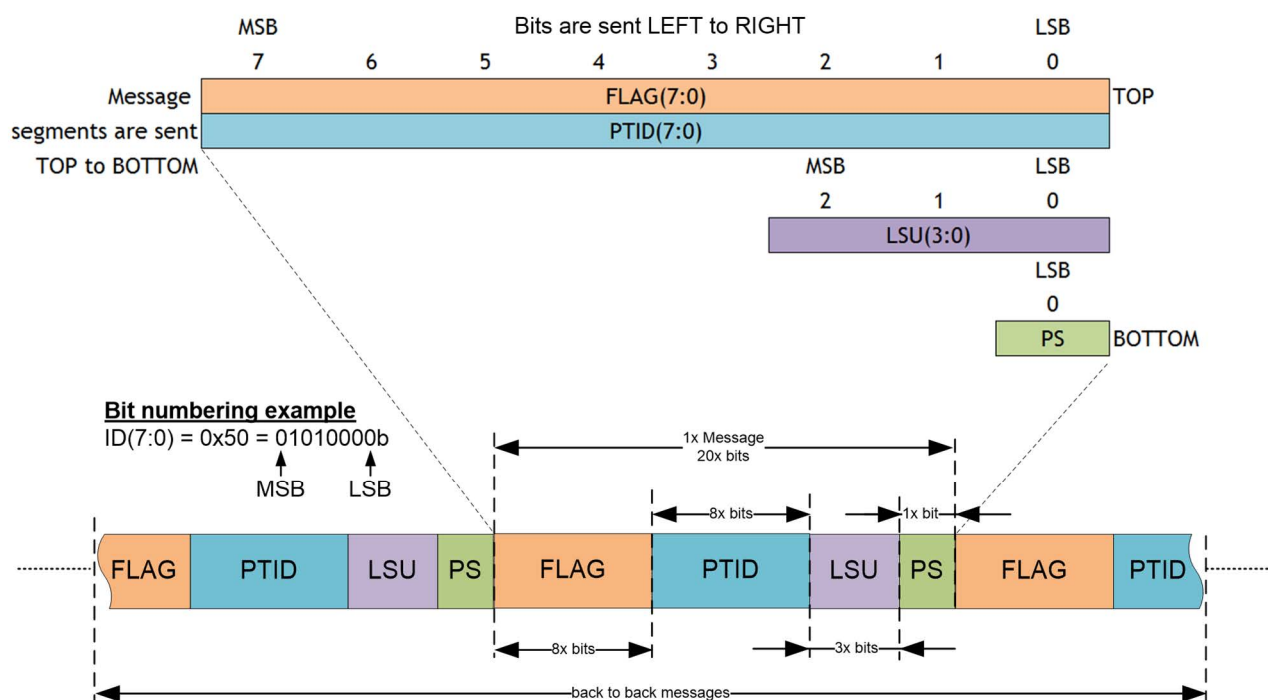


Figure 17: PRP message structure

Table 18: FLAG definition

FLAG	0x7E (hex)
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Table 19: PRP Trigger Identification Definition (PTID)

PRP Trigger name	From > To	PTID value (hex)	Use
"POTS disconnect trigger SR1"	PSE > DPU	0x50	PSE of class SR1 requests DPU to disconnect Exchange POTS and force POTSA-E into Normal mode
"POTS disconnect trigger SR2"	PSE > DPU	0xE8	PSE of class SR2 requests DPU to disconnect Exchange POTS and force POTSA-E into Normal mode
"POTS disconnect trigger SR3"	PSE > DPU	0xB4	PSE of class SR3 requests DPU to disconnect Exchange POTS and force POTSA-E into Normal mode
"POTS disconnect trigger SRany"	PSE > DPU	0x0C	PSE of any class requests DPU to disconnect Exchange POTS and force POTSA-E into Normal mode
"POTS re-connect trigger"	PSE > DPU	0x22	PSE requests DPU to re-connect Exchange POTS and force POTSA-E into Bypass mode
"PA enable trigger"	PSE > POTSA-C/POTSA-D	0x9A	PSE requests POTSA-C and POTSA-D to start up
"PA POTS reconnect trigger"	PSE > POTSA-C/POTSA-D	0xC6	PSE requests POTSA-C and POTSA-D to reconnect POTS

Table 20: Last Start Up (LSU) State definition

Last Start Up State	LSU Value (binary)
Last Start Up successful	000b
Last Start Up fail due to off-hook phone	101b
Last Start Up fail due to other than off-hook phone	110b
Last Start Up condition not available due to loss of Power	011b

Table 21: Power State definition

Power state	PSB Value (binary)
Start-up on mains	0b
Start-up on battery	1b

The start-up protocol is described in the flow charts in Figure 18 and Figure 19 for PSE and DPU respectively. Figure 18 specifies the top level flow-chart for the PSE, the low-level process flows are defined in Annex E (normative). Table 22 shows the related clauses and figures for each of the process flows.

Table 22: PRP Low Level Process Flows

Process Name	Clause	Figure
Perform MDSU	E.2	E.1
POTS RCR MDSU Error Handling	E.3	E.2
PSE reverse Power Active	E.4	E.3
Perform POTS RCR	E.5	E.4
Send PRP Trigger	E.6	E.5
Set Initial State	E.7	E.6
Send ENABLE Trigger to POTS Adapter	E.8	E.7

Start-up of POTSA-C and POTSA-D is shown in Figure 20. The PRP PSE flow of Figure 18 contains the decision symbol "PSE Supports POTS RCR", if the "No" path is followed for every such decision symbol the resulting flow corresponds to the MDSU start-up flow in clause 6.2.4.

The PRP process "Send PRP trigger", as defined in clause E.6, contains the PRP specific Line Status Monitor process. The objective of this process is to detect off-hook phone(s) and other line fault conditions.

The PRP PSE flow requires the timers and counters defined in Table 23 and Table 24 respectively.

Table 23: PRP PSE Timers

Timer	Function
PRP Trigger (PT) timer	Defines how long messages are send back to back by the PSE, as indicated in Figure 18.
Retry Timer 1	Defines the wait time if Retry_Count exceeds its threshold. Its threshold is RTT1.
Retry Timer 2	Defines the wait time after a POTS trigger fails to disconnect POTS, detection of an ELC or persistent MDSU failures. Its threshold is RTT2.
NOTE:	All timers count time to zero, a timer reaching zero is equivalent to expiry of the timer.

Table 24: PRP PSE Counters

Counter	Function
MDSU_Error_Count counter:	Counts amount of MDSU failures not related to an ELC 1, an ELC 2, an ELC 3 or a RPF class mismatch occurrence.
Retry_Count counter:	Counts amount of times a POTS re-connect trigger is sent, and amount of times any POTS disconnect trigger fails to remove POTS.

The corresponding Timer and Counter parameters are defined in Table 25.

Table 25: PRP - Timer and counter parameters

Parameter	Symbol	Unit	Min	Max	Comments
Retry timer time 1	RTT1	Minutes	10	∞	
Retry timer time 2	RTT2	s	2	10	
PT timer expiry time	PTT1	s	60	70	
MDSU_Error_Count threshold	MDEC	Count	3	3	
Retry_Count threshold	ReC	Count	3	10	See note
NOTE: A ReC value of -1 is also allowed. If ReC equals -1, the PSE should not wait RTT1 time after it has sent a predefined amount of POTS re-connect triggers or unsuccessful POTS disconnect triggers, to re-attempt to start-up the potentially present DPU.					

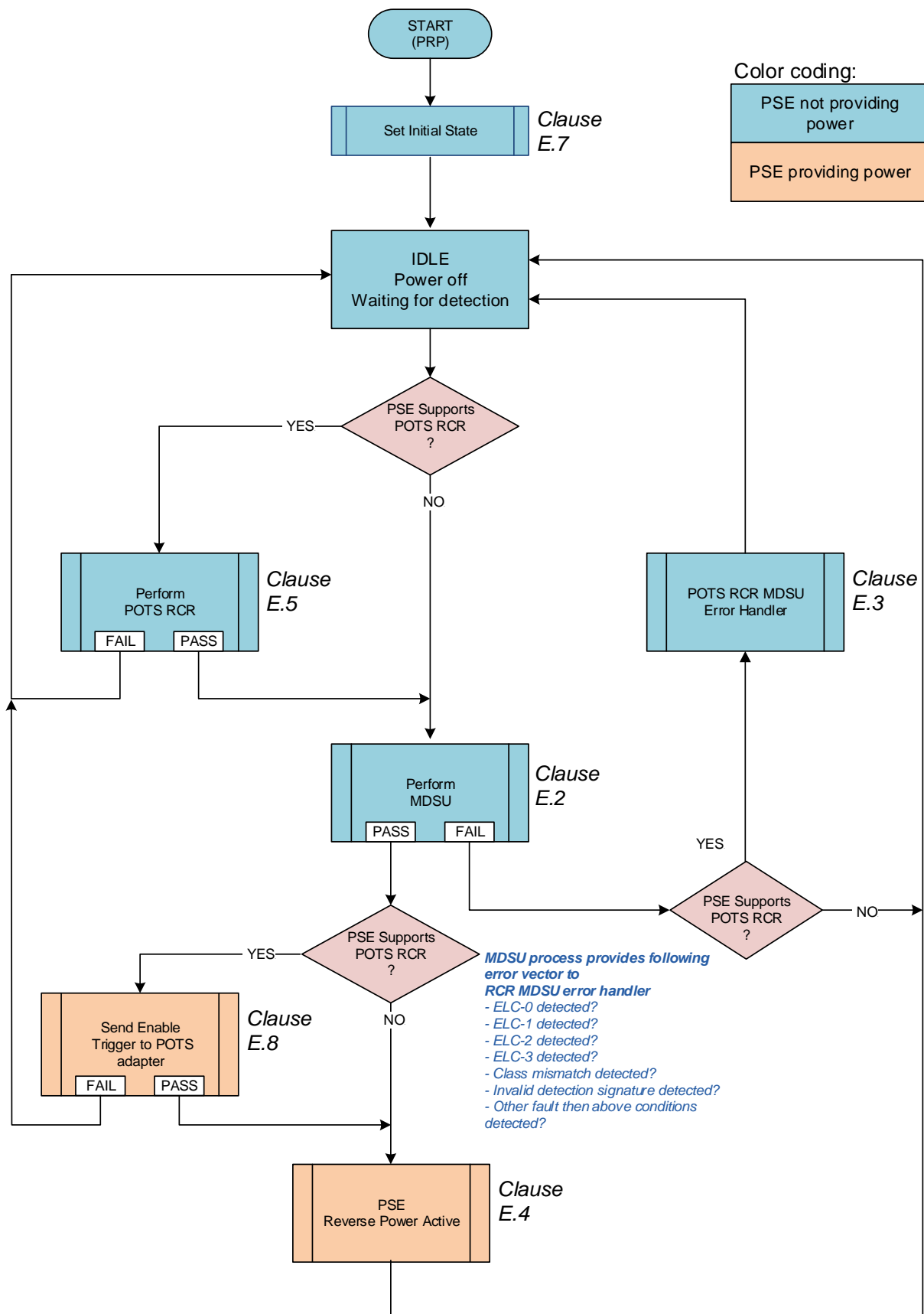


Figure 18: Top Level Flow-chart for PSE using PRP

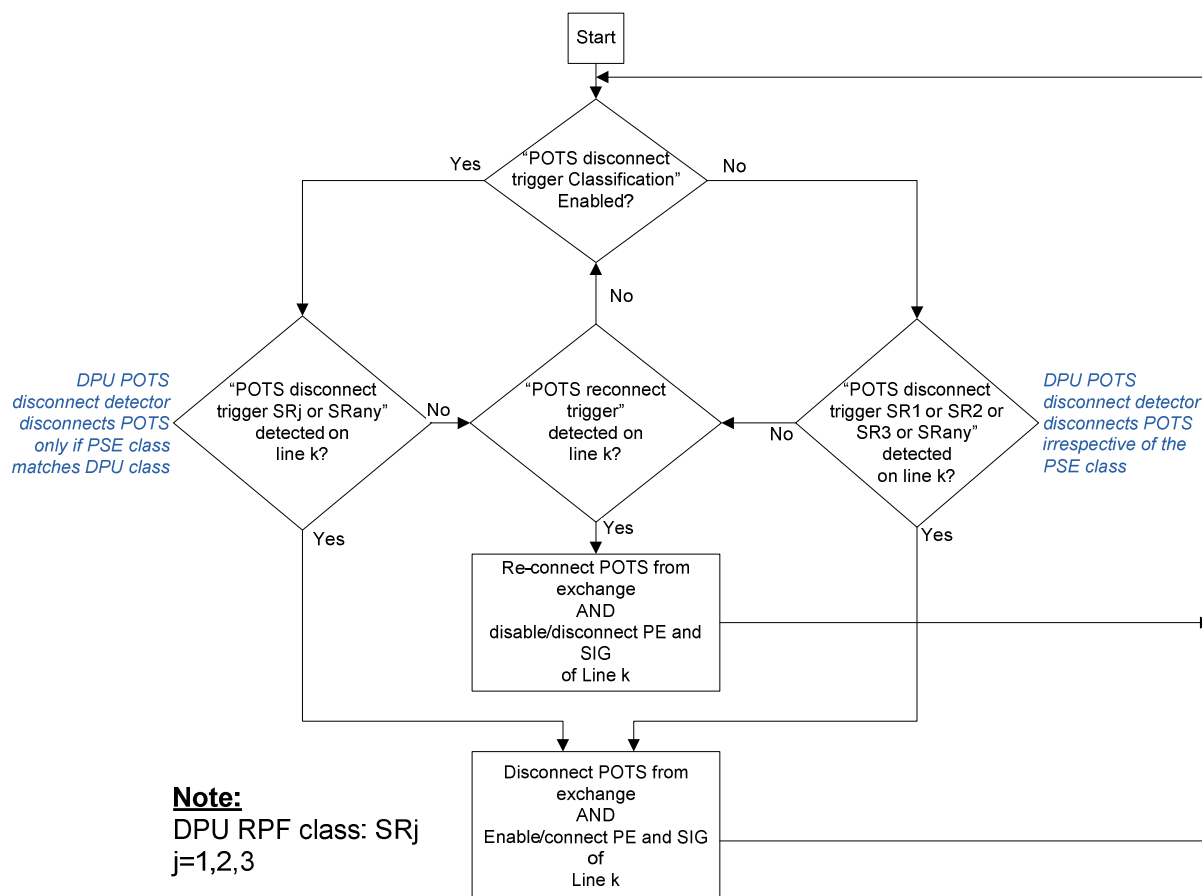


Figure 19: Flow chart for DPU using PRP

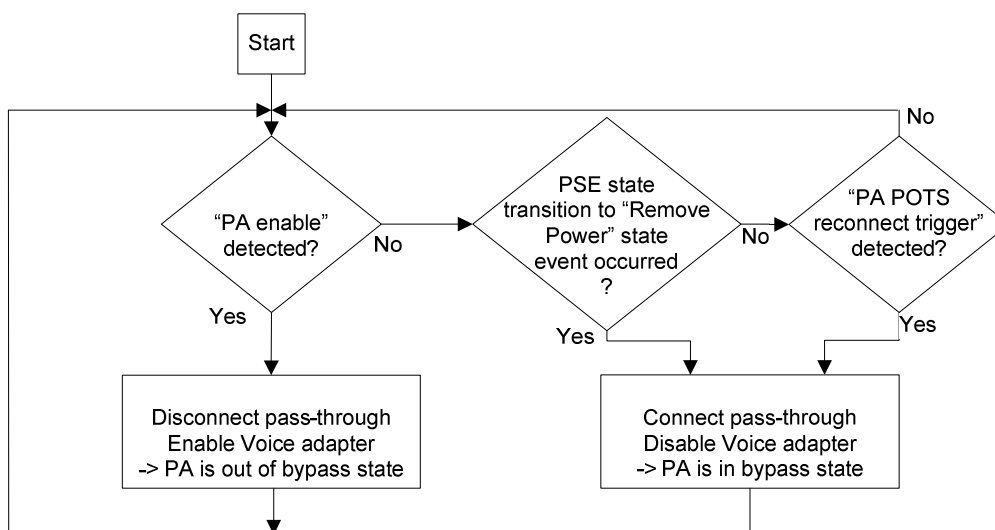


Figure 20: Flow chart for POTSA-C and POTSA-D using PRP

6.2.5.2 PRP electrical specifications

6.2.5.2.1 PSE electrical specification for PRP

Table 26 specifies the PRP specific electrical parameters for a PSE supporting PRP. The PSE shall, in line with the PRP process flow, send PRP messaging FSK modulated at 1 500 Hz and 2 100 Hz. V_{AC-Tx} , the peak to peak voltage of the FSK signal, shall be between $V_{AC-Tx-min}$ and $V_{AC-Tx-max}$ while the PSE is terminated by any impedance whose magnitude is between the magnitude of $Z_{PSE-PRP-min}$ and $Z_{PSE-PRP-max}$ at the U-R or U-R2P interface.

The FSK signal shall be balanced, Figure 21 illustrates a FSK signal superimposed on the DC POTS voltage or on the DC reverse power feed voltage.

NOTE: Implementations should give due attention to minimize impact on the services on neighbouring lines. E.g. harmonic distortion of the FSK signalling should be kept to a minimum.

While a PSE is sending PRP messages it behaves similarly to an AC voltage source, superimposed to the DC voltage, if it is present. V_{AC-TX} is chosen as such, that if a $600\ \Omega$ load is exposed to it, the load will not be subjected to a power exceeding 19,2 dBm, which is below the typical power level of the receiver off-hook tone (aka "howler" tone) (20 dBm).

Table 26: PRP - PSE electrical specifications - at U-R / U-R2P interface

Parameter	Symbol	Unit	Min	Typ	Max
Mark frequency	F_z	Hz	1 485	1 500	1 515
Space frequency	F_A	Hz	2 079	2 100	2 121
Bit rate		baud	297	300	303
Transmit peak to peak AC voltage at U-R2P / U-R of FSK signal	V_{AC-TX}	$V_{AC-peak-peak}$	17	18,5	20
PSE PRP load impedance between 1 kHz and 3 kHz	$Z_{PSE-PRP}$	Ω	70	600	∞

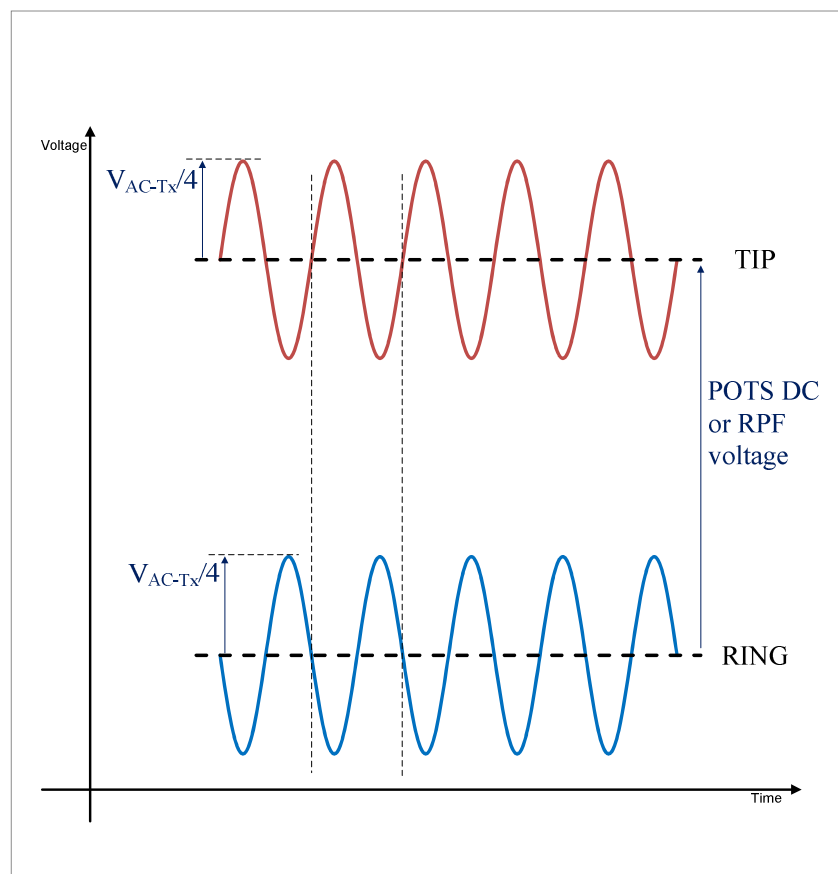


Figure 21: FSK signal, superimposed on DC POTS or RPF voltage

6.2.5.2.2 DPU electrical specification for PRP

To allow message and energy transfer from PSE to the DPU, the load impedance between 1 kHz and 3 kHz, seen by the PSE, shall be higher than $Z_{PSE-PRP,min}$, as defined in Table 26. Two distinct scenarios occur depending on the state of the DPU.

In case POTS from the exchange is still connected to the U-O interface for a given line, the DPU shall be transparent for at least the POTS service and typically also the xDSL service from the exchange for that given line. Hence the DPU should have minimal impact on the load impedance seen by the PSE between 1 kHz and 3 kHz. The level of transparency is a figure of merit for the DPU.

In case the DPU has disconnected POTS from the exchange for a given line, the DPU shall meet the electrical characteristics of the DPU detection signature, as defined in Table 12, for that given line as long as the detection signature is enabled and the classification signature is disabled. The minimum impedance of the detection signature is higher than $Z_{PSE-PRP,min}$. Furthermore $V_{AC-Tx,max}$ is lower than twice the minimum signature circuit disconnection voltage, as defined in Table 12, and the minimum classification circuit Turn ON threshold voltage, as defined in Table 14. Therefore, the PRP trigger can be sent such that the detection signature is enabled and that the classification signature is disabled, ensuring sufficiently high load impedance for the PSE.

NOTE: Similarly at the DPU, POTS adapters should have minimal impact on the load impedance seen by the PSE between 1 kHz and 3 kHz.

6.2.5.3 Interoperability between "PRP capable" and "non PRP capable devices"

As support for PRP is optional for both the DPU and the PSE, the behaviour of a RPF system shall be predictable and safe for the following cases:

- PSE supporting PRP & DPU not supporting PRP
- PSE supporting PRP & DPU supporting PRP
- PSE not supporting PRP & DPU supporting PRP
- PSE not supporting PRP & DPU not supporting PRP

Table 27 specifies the mandatory interoperability behaviour of the RPF system.

Table 27: PRP Interoperability requirements for DPU and PSE

PSE	DPU	Behaviour
PRP supported	PRP supported, Exchange connected to DPU	PSE shall instruct the DPU to disconnect exchange and shall power up the DPU in absence of fault conditions, in line with PRP.
	PRP supported, Exchange disconnected from DPU	PSE shall power up the DPU in absence of fault conditions, in line with PRP.
	PRP not supported, Exchange POTS not present	PSE shall power up the DPU in absence of fault conditions, in line with PRP.
	PRP not supported and Exchange POTS present	PSE detects POTS exchange DC voltage and instructs DPU to disconnect exchange. DPU cannot respond to this instruction, the PSE shall not apply reverse power feed to the DPU.
PRP not supported	PRP supported, Exchange connected to DPU	PSE will not detect a valid detection or classification signature. It will not power up the DPU and exchange will not be disconnected by the DPU. If POTS is present, the PSE detects the POTS Exchange DC voltage, considers this as ELC 2 and the PSE shall not apply reverse power feed to the DPU.
	PRP supported, Exchange disconnected from DPU	PSE shall power up the DPU in absence of fault conditions, in line with MDSU.
	PRP not supported, Exchange POTS not present	PSE shall power up the DPU in absence of fault conditions, in line with MDSU.
	PRP not supported and Exchange POTS present	PSE detects the POTS Exchange DC voltage, considers this as ELC 2 and the PSE shall not apply reverse power feed to the DPU.

6.3 RPF Dying Gasp and Indication Primitives

6.3.1 General

The PSE shall provide the RPF Dying Gasp and Indication Primitives defined in Table 28. The RPF Dying Gasp and Indication Primitives shall either be sent to the DPU by using the RPF OAM channel or by the Embedded Pulse Signalling method, specified in this clause. If RPF OAM is available, these primitives shall be sent using the RPF OAM channel instead of the Embedded Pulse Signalling method.

Table 28: RPF Dying Gasp and Indication Primitives

Signal Name	Full Name	Description	When sent
DGL	Dying Gasp Loss	PSE Lost Power "Dying-Gasp" Indication	When the PSE is about to exit Normal Operations due to loss of input power, being loss of mains power and either battery backup has failed, or no battery backup facility is available.
OHP	Off-Hook Phone	Power Fail with off-hook Phone Indication during NORMAL OPERATION	After ELC-3 occurrence (see note 1).
BAT	Battery	Operation on battery indication	Refer to clause 6.3.4.
ACM	AC Mains	Operation on mains power and no PSE battery backup available indication	Refer to notes 2 and 3.
BBA	Battery Backup Available	Operation on mains power and PSE battery backup available indication	
NOTE 1: If RPF OAM is used, the OHP primitive is sent immediately after the ELC-3 occurrence. Otherwise this primitive is sent after the next successful DPU start-up, following the ELC-3 occurrence. If the PSE shuts down due to loss of input power before the next successful DPU start-up, it may or may not sent the OHP primitive.			
NOTE 2: When the DPU transitions to NORMAL OPERATION, battery backup availability is unknown until either a BAT, ACM, or a BBA indication is received from the PSE unless PRP indicates that the PSE is starting up on battery power (see Table 21).			
NOTE 3: The DPU will assume the PSE powering method is unknown until either a BAT, BBA or ACM indication is received unless the PSE powering method is indicated through the PRP (see Table 21).			

Where there is an external battery backup solution provided at the PSE, it is recommended that the Dying Gasp BBA and BAT indication are sent in line with Table 28.

The Embedded Pulse Signalling method shall use binary amplitude modulation of the PSE output voltage to signal primitives listed in Table 28. For all primitives defined in Table 28, a pulse sequence waveform is defined. A PSE shall signal a primitive by modulating its output voltage such that it complies to the corresponding pulse sequence waveform. Pulse sequence waveforms are shown in Figure 24, Figure 25 and Figure 26, the following definitions apply:

- The High time, W_0 , W_2 and W_3 , is defined as the duration for which the voltage at U-R/U-R2P is below $V_{PSE-SIG-High,max}$ and above $V_{PSE-SIG-High,min}$.
- The Low time, W_1 , is defined as the duration for which the voltage at U-R/U-R2P is below $V_{PSE-SIG-Low,max}$ and above $V_{PSE-SIG-Low,min}$.
- The Fall time, T_f , is defined as the time required for the voltage at U-R/U-R2P to change from $0,9 \times V_{PSE-SIG-High,min}$ to $1,1 \times V_{PSE-SIG-Low,max}$.
- The Rise time, T_r , is defined as the time required for the voltage at U-R/U-R2P to change from $1,1 \times V_{PSE-SIG-Low,max}$ to $0,9 \times V_{PSE-SIG-High,min}$.

For PSEs without integrated power splitter, the voltage measured across C_{sig} of the PSE Signalling Reference Termination 1 (SRT-1) shall comply with the corresponding pulse sequence waveform, while the PSE is terminated with the PSE SRT-1 as defined in Figure 22 at the U-R2P interface and while it is transmitting a pulse sequence.

For PSEs with integrated power splitter, the voltage measured across C_{sig} of the PSE SRT-2 shall comply with the corresponding pulse sequence waveform, while the PSE is terminated with the PSE SRT-2 as defined in Figure 23 at the U-R interface and while it is transmitting a pulse sequence.

Component values of PSE SRT-1 and SRT-2 are defined in Table 29. The Polarity of the PSE output voltage shall be as indicated in Figure 22 and Figure 23.

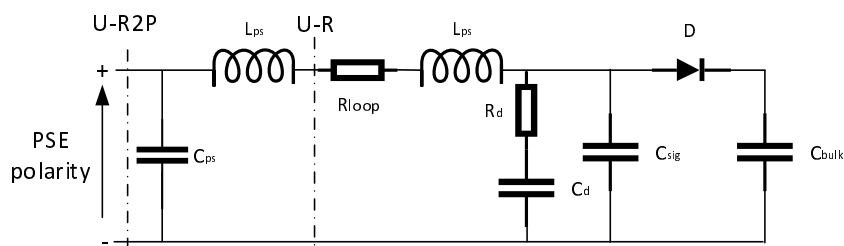


Figure 22: PSE SRT-1 for PSE without integrated Power Splitter

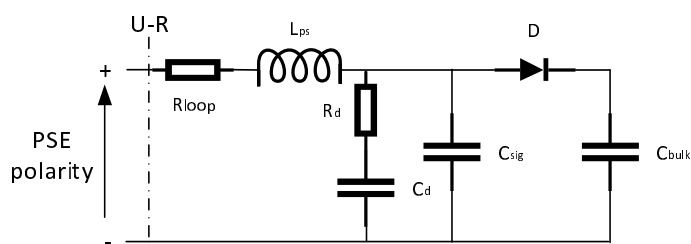


Figure 23: PSE SRT-2 for PSE with integrated Power Splitter

Table 29: Component values of PSE SRT-1 and SRT-2

Component	Value
R_{loop}	2 Ohm \pm 1 % and 43 Ohm \pm 1 %
C_{ps}	100 nF \pm 10 %
C_{sig}	75 nF \pm 10 %
C_{bulk}	100 uF \pm 20 %
D	0 V < Forward voltage < 1 V @ 500 mA
L_{ps}	2 mH \pm 10 %
C_d	75 nF \pm 10 %
R_d	300 Ohm \pm 1 %

6.3.2 DGL pulse sequence

The pulse sequence waveform for "DGL" is defined in Figure 24. The corresponding timing and electrical parameters are listed in Table 30 and Table 31 respectively. The following applies:

- A PSE shall signal the DGL primitive, just before it is about to exit Normal Operations, due to a loss of input power.
- A short loss of AC power shall not result in the signalling of "DGL". A PSE shall not initiate the "DGL" pulse sequence, while it is subjected to a micro-interruption on its AC mains interface with a duration of 20 ms and a repetition period of 10 s.
- A DGL primitive shall only be considered valid by the DPU, if the PSE output voltage remains below $V_{PSE-SIG-Low,max}$ after completing the DGL pulse sequence and the PSE exits Normal Operations.
- If the PSE can maintain Normal Operations, at least sufficiently long to signal a new DGL pulse sequence, after completing the former DGL pulse sequence, it shall either:
 - maintain Normal Operations by setting its output voltage to the Steady State Output Voltage, as indicated by the dashed line in Figure 24; or

- exit Normal Operations and return to Start-up, as indicated by the dotted line in Figure 24.
- If the PSE cannot maintain Normal Operations sufficiently long to signal a new DGL pulse sequence, after completing the former DGL pulse sequence, it shall exit Normal Operations and return to Start-up, as indicated by the dotted line in Figure 24.

A PSE shall not abort a DGL pulse sequence, once the DGL sequence is initiated it shall be fully executed as defined in Figure 24.

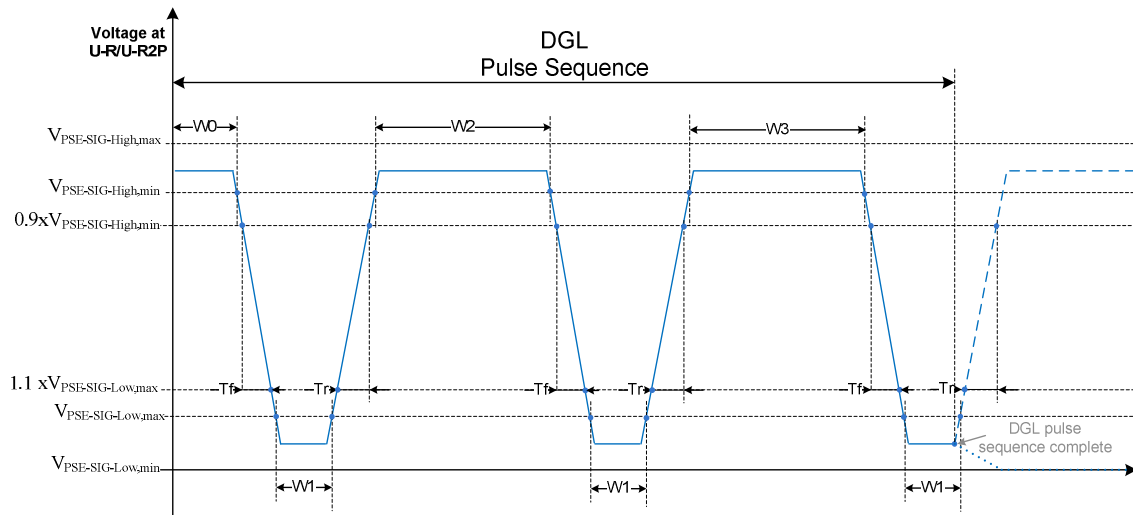


Figure 24: Pulse sequence waveform for DGL primitive

6.3.3 OHP pulse sequence

The pulse sequence waveform for "OHP" is defined in Figure 25. The corresponding timing and electrical parameters are listed in Table 30 and Table 31 respectively. The following applies:

- The PSE shall signal the OHP primitive after the next successful DPU start-up, following an ELC-3 occurrence, while it is in Normal Operations and no earlier than 10 s and no later than 120 s after the transition from Start-up to Normal Operations.
- A PSE shall not abort an OHP pulse sequence, once the OHP sequence is initiated it shall be fully executed as defined in Figure 25.

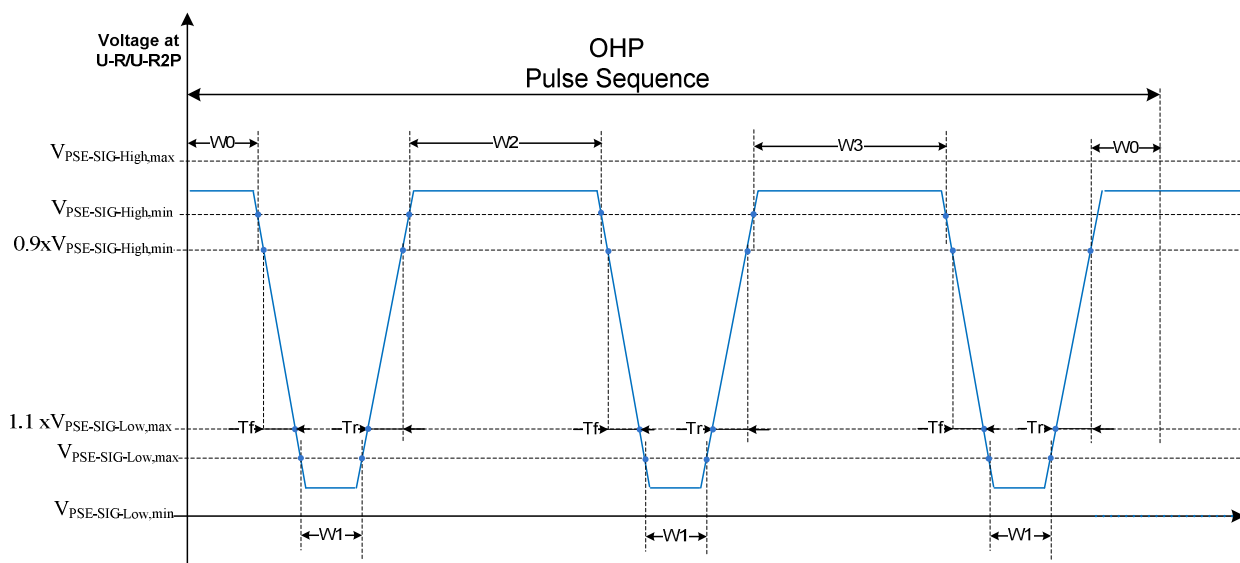


Figure 25: Pulse sequence waveform for OHP primitive

6.3.4 BAT, BBA and ACM pulse sequences

The pulse sequence waveforms for "BAT", "ACM" and "BBA" are defined in Figure 26. The corresponding timing and electrical parameters are listed in Table 30 and Table 31 respectively. The following applies to the PSE:

- The PSE shall signal one of the BAT, ACM or BBA primitive while it is in Normal Operations and no earlier than 10 s and no later than 60 s after the transition from Start-up to Normal Operations and shall be repeated once within 5 to 10 minutes if no relevant state changes occur.
- The BAT, BBA and ACM primitives shall be sent during Normal Operations within 60 s after a relevant state change and shall be repeated once within 5 to 10 minutes if no relevant state changes occur.
- The minimum time between signalling two primitives, both being either OHP, BBA, BAT or ACM shall be at least 50 s. This also applies to signalling that is aborted.
- A PSE may abort the signalling of either BBA, BAT or ACM by forcing the PSE output voltage to its Steady State Output Voltage, as defined in Table 38, and violating the pulse sequence waveform.

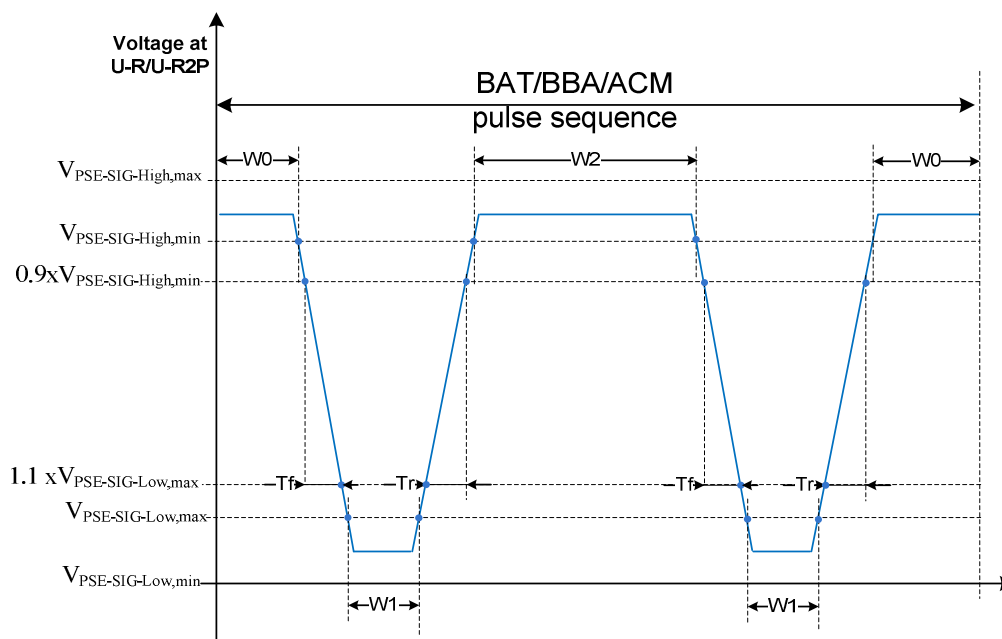


Figure 26: Pulse sequence waveform for BAT, ACM and BBA primitives

Table 30: Timing Parameters for Signalling pulse sequence waveforms

SIGNAL	W0	W1			W2			W3		
	Unit: ms	Unit: μ s			Unit: ms			Unit: ms		
	MIN	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
DGL	8,3	100	170	240	1,2	1,5	1,8	0,7	1,0	1,3
OHP	10	100	170	240	2,2	2,5	2,8	0,7	1,0	1,3
BAT	10	100	170	240	1,2	1,5	1,8	Not Applicable		
ACM	10	100	170	240	2,2	2,5	2,8	Not Applicable		
BBA	10	100	170	240	3,2	3,5	3,8	Not Applicable		

Table 31: Electrical parameters for Signalling pulse sequence waveform

Parameter	Symbol	Unit	Min	Max
PSE Signalling high voltage	$V_{PSE-SIG-High}$	V	55,75	60
PSE Signalling low voltage	$V_{PSE-SIG-Low}$	V	-20	20
Rise time	T_r	μ s	0	100
Fall time	T_f	μ s	0	100

6.4 RPF Operations and Maintenance

This clause applies to the single box model only, where the PSE and CPE are integrated.

The purpose of RPF Operations And Maintenance (OAM) is to exchange the management information defined in Table 32 and clause 6.3 between the CPE ME and the DPU ME. The RPF OAM definition is out of scope for the present document. The PSE shall provide the following to the DPU.

Table 32: RPF OAM Parameters sent from PSE to DPU

Message Payload Type	Parameter Name	Definition	Description
Boolean	NTE-CPF	Inventory per line	Integrated PSE in CPE. The DPU assumes that the state of integration is unknown until a NTE-CPF indication is received.
2-bit scalar	PSE-PC	Inventory per line	PSE RPF Class {SR1, SR2, SR3}.
10-bit Integer	RPF-IFN	Status per line	Average current feed now (in units of mA from 0 mA to 400 mA) at the UR-2P interface (Averaging time window and accuracy to be defined).
Boolean	PSE-PRP	Inventory per line	PSE PRP capability {PRP supported, PRP not supported}.
6-bit array of Booleans whereby only 1 bit is set to true in the array, 000000b is not allowed	PSE-SUF	Diagnostics per line	Latest PSE Start-Up Failure indication, detected during "Start Up", being either: <ul style="list-style-type: none"> • ELC-0 (Open tip-to-ring) • ELC-1 (Short tip-to-ring) • ELC-2 (POTS Exchange (foreign) DC voltage) • ELC-3 (Off-hook phone) • Mismatch of the PSE RPF Class with the DPU RPF Class • Unknown
6-bit array of Booleans whereby only 1 bit is set to true in the array, 000000b is not allowed	PSE-SDC	Diagnostics per line	Latest PSE Shut Down Cause indication, detected during "Normal Operation", being either: <ul style="list-style-type: none"> • ELC-0 (Open tip-to-ring) • ELC-1 (Short tip-to-ring) • ELC-3 (Off-hook phone) • Overload time violation, as defined in Table 38 • Maintain power signature violation, as defined in Table 41 • Unknown
16-bit integer	PSE-IE	Diagnostics per line	Injected Energy by the PSE at U-R2P interface, while PSE is in the "Normal Operations" state, expressed in units of mWh and represented as a 16-bit unsigned integer with valid values from 0 mWh to 65 535 mWh. The integer shall wrap on overflow (accuracy to be defined). This parameter is read by the DPU periodically to construct current and previous 15 minute and 24 hour interval DPU counts.

7 Reverse Power Feed Characteristics

7.1 Safety Aspects

7.1.1 Background

Safety aspects of Reverse Power Feed are covered by CENELEC EN 60950-1 [2] and CENELEC EN 62368-1 [9].

NOTE: At the time of publication of the present document, two CENELEC safety standards for Information and Communications Technology are in force. The current Date of Withdrawal (DoW) of CENELEC EN 60950-1 [2] is 20th December 2020. Therefore, the present document references both standards. In Europe it is mandatory to demonstrate compliance with either CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9].

Reverse powering shall be capable of energizing a DPU by a single customer over a single copper pair between the customers' premises and that powered device. That pair, besides reverse (DC) powering may be also carrying DSL data, POTS (voice) transmission and POTS signalling data. In addition, it may be necessary to ensure a continuous metallic path in order that services such as legacy copper line-testing can be conducted over that same copper pair.

There are three classes of reverse powering when applied with respect to supporting POTS:

- 1) POTS originating in the exchange and Reverse Power Feed shall be simultaneously supported on the same wire-pair by using POTS adapters (see Figure 3, Figure 4 and Figure 5).
- 2) Reverse Power Feed with derived POTS originating in the ATA are using separate wiring such that the outside loop and the customer premise wire pair carry the reverse powering voltage without any support for an analogue POTS connection (see Figure 6 and Figure 7).
- 3) Reverse Power Feed and derived POTS originating in the customer premises shall be simultaneously supported on the same customer premises wire-pair by using POTS adapters and with no analogue POTS connection to/from the exchange (see Figure 8).

There are two classes of reverse powering with respect to installation procedure:

- 1) Self-install.
- 2) Engineer install.

Details of an installation procedure are out of scope of the present document.

7.1.2 Unintended consequences

It should be noted that the operation of telephony apparatus connected to RPF circuitry without an appropriate protective POTSA-C or POTSA-D cannot be guaranteed. Indeed, excessive current may be drawn by telephony apparatus, when entering an off-hook state, which could destroy or cause permanent damage to that device.

To protect against such consequences, RPF systems shall be able to detect un-protected telephony devices going off-hook and reduce the source current to a value below 25 mA within 1 s and until the un-protected device has been removed from the network.

7.2 RPF Range Options and Classes

In order for equipment to implement RPF schemes, it is necessary to define a series of parameters suitable for allowing operation in a number of scenarios. The scenarios are grouped into the following range options:

- Range Option 1: 60 V DC Short Range (SR)
- Range Option 2: 120 V DC Long Range (LR)

Specifications associated with Range Option 2 are incomplete and are provided for information only (see Annex F).

Each of these range options is further characterized in different corresponding classes, each class defining a set of parameters based upon the appropriate reference model and the RPF power supply characteristics. Table 33 defines the safety limit requirements for each of the range options and all classes defined for the corresponding range option. The values apply to the Power Source Equipment (PSE) at reference point U-R2P.

Table 33: Range options and safety limit requirements

Property	60 V DC Short Range TNV-1 (CENELEC EN 60950-1 [2]) or ES1 (CENELEC EN 62368-1 [9])	120 V DC Long Range TNV-3 (CENELEC EN 60950-1 [2]) or ES2 (CENELEC EN 62368-1 [9])
Maximum injected power by PSE per CENELEC EN 60950-1 [2]	100 W	100 W
Maximum DC Voltage on Line applied by PSE between TIP and RING	< 60 V DC	< 120 V DC
Maximum short-circuit Current generated by PSE per CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9] (For all cable types)	1,3 A	1,3 A

Table 34 specifies three short range RPF classes, which includes the maximum power, DC voltage and line current:

- "RPF Class SR1" is defined to support (very) low power DPU designs, when they become available; the applicability of Class SR1 for a considered deployment type (amount of ports per DPU, cable losses, DPU uplink types, DPU feature scope at and beyond the physical layer, amount of additional devices (POTS-Adapters) to be fed from the same PSE, etc.) depends on the availability of low-power solutions.
- "RPF Class SR2" allows a higher maximum power to be transmitted than Class SR1. When compared to Class SR1, a solution that complies with Class SR2 can extend the type of deployments that can be supported, while still avoiding any additional safety measures in the home environment (below 15 W as per CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9]).
- "RPF Class SR3" allows a higher maximum power to be transmitted than Class SR2, making it suitable for demanding deployment situations for which Class SR1 or SR2-compliant power solutions are not available. A PSE of Class SR3 can inject more than 15 W and hence introduces additional safety measures compared to Class SR1 and Class SR2 (see SAFETY NOTE (a) and SAFETY NOTE (b) in Table 34).

The definition of the classes aims:

- to allow RPF designs to be optimized for high efficiency operation at the powers necessary for this particular class of application, i.e. where minimal power shall be dissipated in sealed remote enclosures;
- to take into account the safety constraints for a deployment (safety measures in the context of residential home network depend on the level of injected power and applied voltage, safety requirements on the DPU depend on the power and voltage it is subjected to);
- to take into account the balance between on the one hand aiming for power-efficient DPU solutions (low power dissipation) and on the other hand covering as many deployment cases as possible from early on;
- to assist in interoperability.

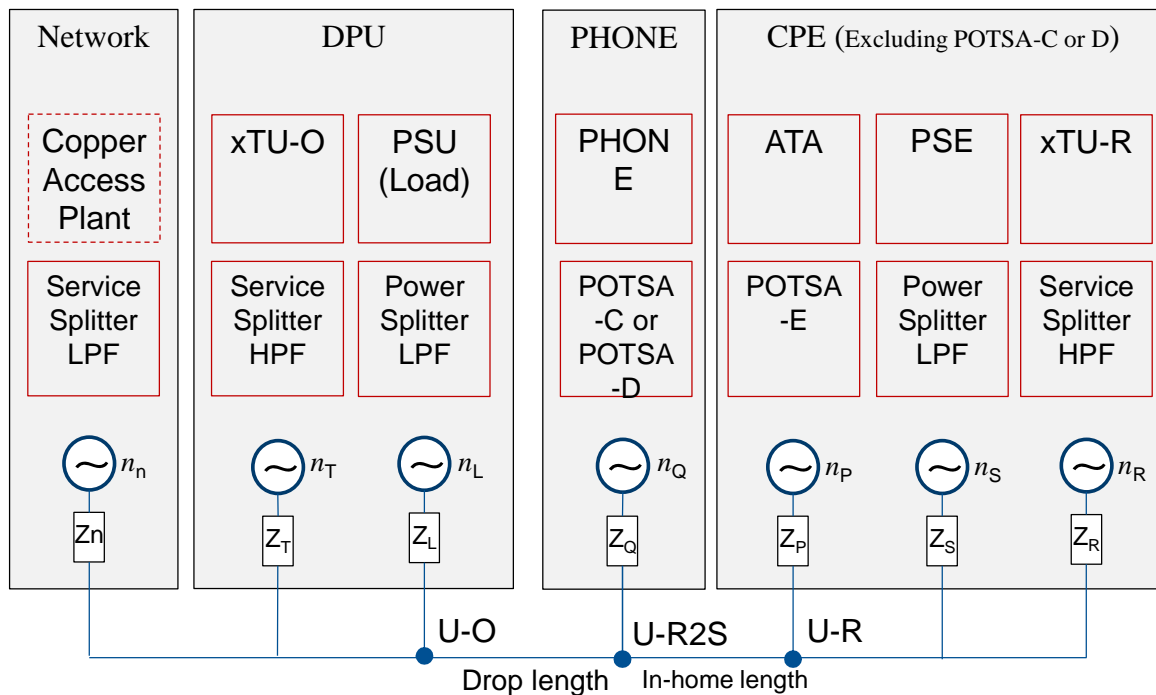
Table 34: Short range reverse power feed class specifications

Parameter	60 V DC Short Range TNV-1 (CENELEC EN 60950-1 [2]) or ES1 (CENELEC EN 62368-1 [9]) RPF Class SR1 Safety Note (a)	60 V DC Short Range TNV-1 (CENELEC EN 60950-1 [2]) or ES1 (CENELEC EN 62368-1 [9]) RPF Class SR2 Safety Note (a)	60 V DC Short Range TNV-1 (CENELEC EN 60950-1 [2]) or ES1 (CENELEC EN 62368-1 [9]) RPF Class SR3 Safety Note (b)
Maximum power injected at U-R2P interface by PSE with external power splitter Or Maximum power injected at U-R interface by PSE with internal power splitter	10 VA	15 VA	21 VA
Maximum DC Voltage between TIP and RING	60 V	60 V	60 V
Maximum line current	See Table 38		
Minimum Reach Resistance supported by a DPU (see clause 7.5.2.1)	43 Ω	43 Ω	43 Ω
<p>SAFETY NOTE (a): In general, the DPU shall be designed according to specifications defined in CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9]. In this RPF class a single-port DPU will not be subject to a power exceeding 15 W, while a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W.</p> <p>SAFETY NOTE (b): In general, the DPU shall be designed according to specifications defined in CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9]. In this RPF Class a single-port and a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W.</p> <p>Additionally, a single PSE can generate more than 15 VA and shall comply with the definition of "limited power source" as per clause 2.5 of CENELEC EN 60950-1 [2] or as per Annex Q of CENELEC EN 62368-1 [9].</p> <p>Additionally, any additional RPF device such as POTS Adapters or components such as plugs connected to the PSE that can be subject to the full PSE power shall also comply to clause 4.7.2 of CENELEC EN 60950-1 [2] or clauses 6.3, 6.4 and 6.5 of CENELEC EN 62368-1 [9].</p> <p>Additionally, in the local network environment of the PSE, it is not allowed to connect any part that does not comply with CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9] to the PSE, e.g. devices, enclosures, plugs, etc. that are already installed in the home network or could be installed at a later stage by the end-user shall be isolated from the DC power injected by the PSE.</p>			

7.3 Electrical reference model and RPF Noise Limits

This clause specifies the electrical reference model and defines the differential mode RPF noise limits. Note that the common mode RPF noise limits are provided in Annex C as informative text.

An example of a high level representation of RPF electrical reference model is shown in Figure 27. This is a high level representation which is based on a hypothetical contiguous copper path (drop wire and in-premises wiring for some options) connecting a remote node (e.g. DPU) to the customer's broadband CPE and telephony instruments. Each functional connection to that path is via an equivalent intermediate function, for example a Power Splitter Low Pass Filter in the case of the Power Source. Each functional connection is characterized by a noise generator and frequency dependent source impedance. Figure 27 shows clusters of functional connections that may be combined into one equivalent connection, if the CPE for example were to be implemented as a single entity, with one port for connection to the copper path. Figure 27 is an example specific to G.fast transport in downstream transmission configuration, where the maximum total loop resistance of the drop wire plus the loop resistance of the in-premises wiring is 43 Ω .



- NOTE 1: n_n is a model of noise emanating from the upstream copper access network from source impedance z_n .
- NOTE 2: n_T is a model of noise emanating from a DSL transmitter with source impedance z_T .
- NOTE 3: n_L is a model of noise emanating from a DPU RPF load (PSU) with source impedance z_L .
- NOTE 4: n_Q is a model of noise emanating from a POTS instrument and POTS signalling adapter with source impedance z_Q .
- NOTE 5: n_P is a model of noise emanating from an ATA and POTS signalling adapter with source impedance z_P .
- NOTE 6: n_S is a model of noise emanating from a CPE RPF source (PSE) with source impedance z_S .
- NOTE 7: n_R is a model of receiver noise expressed in DSL receiver with load impedance z_R .

Figure 27: High Level Representation of RPF Electrical Reference Model

In this example, the upstream model n_T , z_T and n_R , z_R are swapped between DPU and CPE. The FTU-O and FTU-R limits may be common but a separate definition will be required for both transmit and receive modes.

Table 35 defines the Noise PSD $N_{1M}(f)$ and how it is constructed from the Noise PSD Mask $NM(f)$. Row 1 shows the underlying goal $NM(f)$ while row 2 embodies a relaxation to account for concentration of power supply noise energy in discrete tones ($NM_{1M}(f)$). The noise PSD $noise(w)$ is assumed to be in Watt/Hz. The basic masks are unchanged and incorporate scaling to yield PSD in dBm/MHz. They are detailed in row 1, which shows the underlying goal, and row 2 which embodies a relaxation to account for concentration of power supply noise energy in discrete tones. The mask defined in row 2 is normative. Row 3 specifies the sliding window interpretation of the mask, the method for interpolation between corner points specified in row 1, and that the frequency in question applies to the lower extreme of the 1 MHz sliding window. Row 4 mathematically defines the requirement in terms of a continuous integral of noise PSD over a 1 MHz bandwidth. Row 6 contains normative notes that specify the noise limit that shall apply to both ends of an operational link, including noise that may emanate from the DPU power supply.

The limits in Table 35 apply to operation while G.fast or VDSL2 is active on the line and RPF is in normal operation. During RPF initialization there is no impact to G.fast or VDSL2 on the same line as the RPF, only to other pairs in the cable via crosstalk, so the differential mode noise limits may be relaxed during initialization phases, the extent to which this limit may be relaxed is not specified.

- NOTE: The frequency of switched mode power supplies, phase noise, jitter and wander characteristics should be taken into account.

Table 35: PSD mask for differential Reverse Power Feeding noise at active xTU-R and xTU-O subsystem line ports

Row #	Frequency, MHz	0 to 0,01	0,01 to 2	2	4	8	10	20	30	212
1	NM(f), dBm/Hz (Goal Informative)	Not Specified	-135	-135	-138	-141	-144	-150	-154	-154
2	NM _{1M} (f), dBm in 1 MHz RBW (Normative)	Not Specified	-75	-75	-78	-81	-84	-90	-94	-94
3	PSD limit interpolation	Limit interpolated linearly on Log PSD Lin frequency scale in 1 MHz sliding window starting at the frequency in question (see note 2).								
4	Definition: N _{1M} (f) Noise PSD (1 MHz bandwidth)	$N_{1M}(f) \geq 30 + 10 \times \log_{10} \left(\int_{w=f \times 10^6}^{w=(f+1) \times 10^6} noise(w) dw \right) dBm/MHz$ <i>noise(f) = noise power spectral density W/Hz; 0,01 MHz < f < 212 MHz</i>								
5	Noise PSD verification 10 kHz grid method Method (see note 3)	$N_{1M}(f) \geq 30 + 10 \times \log_{10} \left(\sum_{n=0}^{n=99} \int_{w=f \times 10^6 + n \times 10^4}^{w=f \times 10^6 + (n+1) \times 10^4} noise(w) dw \right) dBm/MHz$ <i>f in MHz is an integer multiple of 10 kHz, for 0,01 MHz < f < 212 MHz</i>								
NOTE 1: The noise is defined as the total noise injected into the line due to power source, load and any attached POTS signalling translation functions located at the customer premises.										
NOTE 2: RPF systems shall comply with the 1 MHz sliding window mask NM _{1M} (f) over the entire valid frequency range, on a regular grid of start frequencies not more than 50 kHz apart. The RPF noise characteristics should be stationary and independent of power load and external power supply conditions.										
NOTE 3: Verification of the sliding window noise limit shall be verified on a frequency grid with not greater than 10 kHz spacing.										
NOTE 4: The sum of integrals approach used in the definition could be used as a fast and efficient verification method that avoids the same 10 kHz band PSD measurements being repeated 100 times. Repeated offset full band (1 MHz) integration is a mathematically equivalent approach, if the noise is stationary.										
NOTE 5: Noise Mask NM _{1M} (f) shall only be applicable within the frequency range of the stand-alone power splitter class as defined in clause 8.2 or by the services supported between the U-O and U-R interfaces.										

7.4 Zero touch DPU

A zero touch implementation means that an operator can remotely configure or enable services from a remote node (DPU) without the need for a technician to visit the site. Two classes of zero touch functionality are defined:

- 1) Remote Copper Reconfiguration (ZT-RCR) functionality related to reconfiguration of the copper loop, such that it is physically disconnected from the legacy copper network, cabinet or exchange, and connected to the DPU without a site visit. This also requires the ability to perform the reverse action when the service is removed at the CPE, depending on operator preference.
- 2) Link Auto-Configuration functionality (ZT-LAC) enables services on the CPE according to pre-provisioned attributes and remote control of the service state of DPU ports.

On installation of a DPU, or when a line is reset and reconfigured for a new customer, Link Auto Configuration (ZT-LAC) automatically configures managed objects in the Access Section (including HON, DPU and CPE) to deliver a pre-authorized connection and may be part of an integrated end-to-end service provisioning process. After the loss of reverse power feed, ZT-LAC may be used to reinstate the last known good configuration including coordinated action with the Persistent Management Agent (PMA) that preserves the DPU state whilst it is unpowered. These aspects are mainly out of scope for the present document. In a ZT-RCR environment, all lines at the DP may be provided with VDSL [i.4] or G.fast [i.6] functionality even if they are not currently enabled for the service. Figure 28 shows the basis for a zero touch solution which is derived from the reference model in Figure 27, but reconfigured for separation of legacy and RPF signals, and VDSL or G.fast signals. This approach assumes that legacy services are permanently frequency segregated from the DPU hosted DSL. So the key reconfiguration aspects include: turning the DPU hosted DSL termination on or off, blocking RPF DC from passing back into the legacy telephony network, and connecting or disconnecting the DPU RPF PSU from the low-pass signal path. The basic control of these operations is via network management. However, the presence of reverse powering voltages on the DPU tributary port may optionally force the DC block to the legacy network to be automatically activated. This action properly fits into the category of ZT-LAC.

In Figure 28 the red arcs indicate noise coupling paths from the PSU (load) that are deviant from the reference model in Figure 27.

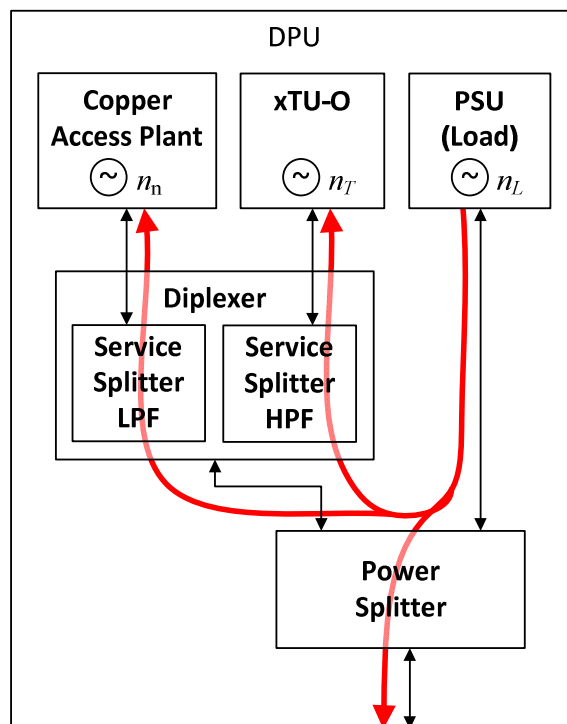


Figure 28: Example of noise coupling paths in a zero touch Integration

The zero touch implementation, also known as the Remote Copper Reconfiguration feature, can be optionally implemented with the RPFA-NOP or RPFA-DRP architectures. In this optional architecture, the DPU power splitter, PE, and PSU can be pre-installed and shall not impact the operation of the legacy POTS or DSL service while in their non-powered state. The reference models shown on Figure 2, Figure 6 and Figure 7 are modified as per Figure 29, Figure 30, and Figure 31 respectively, on which the optional DPU block used to implement this feature is shown. Similarly, Table 2 and Table 5 are modified as per Table 36 and Table 37 to show the reference points that are present prior to the activation of the new service.

The functionality of the power splitter depends on the DPU customer line state: pass-through or DP hosted service:

- The Power Splitter plus Service Splitter LPF define the relationship between U-reference point, power load noise budget and actual PSU load noise requirements. This shaping is vendor discretionary.
- The Power Splitter specification also controls how much PSU noise escapes upstream. This is specified in clause 8.4.

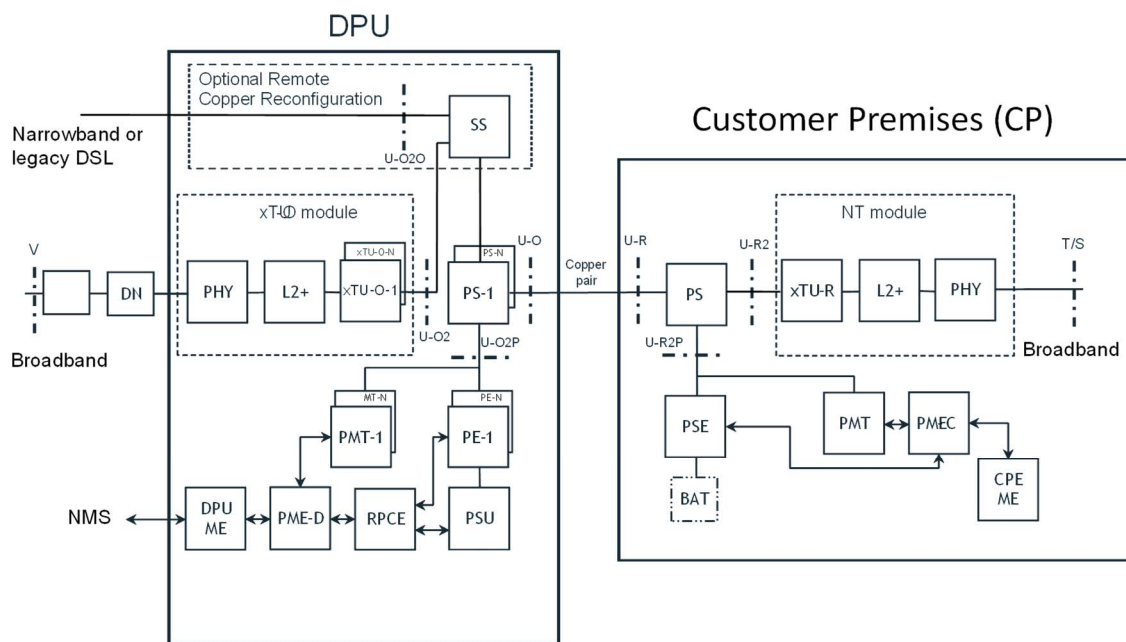


Figure 29: Modified RPFA-NOP Reference Model

Table 36: RPFA-NOP Reference Points - Prior to service activation (If supporting the optional Remote Copper Reconfiguration feature)

Reference Point	Broadband Signals	Reverse Power Feeding	Analogue Voice Signals	Out of band POTS Signalling
U-O2	No	No	No	No
U-O2P	No	No	No	No
U-O2O	Yes - Legacy	No	Yes	No
U-O	Yes - Legacy	No	Yes	No

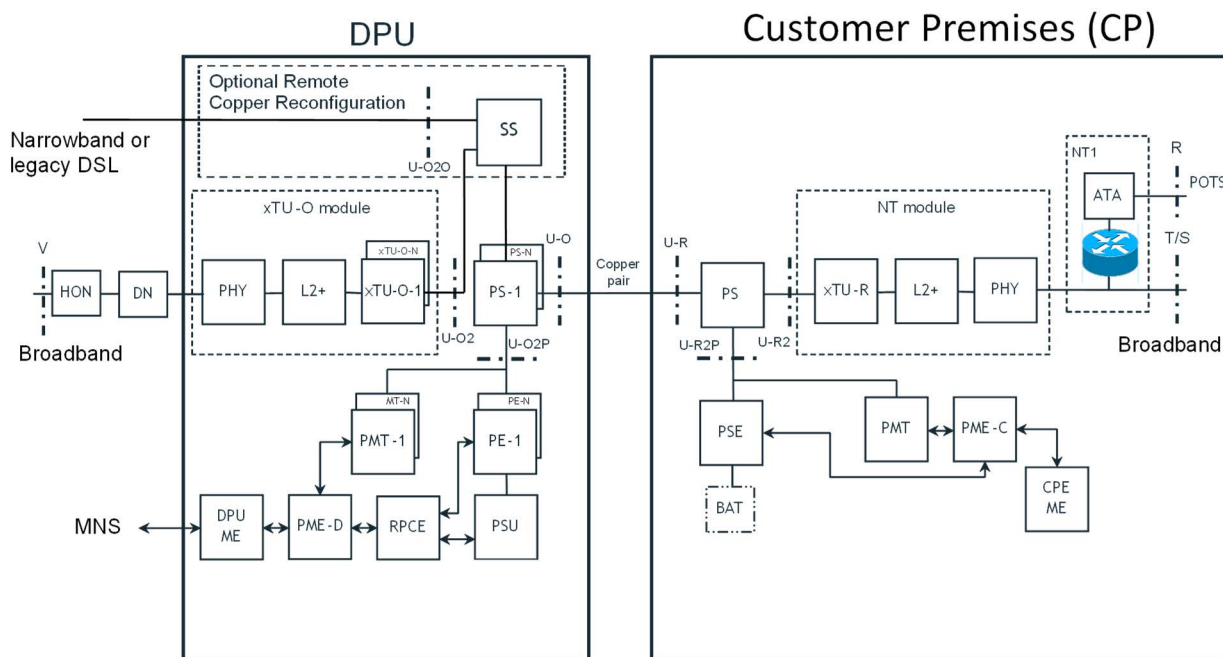


Figure 30: Modified RPFA-DRP Reference Model with derived POTS and a single POTS port

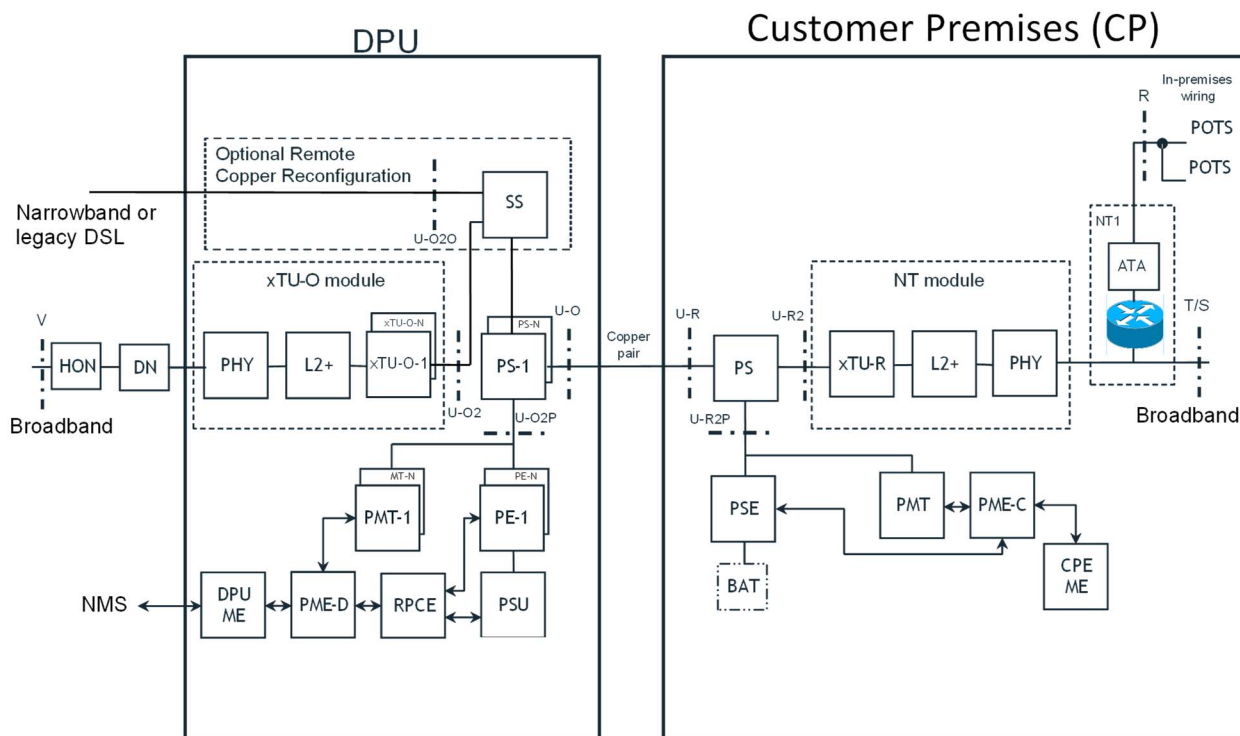


Figure 31: Modified RPFA-DRP Reference Model with derived POTS distributed over In Premises Wiring

Table 37: RPFA-DRP Reference Points - Prior to service activation (If supporting the optional Remote Copper Reconfiguration feature)

Reference Point	Broadband Signals	Reverse Power Feeding	Analogue Voice Signals	Out of band POTS Signalling
U-O2	No	No	No	No
U-O2P	No	No	No	No
U-O2O	Yes - Legacy	No	Yes	No
U-O	Yes - Legacy	No	Yes	No

7.5 PSE and DPU PE electrical specification

7.5.1 PSE electrical specification

7.5.1.1 PSE electrical specification on interface U-R2P

Electrical specification of PSE on interface U-R2P will be the same for all architectural options. In the case where the PSE has an internal power splitter and the U-R2P is an internal interface, the electrical specifications of Table 38 apply to the U-R interface of the PSE.

Table 38: PSE electrical specification on interface U-R2P

Parameter	Symbol	Unit	Min	Max	Comments
Steady state output voltage	V_{PSE}	V	55,75	60	Typical 57 V. Total output voltage deviation, including initial set up, load/ line, temperature regulations is +5 %, -2,2 % Up to 60 V to allow for transient conditions. (See note 2).
Continuous output current in Power_ON state for RPF Class SR1	I_{PSE_SR1}	mA	161	$P_{out_SR1_MAX}/V_{PSE}$	See note 1.
Continuous output current in Power_ON state for RPF Class SR2	I_{PSE_SR2}	mA	241	$P_{out_SR2_MAX}/V_{PSE}$	See note 1.
Continuous output current in Power_ON state for RPF Class SR3	I_{PSE_SR3}	mA	336	$P_{out_SR3_MAX}/V_{PSE}$	See note 1.
Continuous output power for Class SR1	P_{out_SR1}	W	8,98	10	$P_{out_Sri_min} = V_{PSE_min} \times I_{PSE_Sri_min}$ $P_{out_Sri_max} = V_{PSE} \times I_{PSE_Sri_max}$ Where: i is SR class 1, 2, 3.
Continuous Output power for Class SR2	P_{out_SR2}	W	13,44	15	
Continuous Output power Class SR3	P_{out_SR3}	W	18,73	21	
Overload time limit	T_{CUT}	ms	50	75	See note 1.
Inrush current	I_{INRUSH}	mA		450	To allow start up transients measurement should be taken during power up and 1 ms after $V_{PSE} > 30$ V.
NOTE 1:					
a) The PSE shall remain in Reverse Powering Mode state if I_{PSE_Sri} remains below $I_{PSE_Sri_min}$, in absence of any fault condition.					
b) The PSE shall remain in Reverse Powering Mode state, in absence of any fault condition (for example ELC 1) if I_{PSE_Sri} exceeds $I_{PSE_Sri_min}$ or $I_{PSE_Sri_max}$, but for no longer than T_{cut_min} .					
c) If I_{PSE_Sri} exceeds $I_{PSE_Sri_min}$ for longer than T_{cut_min} , the PSE may return to quiescent state; or it may remain in Reverse Powering Mode in absence of any fault condition.					
d) If I_{PSE_Sri} exceeds $I_{PSE_Sri_max}$ for longer than T_{cut_max} , the PSE shall return to quiescent state.					
NOTE 2: V_{pse} is a PSE output voltage and is measured according to CENELEC EN 62368-1 [9] edition 2.0, paragraph 6.2.2.					

The cumulative duration of $T_{cut,max}$ and $T_{cut,min}$ is measured with a sliding window of at least 1 000 ms but no longer than 1 500 ms. A graphical representation of this set of rules is shown in Figure 32.

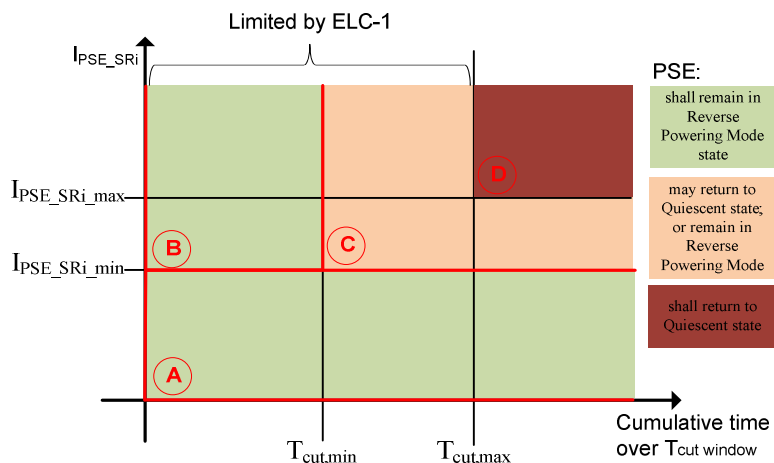


Figure 32: Graphical representation of Note 2 in Table 38

7.5.1.2 PSE isolation requirements

The PSE shall provide isolation between the U-R2P/U-R interface and earth. The isolation shall at least comply to either clause 6.1.2.1 of CENELEC EN 60950-1 [2] or clause 5.4.11.2 of CENELEC EN 62368-1 [9]. The exclusions listed in clause 6.1.2.2 of CENELEC EN 60950-1 [2] and clause 5.4.11.1 of CENELEC EN 62368-1 [9] do not apply.

Additionally, the DC resistance between earth and the U-R2P/U-R interface, whereby both TIP and RING are shorted at U-R/U-R2P, shall exceed 2 M Ω , measured at a test voltage of 100 Vdc and -100 Vdc. During this measurement, the PSE shall be unpowered and standalone, i.e. it shall not be connected to a DPU. This measurement procedure is illustrated in Figure 33. Furthermore, if surge suppressors are used, the absolute value of the test voltage shall be set to a value 10 % below the striking or operating voltage of the surge suppressor, up to a maximum test voltage of 100 Volts.

NOTE 1: The exclusions listed in clause 6.1.2.2 of CENELEC EN 60950-1 [2] and clause of 5.4.11.1 of CENELEC EN 62368-1 [9] refer to equipment that complies to any of the following:

- is permanently connected equipment or pluggable equipment type B;
- is equipment intended to be installed by a service person and has instructions to be connected to a socket-outlet with protective earthing connection; or
- has provision for a permanently connected protective earthing conductor together with instructions for installation of that conductor.

NOTE 2: If a PSE has surge suppressors between U-R2P/U-R and earth, with a striking or operating voltage which is less than or equal to 100 V, this voltage should be listed in the PSE documentation.

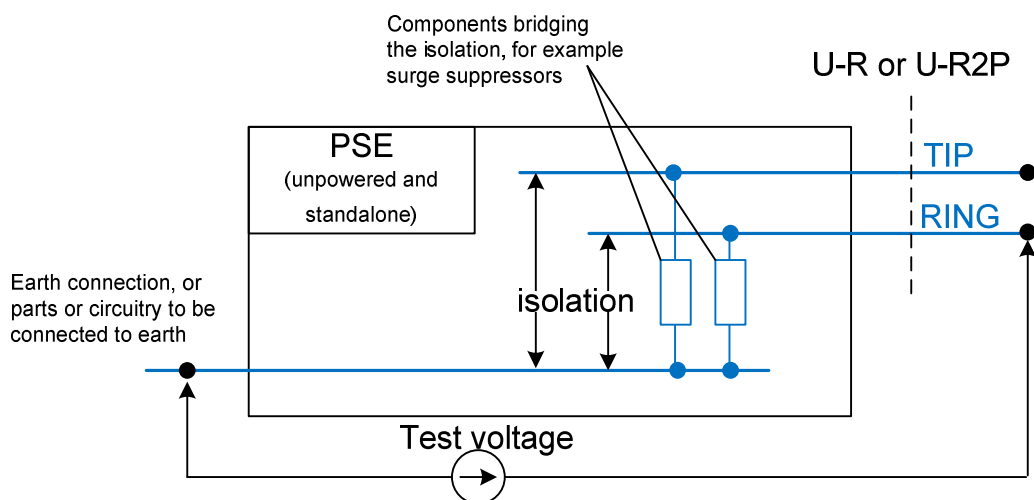


Figure 33: DC resistance between Earth and U-R/U-R2P

7.5.1.3 PSE Touch Current Limitation

The Touch Current from a PSE, powered from the AC Mains, towards the U-R/U-R2P interface, measured as per clause 5.1.8.2 of CENELEC EN 60950-1 [2], shall not exceed 0,0729 mA rms.

Alternatively, the Touch Current from a PSE, powered from the AC Mains, towards the U-R/U-R2P interface, measured as per clause 5.7.6.2 of CENELEC EN 62368-1 [9], shall not exceed 0,0729 mA rms.

7.5.1.4 PSE Power Frequency Common mode immunity

Common mode disturbance at fundamental power frequencies (50 or 60 Hz) can be injected on telecommunications lines by the PSE, multiport DPU implementations can add up such disturbances. Therefore, the PSE shall provide immunity against such common mode disturbances on the twisted pair.

The PSE shall be able to continue to operate in both normal mode and start-up, and in particular the PSE shall perform MDSU detection and MDSU classification compliant to clause 6.2, in presence of common disturbances generated by the disturbance generator as depicted in Figure 34, while the disturbance generator is coupled to the U-R interface via the coupling network as shown in Figure 34. The electrical specifications of the disturbance generator and the coupling circuit shall be as defined in Table 39.

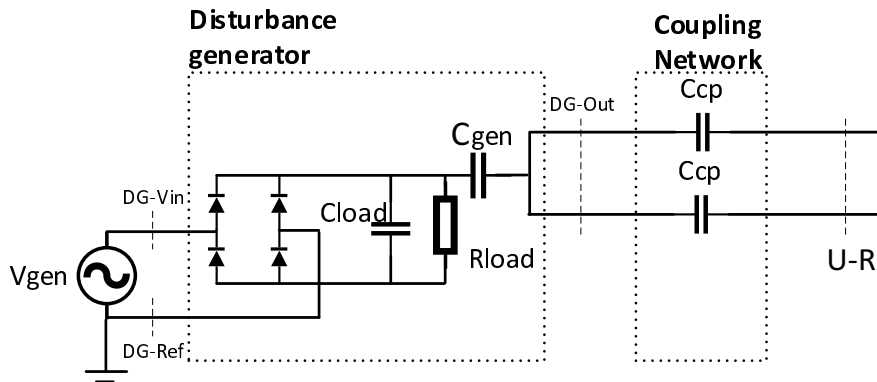


Figure 34: Disturbance generator and coupling circuit

Table 39: Disturbance generator and coupling circuit electrical specifications

Parameter	Symbol	Unit	Min	Max	Comments
Disturbance generator rms Voltage at DG-Vin/DG-Ref	V_{GEN}	Vac,rms	240		See note
Disturbance generator Frequency at DG-Vin/DG-Ref	f_{GEN}	Hz	47	63	
Phase delta between disturbance generator and PSE Mains supply	$\Delta\theta_{GEN}$	degrees	175	185	
Disturbance generator load capacity	C_{load}	μF	86		
Disturbance generator load resistance	R_{load}	kOhm		4	
Disturbance generator output capacitance	C_{gen}	nF	74		
Coupling Capacitance	C_{cp}	nF	198	242	
NOTE: Values for regions with a deviating AC Mains voltage are for further study.					

7.5.2 DPU electrical specification

7.5.2.1 Reach Resistance definition

The reach resistance of a DPU, $R_{reach,dpu}$, is the maximum loop resistance, including all series elements, between the U-O and the U-R2P interface for PSEs with an external power splitter, and between the U-O and the U-R interface for PSEs with an internal power splitter, through which the DPU can be powered by any amount of users, including a single user, while providing service to all those users or the single user, without exceeding the maximum continuous input current for the RPF class in question for any user. $R_{reach,dpu}$ shall be determined using the minimum continuous output current, $I_{PSE,SRi,min}$ and the minimum steady state output voltage, $V_{PSE,min}$, for the RPF class off the DPU.

Whereby, the Loop resistance, R_{loop} , is defined as the total DC resistance measured between the two conductors at one reference point while shorting the other two conductors at the other reference point:

- Loop resistance between U-O and U-RP2 is illustrated in Figure 35.
- Loop resistance between U-O and U-R is illustrated in Figure 36.

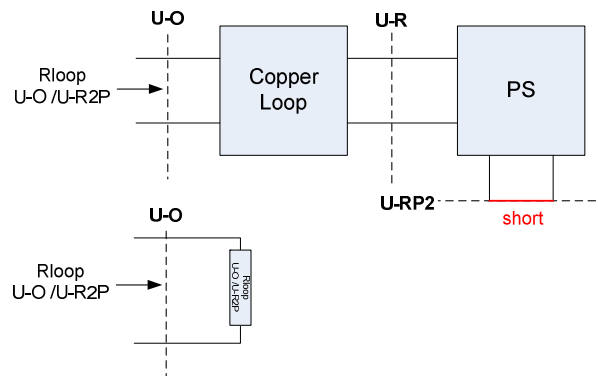


Figure 35: Loop resistance U-R2P to U-O interface

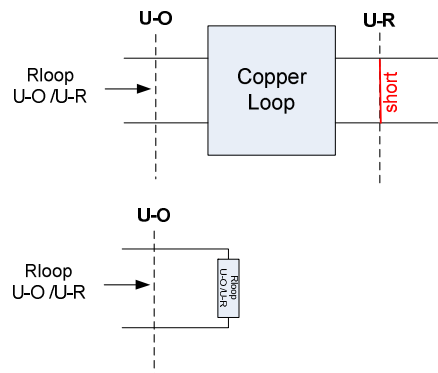


Figure 36: Loop resistance U-R to U-O interface

A DPU shall support a minimum reach resistance of 43Ω as defined in Table 34, in order to be compliant to the present document. Any element, such as a copper cable, a connector, an over-current protector, a power splitter, etc. placed between the U-O and the U-R2P interface for PSEs with external power splitter, and between the U-O and the U-R interface for PSEs with internal power splitter, shall consume part of the reach resistance budget. In case an element cannot be modelled as a resistance, the equivalent loop resistance of the element shall be used, which shall be determined while a current equal to $I_{PSE,SRi,min}$, for $i = 1,2,3$, is flowing through the element in question.

Table 40 calculates the supported loop length of a DPU with a reach resistance of 43Ω for various cable types, at a temperature of $21 \text{ }^\circ\text{C}$, in case a PSE with internal power splitter is used and the entire reach resistance is allocated to each cable type.

Table 40: Loop lengths for a loop resistance of 43Ω

Cable type	PE 0,4 mm	TP100/CAD55	PE 0,6 mm
Diameter	0,4 mm	0,5 mm	0,6 mm
Conductor material	Copper		
Resistivity of copper at $21 \text{ }^\circ\text{C}$	$1,68655\text{E-}08 \Omega\text{m}$		
$R_{conductor_pm}$	$0,136 \Omega/\text{m}$	$0,086 \Omega/\text{m}$	$0,06 \Omega/\text{m}$
Minimum loop length	160 m	250 m	360 m

7.5.2.2 DPU electrical specification at U-O interface

Table 41 defines the DPU electrical specification at the U-O interface for RPFA-NOP, RPFA-DRP and RPFA-NOPBB.

Table 41: DPU electrical specification at U-O interface for RPFA-NOP, RPFA-DRP and RPFA-NOPBB

Parameter	Symbol	Unit	Min	Max	Comments
Maximum continuous input current in Power_ON state for RPF Class SR1	I_{DPU_SR1}	mA	N/A	161	(See note 1)
Maximum continuous input current in Power_ON state for RPF Class SR2	I_{DPU_SR2}	mA	N/A	241	
Maximum continuous input current in Power_ON state for RPF Class SR3	I_{DPU_SR3}	mA	N/A	336	
Maximum available continuous input power for Class SR1	$P_{DPU_UO_SR1}$	W	N/A	7,861	Max available continuous DPU input power if loop resistance is 43 Ω , (see note 2)
Maximum available continuous input power for Class SR2	$P_{DPU_UO_SR2}$	W	N/A	10,938	
Maximum available continuous input power for Class SR3	$P_{DPU_UO_SR3}$	W	N/A	13,877	
Maintain power signature current	I_{DPU_MPS}	mA	10	N/A	(See note 4)
DPU current time derivative	dI/dt_{DPU_lmt}	mA/ μ s	N/A	1	(See note 5)
<p>NOTE 1: The instantaneous input current at the U-O interface may exceed the maximum continuous input current at the U-O interface. However, the DPU shall guarantee that the instantaneous input current does not violate the PSE overload time limit as defined in Table 38.</p> <p>NOTE 2: In essence the DPU may not exceed the maximum continuous input current in Power_ON state for the RPF class in question. The input power limitation is a mere consequence of the loop resistance and the RPF class.</p> <p>NOTE 3: Electrical specifications of this table shall not apply to architectures which require POTS Adapters which might be powered by a PSE.</p> <p>NOTE 4: In order to maintain power supply from a PSE, the DPU shall sink a dc current equal to or above the Maintain Power Signature current, I_{DPU_MPS}, for a minimum duration of at least 75 ms with a repetition period of maximum 325 ms, e.g. when a PSE is operating on battery power and the DSL is in a low power link state.</p> <p>NOTE 5: In order to prevent false ELC-3 detections by a PSE, while it is reverse powering a port of a DPU the following applies to any port of a DPU, reverse powered by a PSE: In absence of fault conditions the time derivative of the current at the U-O interface, $d(I_{DPU_UO})/dt$, shall be below dI/dt_{DPU_lmt}. If $d(I_{DPU_UO})/dt$ exceeds dI/dt_{DPU_lmt}, the DPU shall sink a current lower than 25 mA for at least 4 ms, immediately or up to 1 ms later after violation of dI/dt_{DPU_lmt}. The diagram below illustrates these timing aspects. Under these conditions and in absence of any fault condition, the PSE shall continue to supply reverse power to the port in question of the DPU. Remark that at any given time the DPU shall not violate the PSE overload time limit as defined in Table 38. A $d(I_{DPU_UO})/dt$ greater than zero means an instantaneous power demand increase of a port of DPU. 25 mA is lower than the minimum current an off-hook phone will sink, if it is exposed to a voltage of at least $V_{PSE,min}$, according to the off-hook phone (ELC-3) model.</p> <div style="text-align: center;"> <p>Between t_1 and t_2 DPU current shall be less than 25mA, whereby</p> $t_2 - t_1 \geq 4ms$ $0s \leq t_1 - t_0 \leq 1ms$ </div>					

7.5.3 DPU power modes

The DPU shall be able to be configured on a per port basis to draw minimal power from a line, compliant to maintain power signature as defined in Table 41 when it is in PSE-on battery state, if sufficient power is available from other sources.

Note that TR-301 [4] specifies some recommendations with respect to the power sharing between lines.

7.6 Micro-interruption requirements

7.6.1 PSE micro-interruption requirements

Short loss of AC power in a typical power supply is regulated by IEC 61000-4-11 [6]. A RPF PSE powered from AC mains shall meet a 20 ms micro-interrupt time measured according to IEC 61000-4-11 [6]. For applications where a larger micro-interrupt time is required, the PSE should have battery backup or be powered from a mini-UPS.

7.6.2 DPU micro-interruption specification

There are three types of micro-interruptions. A type-1 micro-interruption is modelled as a temporary open circuit on both wires on the wire pair at the U-O interface, a type-2 as a temporary open circuit on the TIP wire at the U-O interface and a type-3 as a temporary open circuit on the RING wire at the U-O interface. For all three micro-interruption types, the temporary open circuit has a duration of $T_{\text{micro-int}}$ and the repetition period of the micro-interruption shall be $T_{\text{int_RR}}$, meaning that the time between two subsequent micro-interruptions shall be $T_{\text{int_RR}}$. Table 42 specifies these parameters.

A DPU shall be able to continue to operate in presence of micro-interruption of the type 1, 2 and 3 in the following two cases:

- One active line with reverse power and one micro-interruption.
- Two active lines with reverse power applying a synchronized micro-interruption on each line.

This criterion specifies the minimum guaranteed level of immunity against micro-interruptions on the twisted pair. In general, a DPU is most endangered by micro-interruptions when only one port is powered. Even in this case, the DPU shall provide the level of immunity as specified in Table 42. Typically when more than one port is powered, the level of immunity will be greater than as specified in Table 42.

Table 42: DPU micro-interruption parameters

Parameter	Symbol	T
Maximum micro-interruption duration	$T_{\text{micro-int}}$	10 ms
Minimum micro-interruption repetition period	$T_{\text{int_RR}}$	20 s

This criterion applies for a minimum reach resistance of 43 Ω or greater if claimed by the system.

8 Power Splitter Characteristics

8.1 General

The power splitters need to comply with the following general requirements in order to prevent interference of the reverse power feed voltage onto the DSL service, and possibly the POTS service, carried over the same copper pair:

- The DPU and the CPE power splitters shall have a high impedance at the frequencies used by the G.fast or VDSL2 signals to minimize the impact on the data transmission performance.

- When a POTS service is sharing the pair with reverse power feed, the DPU and the CPE power splitters shall have a high impedance at the frequencies used by the POTS signals to minimize the impact on the voice transmission performance.
- The presence of the DPU or CPE power splitter and the related PSE and PSU shall not degrade the longitudinal balance of the POTS transmission loop.
- When a POTS service is sharing the pair with reverse power feed, the DPU and the CPE power splitters shall be tolerant to some level of the ringing signal that may pass through the AC coupling capacitors of the POTS Adapter-E at the beginning of a ringing burst.
- The CPE power splitter shall have DC blocking capacitors on its DSL port, the U-R2 interface, if the DSL transceiver does not have a high DC resistance.

Power splitter classes are defined in clause 8.2 and power splitter use cases are defined in clause 8.3.

The power splitters need to comply with the following requirements to maintain a good performance of the reverse power feed function:

- The DPU power splitter shall have a low voltage drop such as to minimize the power loss when extracting the reverse power feed from the loop.
- The CPE power splitter shall have a low voltage drop such as to minimize the power loss when injecting the reverse power feed onto the loop.

Multiple cases need to be considered in order to cover all the deployment scenarios.

DPU configurations:

- DPU - case 1: No POTS service sharing the loop wiring (RPFA-NOP, RPFA-NOPBB or RPFA-DRP).
- DPU - case 2: With a POTS service from the exchange (RPFA-EXP or RPFA-EXPSW).
- DPU - case 3: With a derived POTS service sharing the wiring (RPFA-DRPSW).

CPE configurations:

- CPE - case 1: No POTS service sharing the loop wiring (RPFA-NOP, RPFA-NOPBB or RPFA-DRP).
- CPE - case 2: With a POTS service from the exchange (RPFA-EXP or RPFA-EXPSW).
- CPE - case 3: With a derived POTS service sharing the wiring (RPFA-DRPSW).

8.2 Power Splitter class definition

Table 43 defines a set of Power Splitter (PS) classes to guarantee compatibility with broadband access services between the U-O2 and U-R2 interface, through the U-O and U-R interface.

All AC electrical specifications for power splitters for the paths from the U-O2 to the U-O interface, from the U-O to the U-O2 interface, from the U-R2 to the U-R interface and from U-R to the U-R2 interface, shall be applicable between $f_{\min,ps}$ and $f_{\max,ps}$.

The requirements of Table 43 shall only apply to standalone power splitter devices which are not integrated in the DPU or CPE devices.

Table 43: Power Splitter Class Definitions

Class	$f_{min,ps}$	$f_{max,ps}$	Compatible with service between U-O2 and U-R2 interface	Reverse Power Feed Architecture (see clause 5)
Class VP	50 Hz	30 MHz	derived POTS All ADSLx annexes [i.9] All VDSL2 annexes [i.3]	RPFA-EXP RPFA-EXPSW RPFA-DRP RPFA-DRPSW
Class VA	25 kHz	30 MHz	ADSLx Annexes A, B, L, M [i.9] ADSLx Annexes I, J [i.9] VDSL2 Annex B [i.3], all types	RPFA-NOP, RPFA-NOPBB
Class VB	120 kHz	30 MHz	ADSLx Annex B [i.9] VDSL2 Annex B [i.3], with no US0 or with US0 type B	RPFA-NOP, RPFA-NOPBB
Class GP	50 Hz	106 MHz	derived POTS All ADSLx annexes [i.9] All VDSL2 annexes [i.3] G.fast [i.4] and [i.5] 106 MHz profile	RPFA-EXP RPFA-EXPSW RPFA-DRP RPFA-DRPSW
Class GA	25 kHz	106 MHz	ADSLx Annexes A, B, L, M [i.9] ADSLx Annexes I, J [i.9] VDSL2 Annex B [i.3], all types G.fast [i.4] and [i.5] 106 MHz profile	RPFA-NOP, RPFA-NOPBB
Class GB	120 kHz	106 MHz	ADSLx Annex B [i.9] VDSL2 Annex B [i.3], with no US0 or with US0 type B G.fast [i.4] and [i.5] 106 MHz profile	RPFA-NOP, RPFA-NOPBB

8.3 Description of Power Splitter Use Cases

8.3.1 General

Clauses 8.3.2 through 8.3.7 describe the various use cases for the DPU and the CPE power splitters. The figures in these clauses (Figure 37 through Figure 42) illustrate the case of the standalone power splitter and may not directly represent an integrated solution.

8.3.2 DPU - case 1: No POTS service sharing the loop wiring

Figure 37 shows the internal structure of the DPU power splitter used for the RPFA-NOP, RPFA-NOPBB and RPFA-DRP (using separate wiring) applications. The low-pass function is represented by two inductors, but this shall not be seen as precluding the use of an active circuit. The optional K1 relay is used to support the remote copper reconfiguration feature. The U-O2 interface is shown as a direct connection to the copper pair going to the DPU DSL transceiver. This assumes the presence of a high-pass function including DC blocking capacitors, in the G.fast or VDSL2 transceiver in order to prevent applying a low DC impedance across the reverse power feed voltage.

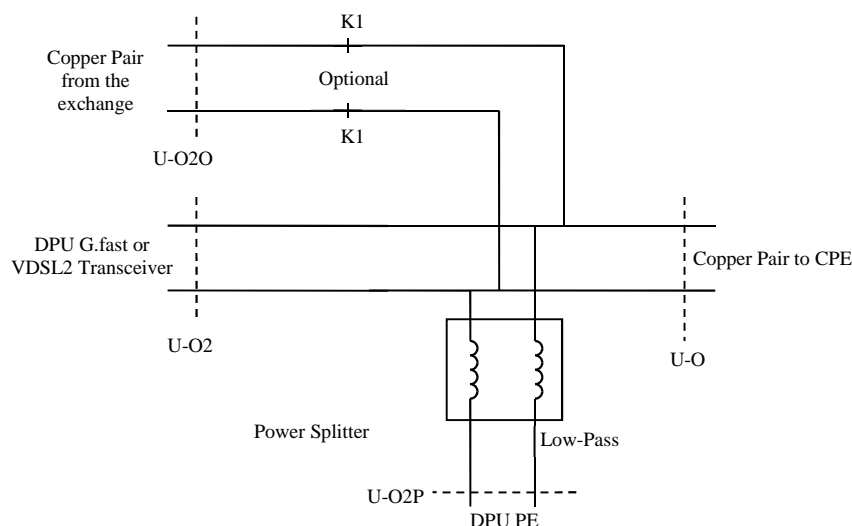


Figure 37: DPU Power Splitter without POTS on the same Pair

When using the optional remote copper reconfiguration feature, the exchange may provide a POTS service and a legacy ADSL or VDSL service prior to the activation of the new G.fast, or VDSL2 service using reverse power feed to the DPU. This zero-touch deployment scenario allows the network operator to fully equip the DP location while continuing to operate the POTS and legacy ADSL service until such time that the subscriber signs up for the new service. In this configuration, a power splitter is installed at the DPU but there is no POTS Adapter needed on the POTS line from the exchange because the POTS service from the exchange is discontinued upon installing the new CPE equipment. The optional relay K1 is used to disconnect the U-O2O port upon detecting the presence of reverse power feed on the U-O port. Due to the complete disconnect of the exchange copper pair when relay K1 is operated, a service splitter is not required to protect the G.fast service.

8.3.3 DPU - case 2: With POTS service from the exchange

Figure 38 shows the internal structure of the DPU power splitter used for the RPFA-EXP and RPFA-EXPSW applications. The U-O2 interface is shown as a direct connection to the copper pair going to the DPU DSL transceiver, this assumes the presence of a high-pass function including DC blocking capacitors, in the G.fast or VDSL2 transceiver in order to prevent applying a low DC impedance across the reverse power feed voltage.

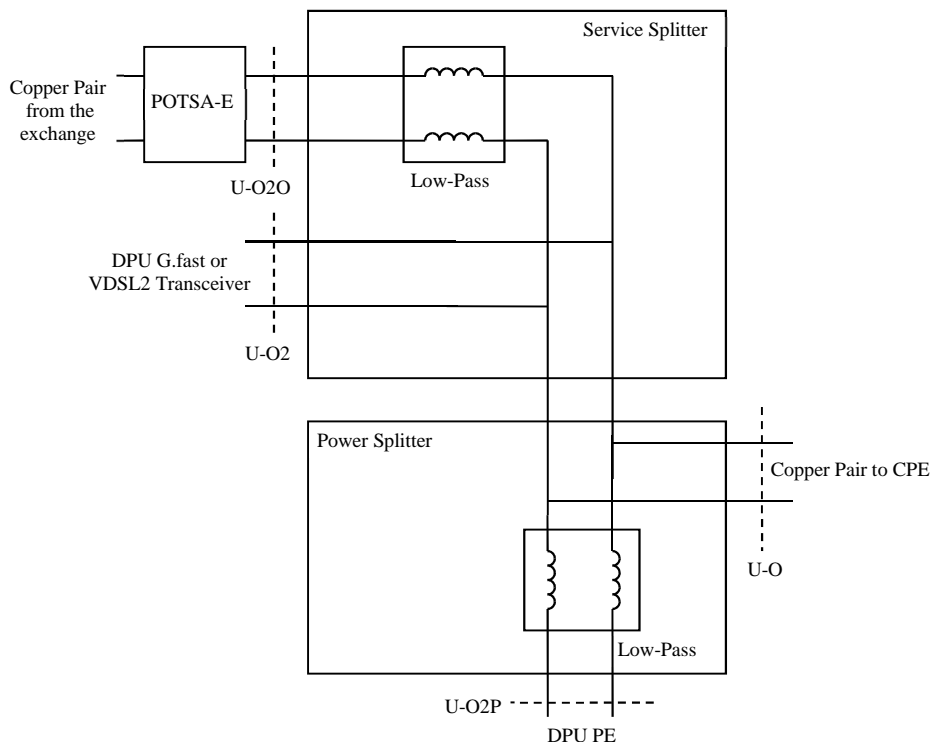


Figure 38: DPU Power Splitter with POTS from the Exchange

In this configuration, the POTS service continues to be provided by the exchange after the installation of the new G.fast, or VDSL2 service using reverse power feed to the DPU. A POTS Adapter-E is required on the POTS line from the exchange. The power splitter will be exposed to the POTS signals and the applicable POTS requirements are described in clauses 8.4.7, 8.4.8, 8.4.9, 8.4.11, 8.4.12 and 8.4.13. In this configuration, it is possible for the POTS Adapter-C, -D, or -E to switch to a bypass mode when access to local power is not available and a lifeline POTS service needs to be maintained. Therefore, the power splitter may need to comply with some POTS requirements even when reverse power feed is not applied to the loop.

The DPU POTS Adapter-E bypass mode may need to be supported even if there is no desire to support a lifeline POTS service during a power outage. This is because the bypass mode of the POTS Adapter-E can be used in a zero-touch deployment scenario to support the optional remote copper reconfiguration feature. For this reason, the power splitter needs to meet the POTS requirements of the optional bypass mode, even if the bypass mode will no longer be used after the service activation. On the other hand, the need to pass a legacy ADSL or VDSL signal has an impact on the specifications of the low-pass function located in the service splitter and introduces some additional requirements for the power splitter while in the pre-activation mode.

8.3.4 DPU - case 3: With a Derived POTS service sharing the wiring

Figure 39 shows the internal structure of the DPU power splitter used for the RPFA-DRPSW application.

The optional K1 relay is used to support the remote copper reconfiguration feature. The U-O2 interface is shown as a direct connection to the copper pair going to the DPU DSL transceiver, this assumes the presence of a high-pass function including DC blocking capacitors, in the G.fast or VDSL2 transceiver in order to prevent applying a low DC impedance across the reverse power feed voltage.

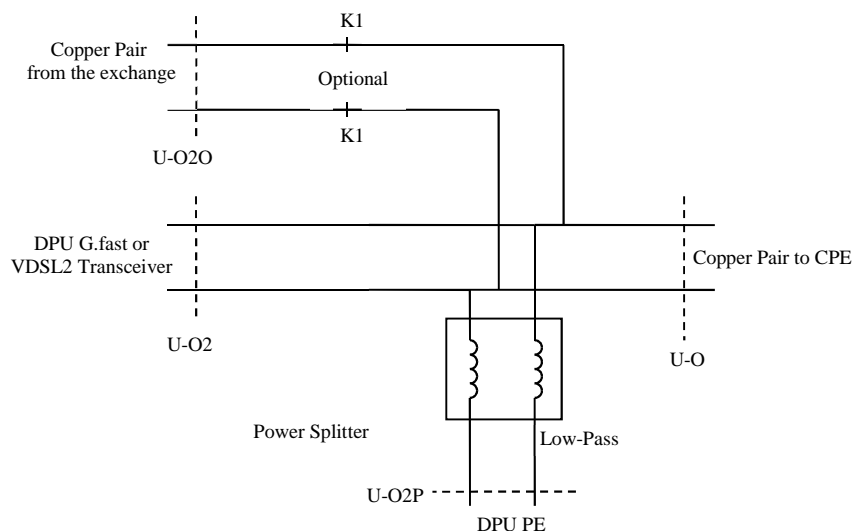


Figure 39: DPU Power Splitter with Derived POTS

The architecture is the same as clause 8.3.2, but the power splitter operational requirements are different from those of the DPU - case 1 due to the presence of the POTS signal on the shared copper pair after the activation of reverse power feed.

8.3.5 CPE - case 1: No POTS service sharing the loop wiring

Figure 40 shows the internal structure of the CPE power splitter used for the RPFA-NOP, RPFA-NOPBB and RPFA-DRP applications.

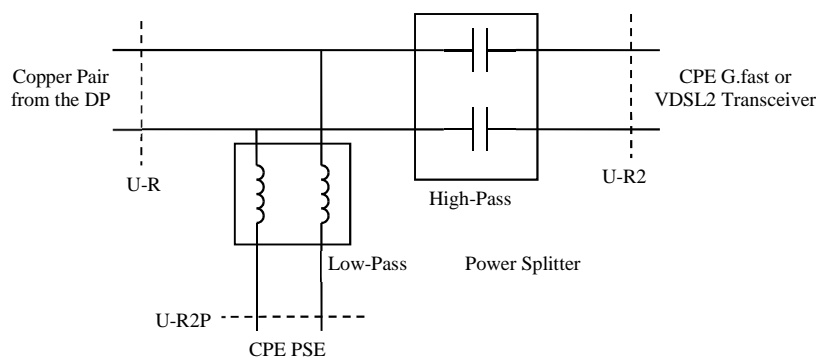


Figure 40: CPE Power Splitter without POTS on the same Pair

8.3.6 CPE - case 2: With POTS service from the exchange

Figure 41 shows the internal structure of the CPE power splitter used for the RPFA-EXP or RPFA-EXPSW applications. The POTS Adapter-C is always present with the RPFA-EXP configuration and may optionally be used with the RPFA-EXPSW configuration to provide a POTS port on the back of the CPE. The POTS Adapter-D is used in series with every additional telephone when using the RPFA-EXPSW configuration.

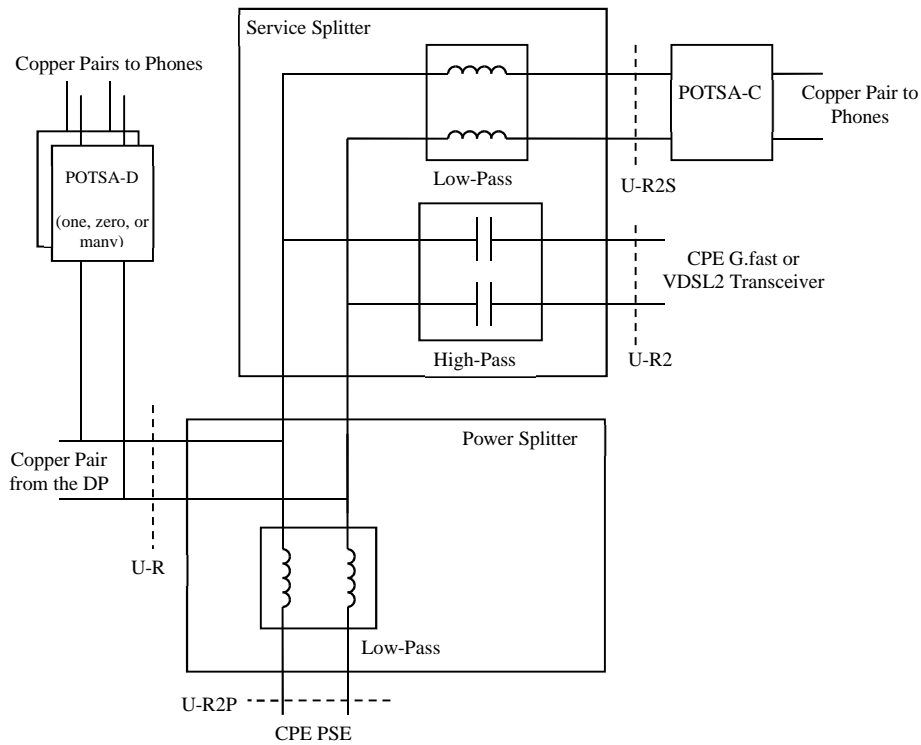


Figure 41: CPE Power Splitter with POTS from the Exchange

In this configuration, it is possible for the POTS Adapter-C, -D, or -E to switch to a bypass mode when access to local power is not available and a lifeline POTS service needs to be maintained. Therefore, the power splitter may need to comply with some POTS requirements when reverse power feed is not applied to the loop.

8.3.7 CPE - case 3: With a derived POTS service sharing the wiring

Figure 42 shows the internal structure of the CPE power splitter used for the RPFA-DRPSW application.

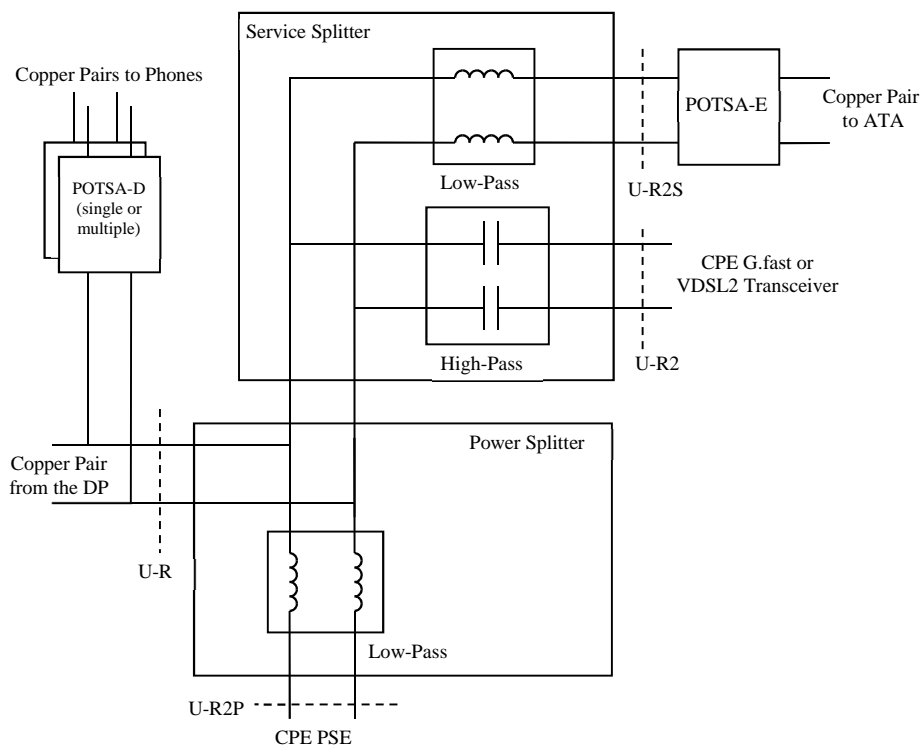


Figure 42: CPE Power Splitter with Derived POTS Sharing the in-premises Wiring

8.4 Power Splitter Requirements

8.4.1 General

The requirements in this clause are applicable to power splitters and need to be complied with in order to ensure correct operation of RPF, DSL and POTS services. It is recognized that where the power splitter is integrated into a DPU or CPE that it will not be feasible to test to all requirements in the complete system, however all requirements should be met in the design of the power splitter based on the test setups shown.

8.4.2 DSL Insertion Loss

Table 44 defines the DSL Insertion losses in Normal mode measured at the U-R interface for the DPU and CPE cases defined in clause 8.1.

The DPU power splitter DSL insertion loss is measured by comparing the DSL signal level at the U-O interface with and without the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces.

The CPE power splitter DSL insertion loss is measured by comparing the DSL signal level at the U-R2 interface with and without the CPE power splitter inserted between the U-R, U-R2P, U-R2S, and U-R2 interfaces.

The DSL insertion loss is measured with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 44: DSL Insertion Loss (Normal Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
25 kHz to 30 MHz	10 V peak per wire (see note 1)	±0,5 dB	±0,5 dB	±0,5 dB	±0,5 dB	±0,5 dB	±0,5 dB
30 MHz to 106 MHz	2,1 V peak per wire (see note 2)	±1 dB	±1 dB	±1 dB	±1 dB	±1 dB	±1 dB

NOTE 1: +20,5 dBm into 100 Ω with peak-to-rms voltage ratio = 6.
NOTE 2: +7 dBm into 100 Ω with peak-to-rms voltage ratio = 6.

When supporting the zero-touch deployment, the DPU power splitter will be exposed to the legacy DSL service prior to the activation of the new service. The DSL insertion loss is measured with idle reverse power feed, no power delivered to the U-O2P interface. Table 45 defines the DSL insertion losses in Bypass mode measured at the U-O2P interface for the DPU cases defined in clause 8.1.

Table 45: DSL Insertion Loss (Bypass Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
25 kHz to 2,2 MHz	10 V peak per wire (see note 1)	±0,5 dB	±0,5 dB	±0,5 dB	N/A	N/A	N/A
2,2 MHz to 30 MHz	2,5 V peak per wire (see note 2)	±0,5 dB	±0,5 dB	±0,5 dB	N/A	N/A	N/A

NOTE 1: +20,5 dBm into 100 Ω with peak-to-rms voltage ratio = 6.
NOTE 2: +8,4 dBm into 100 Ω with peak-to-rms voltage ratio = 6.

8.4.3 DSL Impedance Conversion

The DPU power splitter DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-O2 interface with the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces and with a reference 100 Ω load connected to the U-O interface.

The CPE power splitter DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-R interface with the CPE power splitter inserted between the U-R, U-R2P, U-R2S, and U-R2 interfaces and with a reference 100 Ω load connected to the U-R2 interface.

The DSL impedance conversion is measured with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 46 defines the impedance conversion in Normal mode required at the U-R interface for the DPU and CPE cases defined in clause 8.1.

Table 46: Impedance Conversion (Normal Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
25 kHz to 30 MHz	10 V peak per wire	> 20 dB	> 20 dB	> 20 dB	> 20 dB	> 20 dB	> 20 dB
30 MHz to 106 MHz	2,1 V peak per wire	> 14 dB	> 14 dB	> 14 dB	> 14 dB	> 14 dB	> 14 dB

When supporting the zero-touch deployment, the DPU power splitter will be exposed to the legacy DSL service prior to the activation of the new service. The DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-O2O interface with the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces and with a reference 100 Ω load connected to the U-O interface. This is measured with idle power feed, no power delivered to the U-O2P interface.

Table 47 defines the impedance conversion in Bypass mode required at the U-O2P interface for the DPU cases defined in clause 8.1.

Table 47: Impedance Conversion (Bypass Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
25 kHz to 2,2 MHz	10 V peak per wire	> 20 dB	> 20 dB	> 20 dB	N/A	N/A	N/A
2,2 MHz to 30 MHz	2,5 V peak per wire	> 20 dB	> 20 dB	> 20 dB	N/A	N/A	N/A

8.4.4 DSL-Band Noise Attenuation

The required DSL-band noise attenuation of the power splitter is a function of the DSL-band noise produced by the PSE, and needs to ensure compliance with the noise PSD mask defined in Table 35.

8.4.5 DSL Port DC Isolation Resistance

The CPE power splitter shall provide DC isolation on the DSL port to protect the reverse power feed function from a possible fault in the DSL transceiver. The DC isolation is measured on the U-R interface when shorting both wires to ground at the U-R2 interface and leaving the U-R2P and U-R2S interfaces open-circuit.

The DSL port isolation resistance requirements are defined in Table 48. This is measured between both wires and from any wire to ground with idle reverse power feed; no power is delivered to the U-R interface.

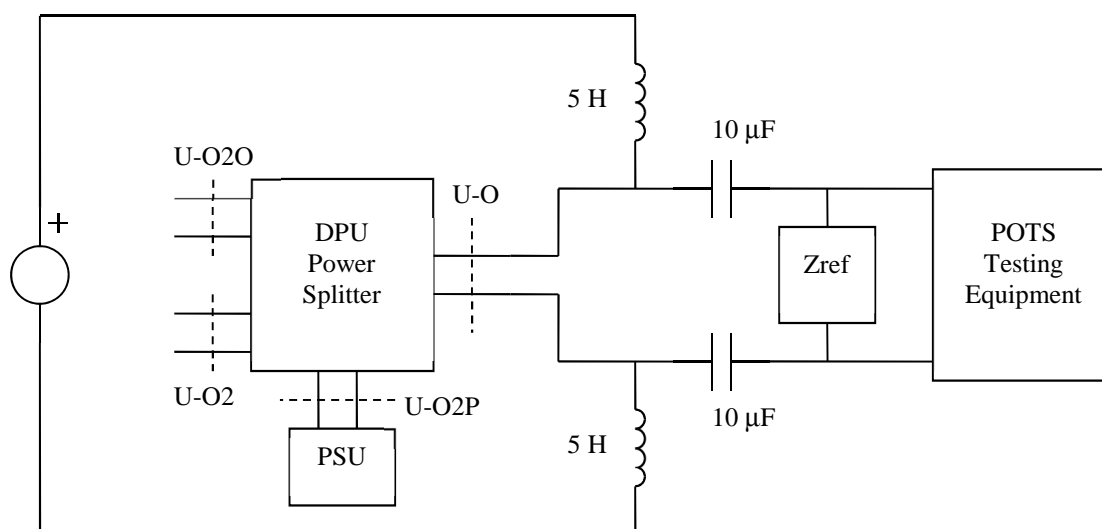
Table 48: DSL Port Isolation Resistance

Measurement Voltage	DPU Power Splitter			CPE Power Splitter		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
250 V	N/A	N/A	N/A	> 1 M Ω	> 1 M Ω	> 1 M Ω

8.4.6 POTS Measurement Procedure

Figure 43 and Figure 44 show the procedures to measure the characteristics of the DPU or CPE power splitter in terms of POTS performance.

In Figure 43, the 5H inductors are used to inject the current required to properly bias the DPU power splitter and operate the PSU. The external voltage source is adjusted to obtain the desired current.

**Figure 43: Testing of DPU Power Splitter POTS Characteristics**

In Figure 44, the 10H inductor is used to provide a path for the current delivered by the PSE and properly bias the CPE power splitter. The resistor is adjusted to obtain the desired current.

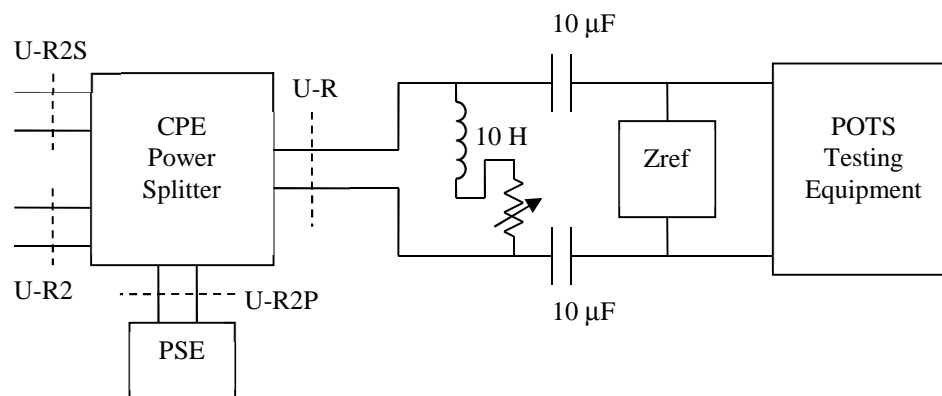


Figure 44: Testing of CPE Power Splitter POTS Characteristics

8.4.7 POTS Insertion Loss

The DPU power splitter POTS insertion loss is measured by comparing the POTS signal level at the U-O interface with and without the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces and with a reference POTS impedance connected to the U-O interface.

The CPE power splitter POTS insertion loss is measured by comparing the POTS signal level at the U-R interface with and without the CPE power splitter inserted between the U-R, U-R2P, U-R2S and U-R2 interfaces and with a reference POTS impedance connected to the U-R interface.

The POTS insertion loss is measured with the ETSI harmonized reference impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 49 and Table 50 define the POTS insertion loss requirements for the normal mode of operation measured at the U-R interface and U-O2P interfaces respectively for the DPU and CPE cases defined in clause 8.1.

Table 49: POTS Insertion Loss (Normal Mode)

Reference Loss Frequency	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
1 020 Hz	5 Vpp differential (see note)	N/A	0 dB to -0,5 dB	0 dB to -0,5 dB	N/A	0 dB to -0,5 dB	0 dB to -0,5 dB

NOTE: +5,7 dBm into the ETSI harmonized impedance [7] at 1 020 Hz, sinewave.

Table 50: POTS Insertion Loss Variation (Normal Mode) wrt 1 020 Hz

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
300 Hz to 3,4 kHz	5 Vpp differential (see note)	N/A	$\pm 0,5$ dB	$\pm 0,5$ dB	N/A	$\pm 0,5$ dB	$\pm 0,5$ dB

NOTE: +5,7 dBm into the ETSI harmonized impedance [7] at 1 020 Hz, sinewave.

When supporting the zero-touch deployment or the POTS Adapter bypass mode, the DPU power splitter will be exposed to the POTS signal. Similarly, the CPE power splitter will be exposed to the POTS signal when supporting the POTS Adapter bypass mode. The POTS insertion loss is measured with idle power feed, no power delivered to the U-O2P and U-R interfaces.

Table 51 and Table 52 define the POTS insertion loss requirements for the bypass mode of operation measured at the U-R interface and U-O2P interfaces respectively for the DPU and CPE cases defined in clause 8.1.

Table 51: POTS Insertion Loss (Bypass Mode)

Frequency	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
1 020 Hz	5 Vpp differential (see note)	0 dB to -0,5 dB	0 dB to -0,5 dB	0 dB to -0,5 dB	N/A	0 dB to -0,5 dB	N/A

NOTE: +5,7 dBm into the ETSI harmonized impedance [7] at 1 020 Hz, sinewave.

Table 52: POTS Insertion Loss Variation (Bypass Mode) wrt 1 020 Hz

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
300 Hz to 3,4 kHz	5 Vpp differential (see note)	±0,5 dB	±0,5 dB	±0,5 dB	N/A	±0,5 dB	N/A

NOTE: +5,7 dBm into the ETSI harmonized impedance [7] at 1 020 Hz, sinewave.

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band insertion loss variation with frequency over a wider bandwidth going up to 6,8 kHz or more.

8.4.8 POTS Impedance Conversion

The DPU power splitter POTS impedance conversion is measured by performing a 2-wire return loss measurement at the U-O interface with the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces and with a reference POTS impedance connected to the U-O interface.

The CPE power splitter POTS impedance conversion is measured by performing a 2-wire return loss measurement at the U-R interface with the CPE power splitter inserted between the U-R, U-R2P, U-R2S and U-R2 interfaces and with a reference POTS impedance connected to the U-R interface.

The POTS impedance conversion is measured with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 53 defines the POTS impedance conversion requirements for normal mode of operation for the DPU and CPE cases defined in clause 8.1.

Table 53: POTS Impedance Conversion (Normal Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
200 Hz to 300 Hz	5 Vpp differential	N/A	> 12 dB	> 12 dB	N/A	> 12 dB	> 12 dB
300 Hz to 500 Hz	5 Vpp differential	N/A	> 14 dB	> 14 dB	N/A	> 14 dB	> 14 dB
500 Hz to 2 kHz	5 Vpp differential	N/A	> 18 dB	> 18 dB	N/A	> 18 dB	> 18 dB
2 kHz to 3,8 kHz	5 Vpp differential	N/A	> 14 dB	> 14 dB	N/A	> 14 dB	> 14 dB

When supporting the zero-touch deployment or the POTS Adapter bypass mode, the DPU power splitter will be exposed to the POTS signal. Similarly, the CPE power splitter will be exposed to the POTS signal when supporting the POTS Adapter bypass mode. The POTS impedance conversion is measured with idle power feed, no power delivered to the U-O2P and U-R interfaces.

Table 54 defines the POTS impedance conversion requirements for bypass mode of operation for the DPU and CPE cases defined in clause 8.1.

Table 54: POTS Impedance Conversion (Bypass Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
200 Hz to 300 Hz	5 Vpp differential	> 12 dB	> 12 dB	> 12 dB	N/A	> 12 dB	N/A
300 Hz to 500 Hz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	N/A	> 14 dB	N/A
500 Hz to 2 kHz	5 Vpp differential	> 18 dB	> 18 dB	> 18 dB	N/A	> 18 dB	N/A
2 kHz to 3,8 kHz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	N/A	> 14 dB	N/A

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band impedance conversion over a wider bandwidth going up to 6,8 kHz or more.

8.4.9 POTS-band longitudinal Balance

The DPU power splitter POTS-band longitudinal balance is measured by measuring the longitudinal balance at the U-O interface with the DPU power splitter inserted between the U-O2, U-O2O, U-O2P, and U-O interfaces and with a reference POTS impedance connected to the U-O interface.

The CPE power splitter POTS-band longitudinal balance is measured by measuring the longitudinal balance at the U-R interface with the CPE power splitter inserted between the U-R2, U-R2S, U-R2P, and U-R interfaces and with a reference POTS impedance connected to the U-R interface.

Table 55 defines the POTS longitudinal balance requirements for normal mode of operation for the DPU and CPE cases defined in clause 8.1.

Table 55: POTS longitudinal Balance (Normal Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
50 Hz	5 Vpp differential	N/A	> 40 dB	> 40 dB	N/A	> 40 dB	> 40 dB
200 Hz to 600 Hz	5 Vpp differential	N/A	> 40 dB	> 40 dB	N/A	> 40 dB	> 40 dB
600 Hz to 3,8 kHz	5 Vpp differential	N/A	> 46 dB	> 46 dB	N/A	> 46 dB	> 46 dB

When supporting the zero-touch deployment or the POTS Adapter bypass mode, the DPU power splitter will be exposed to the POTS signal. Similarly, the CPE power splitter will be exposed to the POTS signal when supporting the POTS Adapter bypass mode. The POTS-band longitudinal balance is measured with idle power feed, no power delivered to the U-O2P and U-R interfaces.

Table 56 defines the POTS longitudinal balance requirements for bypass mode of operation for the DPU and CPE cases defined in clause 8.1.

Table 56: POTS Longitudinal Balance (Bypass Mode)

Frequency Band	Signal Level	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
50 Hz	5 Vpp differential	> 40 dB	> 40 dB	N/A	N/A	> 40 dB	> 40 dB
200 Hz to 600 Hz	5 Vpp differential	> 40 dB	> 40 dB	N/A	N/A	> 40 dB	> 40 dB
600 Hz to 3,8 kHz	5 Vpp differential	> 46 dB	> 46 dB	N/A	N/A	> 46 dB	> 46 dB

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band longitudinal balance over a wider bandwidth going up to 6,8 kHz or more.

8.4.10 POTS-band Noise Attenuation

The required POTS-band noise attenuation of the power splitter is a function of the POTS-band noise produced by the PSE and needs to ensure an idle channel noise lower than -80 dBmP.

8.4.11 POTS DC Isolation Resistance

This requirement applies to any terminal connected to an exchange line as per ETSI ES 203 021 [3].

In the case of a zero-touch deployment, the DPU power splitter is present on the POTS line prior to activating the new service. The DPU power splitter DC isolation resistance is measured at the U-O2O interface when configured for the legacy service and with an open-circuit on the U-O and U-O2 interfaces.

In the case of a POTS service from the exchange, the same is required to support the POTS Adapter bypass mode when reverse power feed is turned off.

In the case of a POTS service from the exchange, the CPE power splitter will be present on the POTS line when reverse power feed is not available and the POTS Adapters have switched to their bypass mode. The CPE power splitter DC isolation resistance is measured at the U-R interface and with an open-circuit on the U-R2S and U-R2 interfaces.

Table 57 defines the POTS DC isolation resistance requirements for DPU and CPE power splitters as defined in clause 8.1.

The DC isolation resistance in bypass mode is measured with idle reverse power feed; no power delivered to the U-R and U-O2P interfaces.

Table 57: POTS DC Isolation Resistance (Bypass Mode)

Measurement Voltage	Test Condition	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
100 V	Both wires shorted together, and measured with respect to earth ground	> 40 MΩ	> 40 MΩ	> 40 MΩ	N/A	> 40 MΩ	N/A
100 V	Between both wires	> 4 MΩ	> 4 MΩ	> 4 MΩ	N/A	> 4 MΩ	N/A

8.4.12 Tolerance to DC Feed

When in the non-activated state, the power splitters can be exposed to a POTS DC feed voltage on the copper loop. The power splitters shall be operational across the full span of the POTS DC feed voltage.

In the case of a zero-touch deployment, the DC feed voltage will be present onto the loop when operating the legacy service. In the case of a POTS service from the exchange, the DC feed voltage will be present in the POTS Adapter bypass mode.

During the application of a POTS DC feed voltage and while in the on-hook state, one wire will be close to ground, the other one will be close to battery. While in the off-hook state, the battery wire may move closer to ground, or both wires may simply move closer together toward mid-rail, or any other point, to perform current limiting.

Table 58 defines the POTS DC isolation resistance requirements in bypass mode for DPU and CPE power splitters as defined in clause 8.1.

The power splitter compliance voltage range shall be measured with idle reverse power feed; no power delivered to the U-R and U-O2P interfaces.

Table 58: Power Splitter Compliance Voltage Range (Bypass Mode)

Specification	DPU Power Splitter			CPE Power Splitter		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Tip voltage range	0 V to -66 V	0 V to -66 V	0 V to -66 V	N/A	0 V to -66 V	N/A
Ring voltage range	0 V to -66 V	0 V to -66 V	0 V to -66 V	N/A	0 V to -66 V	N/A

8.4.13 Tolerance to Ringing

When in the non-activated state, the power splitters can be exposed to a ringing signal on the copper loop. The power splitters shall be operational across the full span of the ringing signal.

The ringing signal from the exchange line can be superimposed on the tip wire, the ring wire, or balanced on both wires (180 degrees out of phase) up to a level of 120 V_{rms} and at any frequency between 15 Hz and 55 Hz. A DC voltage between 0 V and -66 V may be present on the tip wire, the ring wire, or both simultaneous with the application of the ringing signal.

The ringing signal from a derived POTS service can be superimposed on the tip wire, the ring wire, or balanced on both wires (180 degrees out of phase) up to a level of 100 V_{rms} and at 25 Hz and at 50 Hz. A DC voltage between 0 V and ±60 V may be present on the tip wire, the ring wire, or both simultaneous with the application of the ringing signal.

In the case of a zero-touch deployment, when reverse power feed is not applied to the DPU, the ringing signal may be present up to 2 s consecutively and have a pause of no more than 2 s before starting a new cycle. The maximum DC current at the full ringing voltage and the AC impedance at the ringing frequency are measured with idle reverse power feed; no power delivered to the U-R and U-O2P interfaces. The CPE power splitter has no requirement in the case of zero-touch deployment because it is not installed prior to the service activation.

In the case of POTS from the exchange, the same condition applies to the DPU and CPE power splitters to support the POTS Adapter bypass mode when reverse power feed is turned off.

When operating with POTS from the exchange, or when operating with a derived POTS service, and when reverse power feed is present on the loop, the ringing signal may be present for 100 ms which is the maximum time for the DPU POTS Adapter-E to switch out the AC transmission capacitors. The residual ringing signal will be reduced to less than 1 Vrms after the DPU POTS Adapter-E removes the AC transmission capacitors. The maximum DC current at the full ringing voltage and the AC impedance at the ringing frequency are measured with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 59 defines the power Splitter tolerance to ringing requirements for DPU and CPE power splitters as defined in clause 8.1.

Table 59: Power Splitter Tolerance To Ringing

Parameter	Test Condition	DPU Power Splitter			CPE Power Splitter		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Maximum AC voltage	RPF idle	120 Vrms	120 Vrms	120 Vrms	N/A	120 Vrms	N/A
Maximum DC voltage	RPF idle	±66 V	±66 V	±66 V	N/A	±66 V	N/A
Maximum duration	RPF idle	2 s	2 s	2 s	N/A	2 s	N/A
Maximum DC current drain	RPF idle	< 0,6 mA	< 0,6 mA	< 0,6 mA	N/A	< 0,6 mA	N/A
AC impedance	RPF idle	> 25 kΩ	> 25 kΩ	> 25 kΩ	N/A	> 25 kΩ	N/A
Maximum AC voltage	RPF active	N/A	120 Vrms	100 Vrms	N/A	120 Vrms	100 Vrms
Maximum DC voltage	RPF active	N/A	±66 V	±60 V	N/A	±66 V	±60 V
Maximum duration	RPF active	N/A	100 ms	100 ms	N/A	100 ms	100 ms
Maximum DC current drain	RPF active	N/A	< 3 mA	< 3 mA	N/A	< 3 mA	< 3 mA
AC impedance	RPF active	N/A	> 5 kΩ	> 5 kΩ	N/A	> 5 kΩ	> 5 kΩ

8.4.14 Power Drain

The DPU power splitter shall limit the differential voltage drop from the U-O interface to the U-O2P interface. In the case of a DPU power splitter exposed to POTS, it is recognized that an active splitter will most certainly be used and that it will have to be located inside a diode bridge to be insensitive to the wiring polarity between the CPE and the DPU. An allocation has been made to this effect in the voltage drop values.

The CPE power splitter shall limit the differential voltage drop from the U-R2P interface to the U-R interface.

Table 60 and Table 61 show the power drain requirements for DPU and CPE power splitters as defined in clause 8.1 for normal and bypass modes of operation respectively.

Table 60: DPU and CPE Power Splitter Power Drain (Normal mode)

Power Splitter Current	DPU Power Splitter			CPE Power Splitter		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
< 250 mA	< 2 V	< 10,5 V	< 10,5 V	< 2 V	< 6 V	< 6 V
< 350 mA	< 3 V	< 11,5 V	< 11,5 V	< 3 V	< 7 V	< 7 V

In the case of a zero-touch deployment, when reverse power feed is not applied to the loop, the DPU power splitter shall limit the voltage drop from the U-O2O interface to the U-O interface. The same applies when the POTS Adapter-E is in the bypass mode.

Table 61: DPU and CPE Power Splitter Power Drain (Bypass Mode)

DC feed Current	DPU Power Splitter			CPE Power Splitter		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
< 100 mA	< 1 V	< 1 V	< 1 V	N/A	N/A	N/A

9 POTS Adapter Characteristics

9.1 Introduction

The POTS Adapters need to comply with the following general requirements in order to maintain the POTS service integrity while carrying the reverse power feed voltage over the same copper pair:

- Extract the DC feed and power ringing voltages and convert them to an out-of-band signalling method such that they can be communicated to the POTS Adapters located at the other end of the copper pair carrying the reverse power feed function.
- Extract the on-hook and off-hook DC signalling states and convert them to an out-of-band signalling method such that they can be communicated to the POTS Adapter located at the other end of the copper pair carrying the reverse power feed function.
- Decode the out-of-band signalling and regenerate the DC feed and power ringing voltages present at the other end of the copper pair carrying the reverse power feed function.
- Decode the out-of-band signalling and regenerate the on-hook and off-hook DC signalling states present at the other end of the copper pair carrying the reverse power feed function.
- Have a minimal impact on the AC transmission characteristics, whether in the on-hook or off-hook state.
- Detect and reproduce polarity reversal and open-feed intervals.
- Detect and reproduce any ringing frequency and cadence.
- Support on-hook transmission in both directions at any time including the silent intervals of a ringing cadence.
- Accurately reproduce the timing of on-hook and off-hook transitions to support dial pulsing telephones.
- Detect an off-hook applied by the telephone during the power cycle of ringing and autonomously remove the ringing signal. Communicate the presence of that off-hook state to the far-end POTS Adapter via the signalling channel.
- Full compliance with all implementations of caller ID services.
- When operating with a POTS service from the exchange, provide an optional bypass mode for lifeline service during power outages with transitions in and out of the bypass mode without dropping an on-going call.
- Provide a controlled rate of change in the current taken from the copper pair when reverse power feed is active and an off-hook is generated on one telephone (POTS Adapter-D only) to differentiate between telephones with and without adapters.
- The presence of the DPU or CPE POTS Adapters shall not degrade the longitudinal balance of the POTS transmission loop.

Multiple cases need to be considered in order to cover all the deployment scenarios.

DPU configurations:

- DPU - case 1: No POTS service sharing the loop wiring (RPFA-NOP, RPFA-NOPBB or RPFA-DRP).
- DPU - case 2: With a POTS service from the exchange (RPFA-EXP or RPFA-EXPSW).
- DPU - case 3: With a derived POTS service sharing the wiring (RPFA-DRPSW).

CPE configurations:

- CPE - case 1: No POTS service sharing the loop wiring (RPFA-NOP, RPFA-NOPBB or RPFA-DRP).
- CPE - case 2: With a POTS service from the exchange (RPFA-EXP or RPFA-EXPSW).
- CPE - case 3: With a derived POTS service sharing the wiring (RPFA-DRPSW).

9.2 Description of POTS Adapters Use Cases

9.2.1 General

Clauses 9.2.2 through 9.2.9 describe the various use cases for the DPU and the CPE POTS Adapters. Figure 45 through Figure 49 illustrate the case of the standalone POTS Adapter and may not directly represent an integrated solution.

9.2.2 DPU - case 1: No POTS service sharing the loop wiring

A DPU POTS Adapter is not required if no POTS service is provided.

A DPU POTS Adapter is not required if the DPU performs a switch over from the exchange POTS to a no POTS or to a derived POTS service using separate wiring after having detected the presence of reverse power feed in a zero-touch deployment scenario implementing the remote copper reconfiguration feature.

9.2.3 DPU - case 2: With a POTS service from the exchange - Adapter-E

In this configuration, a POTS Adapter-E is required at the DPU site if the POTS service continues to be provided from the exchange line after deploying the new G.fast or VDSL2 service with reverse power feed.

Figure 45 shows the internal structure of the DPU POTS Adapter-E used for the RPFA-EXP and RPFA-EXPSW applications.

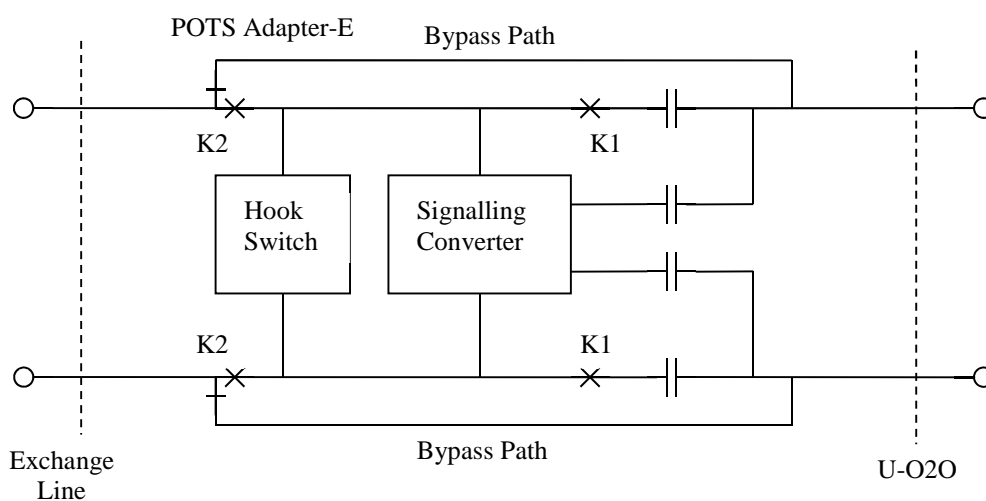


Figure 45: DPU POTS Adapter-E for POTS from the exchange

In Figure 45 the relay K1 cuts off the low frequency AC transmission path when a ringing signal is detected on the exchange line. The relay K2 provides a bypass mode allowing a lifeline POTS service during power interruptions for which the reverse power feed function is not maintained. This relay can be omitted if maintaining a lifeline service is not required. However, the same relay can also be used to implement the optional remote copper reconfiguration feature in a zero-touch deployment scenario.

9.2.4 DPU - case 3: With a derived POTS service sharing the wiring

A DPU POTS Adapter is not required if a derived POTS service is present on the same copper loop as the one used by the reverse power feed function.

A DPU POTS Adapter is not required if the DPU performs a switch over from the exchange POTS to a derived POTS service sharing the loop wiring after having detected the presence of reverse power feed in a zero-touch deployment scenario implementing the remote copper reconfiguration feature.

9.2.5 CPE - case 1: No POTS service sharing the loop wiring

A CPE POTS Adapter is not required if there is no POTS service sharing the copper loop used by the reverse power feed function.

9.2.6 CPE - case 2: With a POTS service from the exchange - Adapter-C

In this configuration, a POTS Adapter-C is required at the CPE site if the POTS service continues to be provided from the exchange line after deploying the new G.fast or VDSL2 service with reverse power feed and if a POTS port is located on the CPE modem. This condition applies to the RPFA-EXP use case and can optionally apply to the RPFA-EXPSW use case.

Figure 46 shows the internal structure of the CPE POTS Adapter-C used for the RPFA-EXP or RPFA-EXPSW applications.

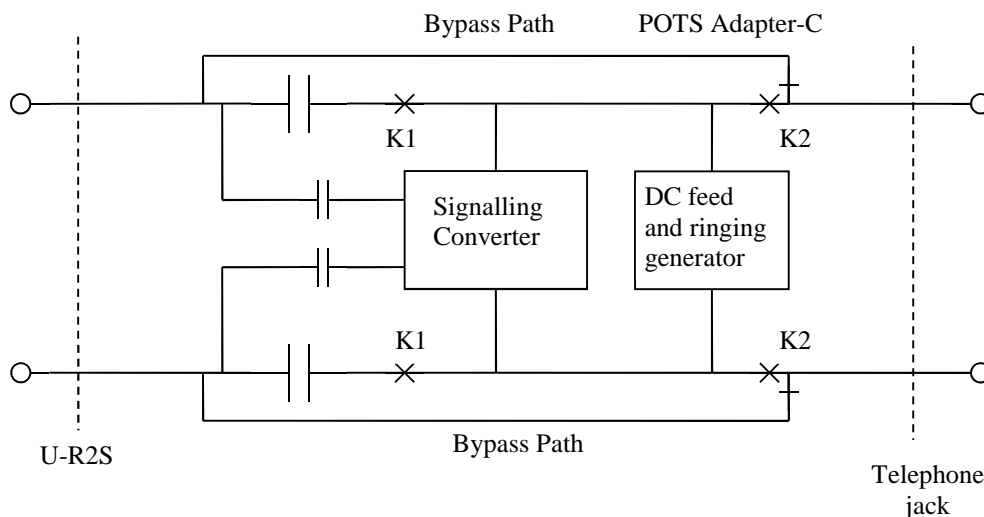


Figure 46: POTS Adapter-C for POTS from the exchange

In Figure 46, the relay K1 cuts off the low frequency AC transmission path when a ringing signal is generated on the telephone jack. Relay K2 provides a bypass mode allowing a lifeline POTS service during power interruptions for which the reverse power feed function is not maintained. This relay can be omitted if maintaining a lifeline service is not required.

9.2.7 CPE - case 2: With a POTS service from the exchange - Adapter-D

When providing a POTS service from the exchange, some POTS Adapter-D are also required at the CPE site if additional telephones are present, not being connected to the phone port of the CPE modem. One POTS Adapter-D is required for each additional telephone.

Figure 47 shows the internal structure of the CPE POTS Adapter-D used for the RPFA-EXPSW application.

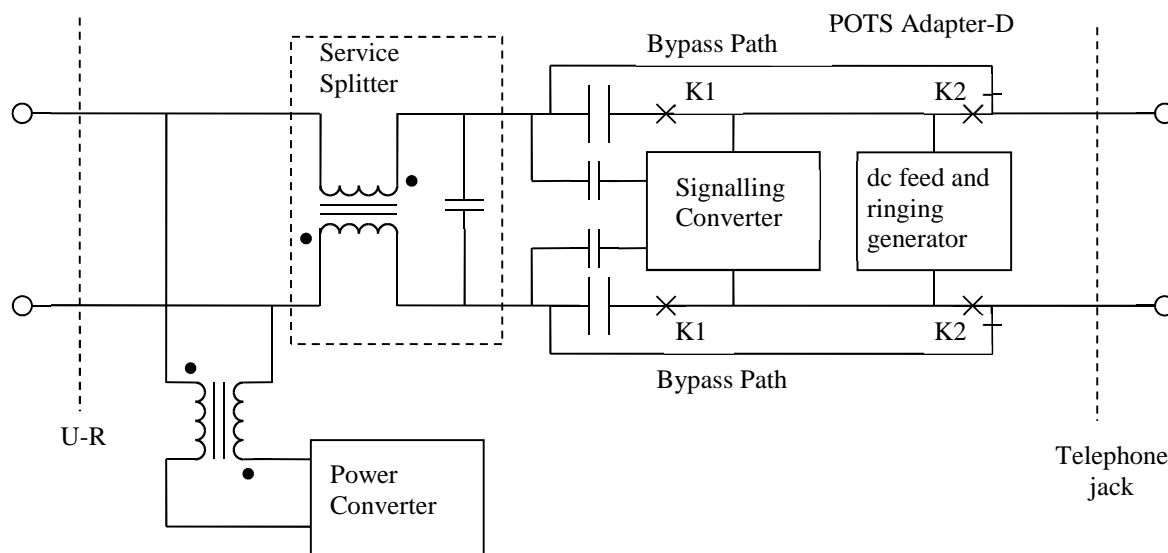


Figure 47: POTS Adapter-D for POTS from the exchange

In Figure 47, the relay K1 cuts off the low frequency AC transmission path when a ringing signal is generated on the telephone jack. Relay K2 provides a bypass mode allowing a lifeline POTS service during power interruptions for which the reverse power feed function is not maintained. This relay can be omitted if maintaining a lifeline service is not required.

The POTS Adapter-D, being a dongle inserted between the wall jack and the telephone, has no access to a local power source and shall extract its power from the reverse power feed present on the subscriber loop. To this effect it shall contain an equivalent of the power splitter to extract the DC power without affecting the POTS or DSL signal performance. Similarly, it shall also include an equivalent of the service splitter to avoid exposing the telephone to the DSL signal and to avoid loading the DSL signal with the POTS impedance.

9.2.8 CPE - case 3: With derived POTS sharing the wiring - Adapter-D

Figure 48 shows the internal structure of the CPE POTS Adapter-D used for the RPFA-DRPSW application.

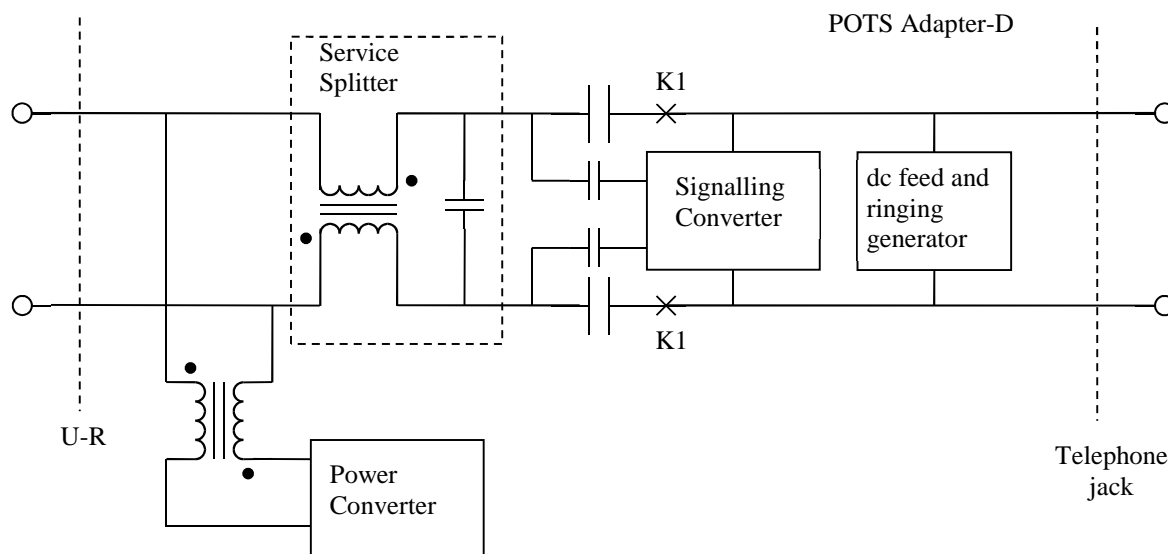


Figure 48: POTS Adapter-D for derived POTS from an ATA

In Figure 48, the relay K1 cuts off the low frequency AC transmission path when a ringing signal is generated on the telephone jack.

The POTS Adapter-D, being a dongle inserted between the wall jack and the telephone, has no access to a local power source and shall extract its power from the reverse power feed present on the subscriber loop. To this effect it shall contain an equivalent of the power splitter to extract the DC power without affecting the POTS or DSL signal performance. Similarly, it shall also include an equivalent of the service splitter to avoid exposing the telephone to the DSL signal and to avoid loading the DSL signal with the POTS impedance.

9.2.9 CPE - case 3: With derived POTS sharing the wiring - Adapter-E

Figure 49 shows the internal structure of the CPE POTS Adapter-E used for the RPFA-DRPSW application.

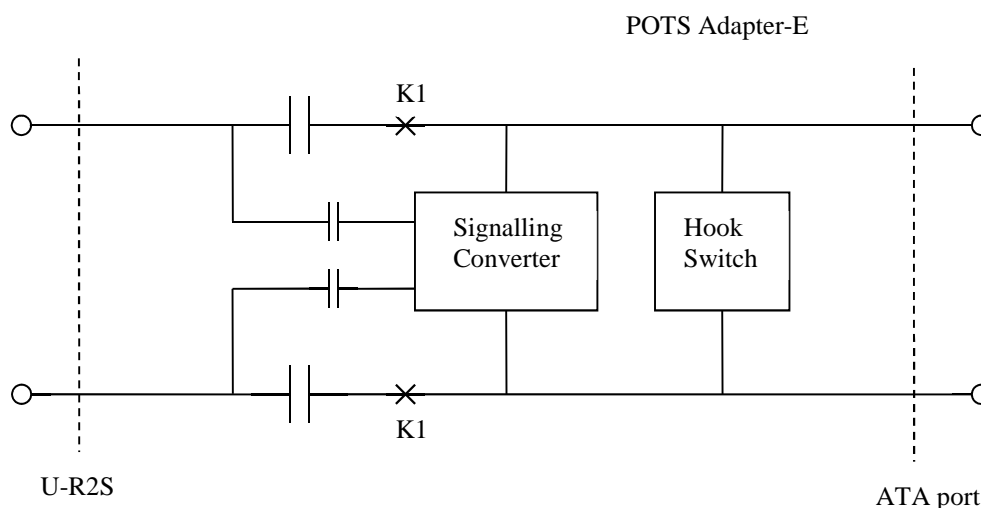


Figure 49: POTS Adapter-E for derived POTS from an ATA

In Figure 49, the relay K1 cuts off the low frequency AC transmission path when a ringing signal is detected on the ATA port.

9.3 POTS Adapter Requirements

9.3.1 General

The requirements in this clause are applicable to POTS Adapters and need to be complied with in order to ensure correct operation of RPF, DSL and POTS services. It is recognized that where the POTS Adapter is integrated into a DPU or CPE it will not be feasible to test to all requirements in the complete system, however all requirements should be met in the design of the POTS Adapter based on the test setups shown.

9.3.2 DSL Insertion Loss

The POTS Adapter-D (POTSA-D) is connected directly to the U-R interface, not being protected by the service splitter, and has the potential of degrading the DSL signal quality. Therefore, it shall meet the same requirements as the power splitter.

The POTSA-D DSL insertion loss is measured by comparing the DSL signal level at the U-R interface with and without the POTSA-D connected to the U-R interface. This is measured with active reverse power feed delivering minimum and maximum power to the POTSA-D and with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] connected to the telephone jack of the POTS Adapter-D.

The requirements for the POTSA-D insertion loss are defined in Table 62 for the cases detailed in clause 9.1.

Table 62: POTS Adapter-D Insertion Loss

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
25 kHz to 120 kHz (see note)	10 V peak per wire	N/A	N/A	$\pm 0,5$ dB	$\pm 0,5$ dB	N/A
120 kHz to 30 MHz	10 V peak per wire	N/A	N/A	$\pm 0,5$ dB	$\pm 0,5$ dB	N/A
30 MHz to 106 MHz	2,1 V peak per wire	N/A	N/A	± 1 dB	± 1 dB	N/A
NOTE: The requirement in this frequency band may have to be revised depending on the specifications selected for the out-of-band signalling channel.						

9.3.3 DSL Impedance Conversion

The POTS Adapter-D (POTSA-D) DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-R interface with the POTSA-D connected to the U-R interface and with a reference 100Ω load connected to the U-R interface. This is measured with active reverse power feed delivering minimum and maximum power to the POTSA-D and with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] connected to the telephone jack of the POTSA-D.

The requirements for the POTSA-D impedance conversion are defined in Table 63 for the cases detailed in clause 9.1.

Table 63: POTS Adapter-D Impedance Conversion

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
25 kHz to 120 kHz (see note)	10 V peak per wire	N/A	N/A	> 20 dB	> 20 dB	N/A
120 kHz to 30 MHz	10 V peak per wire	N/A	N/A	> 20 dB	> 20 dB	N/A
30 MHz to 106 MHz	2,1 V peak per wire	N/A	N/A	> 14 dB	> 14 dB	N/A
NOTE: The requirement in this frequency band may have to be revised depending on the specifications selected for the out-of-band signalling channel.						

9.3.4 DSL-band Noise Generation

The POTS Adapter-D (POTSA-D) DSL-band noise generation is verified by measuring the noise on the U-R interface with the POTSA-D connected to the U-R interface and with a reference $100\ \Omega$ load connected to the U-R interface. The DSL-band noise generation shall comply with the reverse power feed generated noise template. This is measured with active reverse power feed delivering minimum and maximum power to the POTSA-D and with the ETSI harmonized impedance of $270\ \Omega + (750\ \Omega \parallel 150\ \text{nF})$ [7] connected to the telephone jack of the POTSA-D.

The requirements for the POTSA-D DSL band noise generation are detailed in Table 64 for the cases detailed in clause 9.1.

Table 64: POTS Adapter-D DSL-band Noise Generation

Frequency Band	Case 2			Case 3	
	DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
25 kHz to 30 MHz	N/A	N/A	see note	see note	N/A
30 MHz to 106 MHz	N/A	N/A	see note	see note	N/A

NOTE: The noise power spectral density shall be lower than the noise mask defined in Table 35 of clause 7.3 over the frequency range applicable to the power splitter class.

9.3.5 POTS Measurement Procedure

The following diagrams show the procedure to measure the characteristics of the DPU or CPE POTS Adapters in terms of POTS performance. In those diagrams, the box shown as Z_{ref} represents the ETSI harmonized impedance of $270\ \Omega + (750\ \Omega \parallel 150\ \text{nF})$ [7].

In Figure 50, the 10 H inductor is used to draw the DC feed current produced by the POTS Adapter-C (POTSA-C) and emulate the telephone DC load. The resistor is adjusted to obtain the desired current.

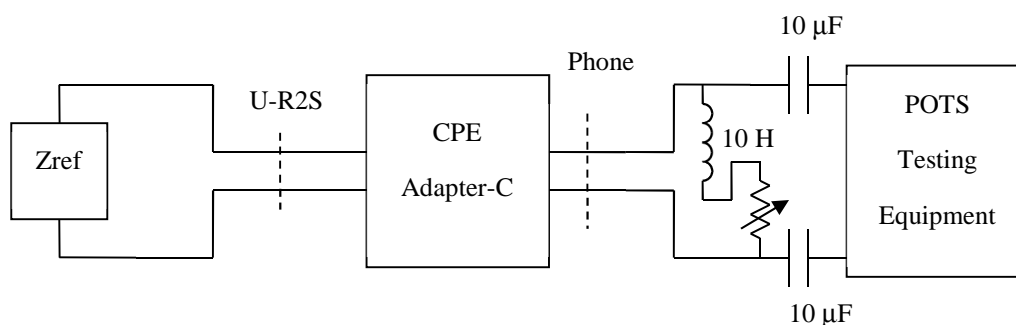


Figure 50: Testing of CPE POTS Adapter-C Characteristics

In Figure 51, the pair of 5 H inductors are used to inject the reverse power feed current required to operate the CPE Adapter-D. The external voltage source is adjusted to obtain the desired operating voltage. The 10 H inductor is used to draw the DC feed current produced by the POTS Adapter-D (POTSA-D) and emulate the telephone DC load. The resistor is adjusted to obtain the desired current.

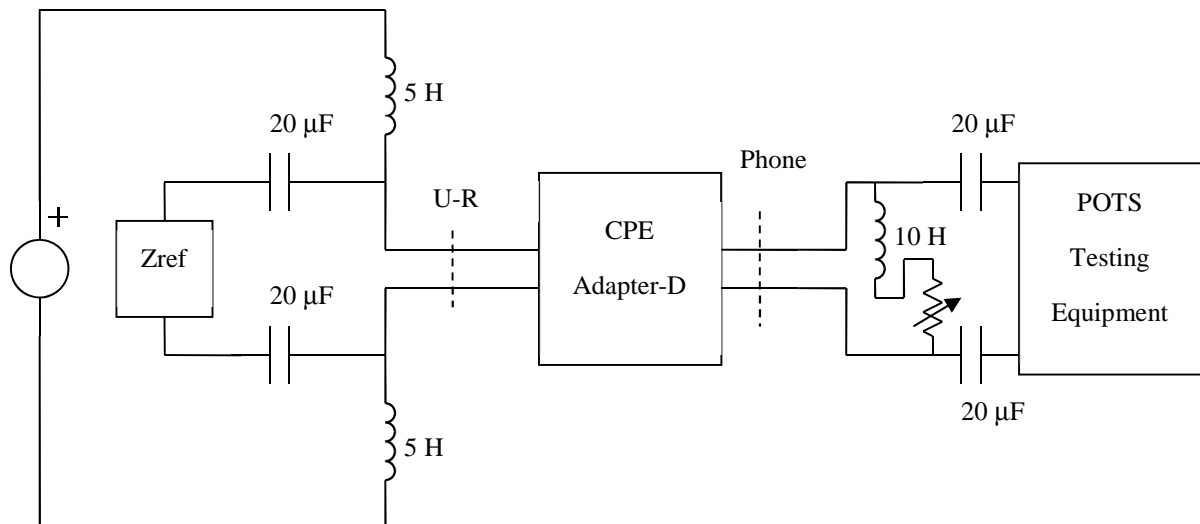


Figure 51: Testing of CPE POTS Adapter-D Characteristics

In Figure 52, the 5 H inductors are used to inject the DC feed current required to properly bias the DPU Adapter-E and emulate the DC feed function of the exchange line. The external voltage source is adjusted to obtain the desired current.

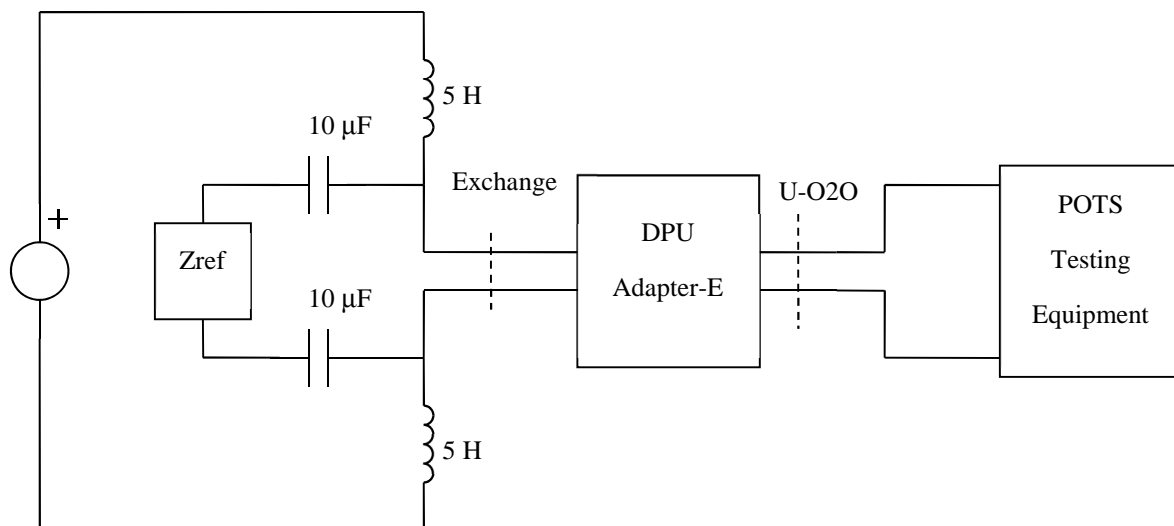


Figure 52: Testing of DPU POTS Adapter-E Characteristics

In Figure 53, the 5 H inductors are used to inject the DC feed current required to properly bias the CPE Adapter-E (CPEA-E) and emulate the DC feed function of the ATA port. The external voltage source is adjusted to obtain the desired current.

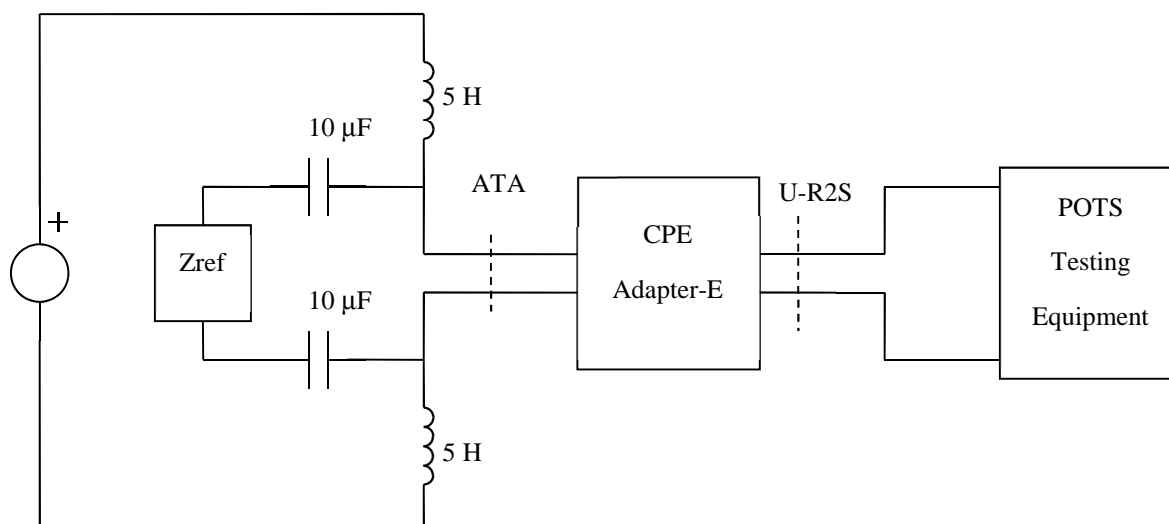


Figure 53: Testing of CPE POTS Adapter-E Characteristics

9.3.6 POTS Insertion Loss

The DPU POTS Adapter-E POTS insertion loss is measured by comparing the POTS signal level at the reference impedance with and without the DPU POTS Adapter-E inserted between the exchange line and the U-O2O interface and with the reference POTS impedance connected to the exchange line port.

The POTS Adapter-C POTS insertion loss is measured by comparing the POTS signal level at the U-R2S interface with and without the POTS Adapter-C inserted between the telephone port and the U-R2S interface and with the reference POTS impedance connected to the U-R2S interface.

The POTS Adapter-D POTS insertion loss is measured by comparing the POTS signal level at the reference impedance with and without the POTS Adapter-D inserted between the U-R interface and the telephone port and with the reference POTS impedance connected to the U-R interface.

The CPE POTS Adapter-E POTS insertion loss is measured by comparing the POTS signal level at the reference impedance with and without the CPE POTS Adapter-E inserted between the ATA port and the U-R2S interface and with the reference POTS impedance connected to the ATA port.

The POTS insertion loss is measured with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces. This is tested in the on-hook and off-hook states with both polarities of DC feed.

The requirements for the POTS Adapters POTS insertion loss and insertion loss variation with frequency in the normal mode are defined in Table 65 and Table 66 respectively for the cases detailed in clause 9.1.

Table 65: POTS Adapters POTS Insertion Loss (Normal Mode)

Frequency	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
1 020 Hz	5 Vpp differential	0 dB to -0,5 dB	0 dB to -0,5 dB	0 dB to -0,5 dB	0 dB to -0,5 dB	0 dB to -0,5 dB

Table 66: POTS Adapters POTS Insertion Loss Variation With Frequency (wrt 1 020 Hz) (Normal Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
300 Hz to 3,4 kHz	5 Vpp differential	±0,5 dB	±0,5 dB	±0,5 dB	±0,5 dB	±0,5 dB

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band insertion loss variation with frequency over a wider bandwidth going up to 6,8 kHz or more.

The DPU POTS Adapter-E also needs to meet the POTS insertion loss requirements in the case of a zero-touch deployment, or to support the POTS Adapter bypass mode.

The POTS Adapter-C (POTSA-C) and POTS Adapter-D (POTSA-D) also need to meet the POTS insertion loss requirements to support the POTS Adapter bypass mode.

The POTS insertion loss is measured with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with idle reverse power feed, no power delivered to the U-R or U-O2P interfaces. This is tested in the on-hook and off-hook states with both polarities of DC feed.

The requirements for POTS Adapter POTS insertion loss and insertion loss variation with frequency in the bypass mode are defined in Table 67 and Table 68 respectively for the cases detailed in clause 9.1.

Table 67: DPU POTS Adapters POTS Insertion Loss (Bypass Mode)

Frequency	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
1 020 Hz	5 Vpp differential	0 dB to -0,5 dB	0 dB to -0,5 dB	0 dB to -0,5 dB	N/A	N/A

Table 68: DPU POTS Adapters Insertion Loss Variation With Frequency (wrt 1 020 Hz) (Bypass Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
300 Hz to 3,4 kHz	5 Vpp differential	$\pm 0,5$ dB	$\pm 0,5$ dB	$\pm 0,5$ dB	N/A	N/A

9.3.7 POTS Impedance Conversion

The DPU POTS Adapter-E POTS impedance conversion is measured by performing a 2-wire return loss measurement at the U-O2O interface with the DPU POTS Adapter-E inserted between the exchange line and the U-O2O interface and with the reference POTS impedance connected to the exchange line interface.

The POTS Adapter-C POTS insertion loss is measured by performing a 2-wire return loss measurement at the telephone port with the POTS Adapter-C inserted between the telephone port and the U-R2S interface and with the reference POTS impedance connected to the U-R2S interface.

The POTS Adapter-D POTS impedance conversion is measured by performing a 2-wire return loss measurement at the telephone port with the POTS Adapter-D inserted between the telephone port and the U-R interface and with the reference POTS impedance connected to the U-R interface.

The CPE POTS Adapter-E POTS impedance conversion is measured by performing a 2-wire return loss measurement at the U-R2S interface with the CPE POTS Adapter-E inserted between the ATA port and the U-R2S interface and with the reference POTS impedance connected to the ATA port.

The POTS impedance conversion is measured with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces. This is tested in the on-hook and off-hook states with both polarities of DC feed.

The requirements for the POTS impedance conversion for Adapters C, D and E for normal mode are detailed in Table 69 and Table 70 respectively for the cases detailed in clause 9.1.

Table 69: POTS Impedance Conversion for Adapters C, D and E (Normal Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
200 Hz to 300 Hz	5 Vpp differential	> 12 dB	> 12 dB	> 12 dB	> 12 dB	> 12 dB
300 Hz to 500 Hz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	> 14 dB	> 14 dB
500 Hz to 2 kHz	5 Vpp differential	> 18 dB	> 18 dB	> 18 dB	> 18 dB	> 18 dB
2 kHz to 3,8 kHz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	> 14 dB	> 14 dB

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band impedance conversion over a wider bandwidth going up to 6,8 kHz or more.

The DPU POTS Adapter-E also needs to meet the POTS impedance conversion requirements in the case of a zero-touch deployment, or to support the POTS Adapter bypass mode.

The POTS Adapter-C and POTS Adapter-D also need to meet the POTS impedance conversion requirements to support the POTS Adapter bypass mode.

The POTS impedance conversion is measured with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] and with idle reverse power feed, no power delivered to the U-R or U-O2P interface. This is tested in the on-hook and off-hook states with both polarities of DC feed.

The requirements for the POTS impedance conversion for Adapters C, D and E in bypass mode are detailed in Table 70 for the cases detailed in clause 9.1.

Table 70: POTS Impedance Conversion for Adapters C, D and E (Bypass Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
200 Hz to 300 Hz	5 Vpp differential	> 12 dB	> 12 dB	> 12 dB	N/A	N/A
300 Hz to 500 Hz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	N/A	N/A
500 Hz to 2 kHz	5 Vpp differential	> 18 dB	> 18 dB	> 18 dB	N/A	N/A
2 kHz to 3,8 kHz	5 Vpp differential	> 14 dB	> 14 dB	> 14 dB	N/A	N/A

9.3.8 POTS-band longitudinal Balance

The DPU POTS Adapter-E POTS-band longitudinal balance is measured by measuring the longitudinal balance at the U-O2O interface with the DPU POTS Adapter-E inserted between the exchange line and the U-O2O interface and with the ETSI harmonized impedance of $270 \Omega + (750 \Omega \parallel 150 \text{ nF})$ [7] connected to the exchange line port.

The CPE POTS Adapter-E POTS-band longitudinal balance is measured by measuring the longitudinal balance at the U-R2S interface with the CPE POTS Adapter-E inserted between the ATA port and the U-R2S interface and with the ETSI harmonized impedance connected to the ATA port.

The CPE POTS Adapter-C or POTS Adapter-D POTS-band longitudinal balance is measured by measuring the longitudinal balance at the telephone port with the CPE POTS Adapter-C or Adapter-D inserted between the phone port and the U-R or U-R2S interface and with the ETSI harmonized impedance connected to the U-R or U-R2S interface.

The requirements for the POTS longitudinal balance for Adapters C, D and E in normal mode are detailed in Table 71 for the cases detailed in clause 9.1.

Table 71: POTS Longitudinal Balance for Adapters C, D and E (Normal Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
50 Hz	5 Vpp differential	> 40 dB	> 40 dB	> 40 dB	> 40 dB	> 40 dB
200 Hz to 600 Hz	5 Vpp differential	> 40 dB	> 40 dB	> 40 dB	> 40 dB	> 40 dB
600 Hz to 3,8 kHz	5 Vpp differential	> 46 dB	> 46 dB	> 46 dB	> 46 dB	> 46 dB

In the case of a derived-voice service supporting wideband telephony, it will be required to specify the POTS-band longitudinal balance over a wider bandwidth going up to 6,8 kHz or more.

The DPU POTS Adapter-E also needs to meet the POTS-band longitudinal balance requirements in the case of a zero-touch deployment, or to support the POTS Adapter bypass mode.

The POTS Adapter-C and POTS Adapter-D also need to meet the POTS-band longitudinal balance requirements to support the POTS Adapter bypass mode.

The POTS-band longitudinal balance is measured with the ETSI harmonized impedance and with idle reverse power feed and no power delivered to the U-R or U-O2P interface. This is tested in the on-hook and off-hook states with both polarities of DC feed.

The requirements for the POTS longitudinal balance for Adapters C, D and E in bypass mode are detailed in Table 72 for the cases detailed in clause 9.1.

Table 72: POTS Longitudinal Balance for Adapters E, C, D (Bypass Mode)

Frequency Band	Signal Level	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
50 Hz	5 Vpp differential	> 40 dB	> 40 dB	> 40 dB	N/A	N/A
200 Hz to 600 Hz	5 Vpp differential	> 40 dB	> 40 dB	> 40 dB	N/A	N/A
600 Hz to 3,8 kHz	5 Vpp differential	> 46 dB	> 46 dB	> 46 dB	N/A	N/A

9.3.9 Signalling Channel Noise

The signalling channel noise is measured at the U-R interface when the signalling channel is active. Because dial pulsing, DC feed polarity reversal, and ring start-stop can create some transient noise, it shall be measured while the POTS service is in a steady state and the signalling channel is active.

The POTS signalling channel noise requirements are defined in Table 73 for the cases detailed in clause 9.1.

Table 73: POTS Signalling Channel Noise

Parameter	Case 2			Case 3	
	DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
POTS noise level	< -70 dBmP	< -70 dBmP	< -70 dBmP	< -70 dBmP	< -70 dBmP

9.3.10 POTS DC Isolation Resistance

This requirement applies to any terminal connected to an exchange line as per ETSI ES 203 021 [3].

The DPU POTS Adapter-E DC isolation resistance is measured at the exchange line interface with active reverse power feed delivering minimum and maximum power to the U-O2P interface. It is measured with respect to ground in the on-hook and off-hook states with both polarities of DC feed and between wires in the on-hook state with both polarities of DC feed.

The POTS DC Isolation Resistance requirements in the normal mode for POTS Adapter-E are defined in Table 74 for the cases detailed in clause 9.1.

Table 74: POTS DC Isolation Resistance (Adapter-E) (Normal Mode)

Measurement Voltage	Test Condition	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
100 V	Both wires shorted together, and measured with respect to earth ground	> 40 M Ω	N/A	N/A	N/A	N/A
100 V	Between both wires	> 4 M Ω	N/A	N/A	N/A	N/A

In the case of a zero-touch deployment, or to support the POTS Adapter bypass mode, the DPU POTS Adapter-E DC isolation resistance also needs to be measured with idle reverse power feed, no power delivered to the U-O2P interface.

To support the POTS Adapter bypass mode, the POTS Adapter-C and Adapter-D DC isolation resistance also need to be measured with idle reverse power feed, no power delivered to the U-R interface.

The POTS DC Isolation Resistance requirements in the bypass mode for POTS adapters are defined in Table 75 for the cases detailed in clause 9.1.

Table 75: POTS DC Isolation Resistance (Adapters-C,D, E) (Bypass Mode)

Measurement Voltage	Test Condition	Case 2			Case 3	
		DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
100 V	Both wires shorted together, and measured with respect to earth ground	> 40 M Ω	> 40 M Ω	> 40 M Ω	N/A	N/A
100 V	Between both wires	> 4 M Ω	> 4 M Ω	> 4 M Ω	N/A	N/A

9.3.11 Ringing Detection

The DPU POTS Adapter-E shall detect a ringing signal with an AC voltage from 40 Vrms to 120 Vrms present on the exchange line at a frequency from 15 Hz to 55 Hz. The AC voltage may be applied only to the tip wire, only to the ring wire, or differentially on both wires simultaneously. A DC voltage between 0 V and -66 V may be present on the tip wire and on the ring wire during the application of the AC voltage.

The CPE POTS Adapter-E shall detect a ringing signal with an AC voltage from 40 Vrms to 100 Vrms present on the ATA port at a frequency of 25 Hz or 50 Hz. The AC voltage may be applied only to the tip wire, only to the ring wire, or differentially on both wires simultaneously. A DC voltage between 0 V and ± 60 V may be present on the tip wire and on the ring wire during the application of the AC voltage.

The AC load at the ringing frequency presented by the DPU or CPE POTS Adapter-E on the exchange line or the ATA port shall be greater than 16 k Ω .

The DPU or CPE POTS Adapter-E shall detect the ringing signal and its frequency and issue the start-of-ringing command with a maximum delay of 200 ms from the start of the ringing burst. The frequency shall be measured with an accuracy of ± 1 Hz. The POTS Adapter-E shall operate relay K1 in Figure 49 to disconnect the AC transmission capacitors and remove the ringing signal from the loop shared with reverse power feed. Relay K1 shall be operated with a maximum delay of 100 ms from the start of the ringing burst. The level of the residual ringing signal leaking through on the U-R2S port or U-O2O port after operating relay K1 shall be less than 1 Vrms. The difference in the delay to signal the start and the end of ringing shall be minimized such that the distortion on the ringing burst duration does not exceed 50 ms.

The DPU or CPE POTS Adapter-E shall meet the POTS insertion loss and impedance conversion loss requirements 200 ms following the end of a ringing burst to support on-hook transmission of caller ID information during the silent interval.

When in the ringing state, the DPU or CPE POTS Adapter-E shall send a command on the out-of-band signalling channel to indicate the end of ringing within 10 ms of receiving an off-hook indication from a POTS Adapter-C or Adapter-D. The purpose of that command is to stop the ringing generation on the POTS Adapters that are connected to telephones other than the one that went off-hook.

9.3.12 Ringing Generation

The POTS Adapter-C shall generate an open-circuit ringing signal with an AC voltage higher than 40 Vrms at a frequency from 15 Hz to 55 Hz as requested by the out-of-band signalling command. The open-circuit ringing AC voltage shall not exceed 100 Vrms. The peak-to-rms ratio shall be in the range of 1,2 to 1,6. The ringing signal generator shall provide enough current to generate a minimum of 35 Vrms across four parallel on-hook telephones presenting a regular ringing load (> 8 k Ω each), or one single telephone presenting a heavy ringing load (> 2 k Ω).

The POTS Adapter-D shall generate an open-circuit ringing signal with an AC voltage higher than 40 Vrms at a frequency from 15 Hz to 55 Hz (case 2) or at a frequency of 25 Hz or of 50 Hz (case 3) as requested by the out-of-band signalling command. The open-circuit ringing AC voltage shall not exceed 100 Vrms. The peak-to-rms ratio shall be in the range of 1,2 to 1,6. The ringing signal generator shall provide enough current to generate a minimum of 35 Vrms onto a single telephone. This telephone might be presenting a regular ringing load (> 8 k Ω) or a heavy ringing load (> 2 k Ω).

In order to limit the power drawn from the PSE, the total number of telephones serviced by all POTS Adapter-C and POTS Adapter-D is limited to four when presenting a regular ringing load (> 8 k Ω each), or to one when presenting a heavy ringing load (> 2 k Ω).

For both POTS Adapter-C and Adapter-D, the AC voltage may be applied only to the tip wire, only to the ring wire, or differentially on both wires simultaneously. A differential DC voltage between 0 V and ± 60 V may be present between the tip wire and the ring wire during the application of the AC voltage.

When receiving a start-of-ringing command, the POTS Adapter-C and Adapter-D shall initiate the ringing signal with a maximum delay of 50 ms and operate relay K1 to prevent the ringing signal from leaking back onto the loop shared with reverse power feed. The frequency shall be accurate to ± 1 Hz. Relay K1 shall be operated before the start of the ringing signal. The level of the residual ringing signal leaking through on the U-R port or the U-R2S port shall be less than 1 V_{rms}. The POTS Adapter-C and Adapter-D shall terminate the ringing signal and release relay K1 to be ready for on-hook transmission with a maximum delay of 50 ms. The difference in delay between starting and stopping a ringing burst shall be such that the distortion on the ringing burst duration does not exceed 10 ms.

The POTS Adapter-C and Adapter-D shall meet the POTS insertion loss and impedance conversion loss requirements 200 ms following the end of a ringing burst such as to support on-hook transmission of caller Id information during the silent interval.

The POTS Adapter-C and Adapter-D shall autonomously stop the generation of ringing within 150 ms of the telephone going off-hook. An off-hook indication shall be communicated to the POTS Adapter-E within a maximum delay of 150 ms from the time of the off-hook state change at the telephone.

9.3.13 DC Feed Detection

The DPU POTS Adapter-E shall operate with a DC voltage between 0 V and -66 V on the tip wire and on the ring wire.

The CPE POTS Adapter-E shall operate with a DC voltage between 0 V and -60 V on the tip wire and on the ring wire. It is also possible that the ATA be high impedance with respect to ground and only generate a floating metallic voltage. The CPE POTS Adapter-E shall operate with a metallic DC voltage between ± 80 V present between the tip wire and the ring wire and shall not rely on any specific voltage to ground.

For both DPU and CPE Adapter-E, while in the on-hook state, one wire will be close to ground, the other one will be close to battery. While in the off-hook state, the battery wire may move closer to ground, or both wires may simply move closer together toward mid-rail, or any other point, to perform current limiting.

The DPU or CPE POTS Adapter-E shall detect a reversal in the DC feed voltage polarity applied onto the exchange line or ATA port and generate an out-of-band signal reporting the reversed polarity condition within 25 ms.

The DPU or CPE POTS Adapter-E shall detect an interruption in the DC feed voltage applied onto the exchange line or ATA port and generate an out-of-band signal reporting the open feed interval condition within 25 ms. During the open feed interval, both wires may go high impedance, or may continue to be actively driven but converge to a common voltage at any point between ground and battery.

If the lifeline bypass mode is supported by the DPU POTS Adapter-E, the voltage drop between the exchange line and the U-O2O interface shall be less than 0,5 V per wire at 100 mA of loop current when reverse power feed is idle, no power being delivered to the U-O2P interface.

9.3.14 DC Feed Generation

The POTS Adapter-C or Adapter-D shall generate a DC voltage between 0 V and -60 V on the tip wire and on the ring wire when having access to a ground reference. If fully floating, the POTS Adapter-C or Adapter-D shall generate a metallic DC voltage between ± 60 V between the tip wire and the ring wire. While the telephone is in the on-hook state, one wire will be close to ground, the other one will be close to battery. While the telephone in the off-hook state, the battery wire may move closer to ground, or both wires may simply move closer together toward mid-rail, or any other point, to perform current limiting. The loop current shall be limited to 25 mA \pm 2 mA.

The POTS Adapter-C and Adapter-D shall perform a polarity reversal in the DC feed voltage applied to the telephone jack within 25 ms of receiving an out-of-band signal requesting a reversed polarity condition.

The POTS Adapter-C and Adapter-D shall interrupt the DC feed voltage applied to the telephone jack within 25 ms of receiving an out-of-band signal requesting an open feed interval condition. During the open feed interval, both wires may go high impedance, or may continue to be actively driven but converge to a common voltage at any point between ground and battery.

If the lifeline bypass mode is supported by the POTS Adapter-C or Adapter-D, the voltage drop between the U-R or U-R2S interface and the telephone jack shall be less than 0,5 V per wire at 100 mA of loop current when reverse power feed is idle, no power being delivered to the U-R interface.

9.3.15 Hook Switch

The DPU or CPE POTS Adapter-E shall draw a minimum of 20 mA from the exchange line or ATA port when operating its hook switch in the off-hook state and the exchange line or ATA port provides the normal feed voltage. The voltage drop across the POTS Adapter-E shall not exceed 8 V at 20 mA. The hook switch shall comply with this requirement in any DC feed polarity.

The DPU POTS Adapter-E shall draw a maximum of 1 mA from the exchange line when releasing its hook switch in the on-hook state and with a DC feed voltage from 0 V to 66 V in any polarity.

The CPE POTS Adapter-E shall draw a maximum of 1 mA from the ATA port when releasing its hook switch in the on-hook state and with a DC feed voltage from 0 V to 60 V in any polarity.

The DPU or CPE POTS Adapter-E hook switch shall be operated within a maximum delay of 5 ms after receiving an out-of-band signalling command. The delay differential between operating and releasing the hook switch shall be less than 1 ms.

As there may be more than one telephone off-hook at any time, the POTS Adapter-E shall keep track of all adapters that have reported an off-hook condition and return to its on-hook state only after all adapters have reported an on-hook condition.

9.3.16 Hook State Detection

The POTS Adapter-C and POTS Adapter-D shall detect a telephone going off-hook and drawing more than 10 mA from the telephone jack and generate an out-of-band signal in less than 5 ms. The hook state detection shall operate in both polarities of DC feed.

The POTS Adapter-C and POTS Adapter-D shall detect a telephone going on-hook and drawing less than 3 mA from the telephone jack and generate an out-of-band signal in less than 5 ms. The hook state detection shall operate in both polarities of DC feed.

The difference in delay between off-hook and on-hook detection shall be less than 1 ms.

Note that when dial pulsing is generated by the telephone, the first on-hook transition is used as a trigger to remove the dial tone signal from the line. Therefore, it has to be immediately reproduced by the POTS Adapter-E. Waiting for the end of a pulse train and sending a more elaborate message containing the decoded digit indication would not make the dial tone signal to be removed on time.

9.3.17 Bypass Mode

The DPU POTS Adapter-E can optionally support a bypass mode used for zero-touch configuration or to provide a lifeline service during power outages.

When delivering a POTS service from the exchange, the POTS Adapter-C and Adapter-D can optionally support a bypass mode providing a lifeline service during power outages.

The following conditional requirements shall be met if the bypass mode is used to provide a lifeline service:

- It shall be possible to originate and receive calls when operating in the bypass mode with no local power available at the CPE location.
- If the local power source is lost at the CPE location while an active telephone call is present, the transition into the bypass mode shall be done without dropping that call and with an interruption time of less than 100 ms.
- If the local power source is restored at the CPE location while an active telephone call is present, the transition out of the bypass mode and into active reverse power feed can be delayed until the end of that call. If the implementation returns to active reverse power feed without waiting for the end of the call, it shall occur without dropping the call and with an interruption time of less than 100 ms.

9.3.18 Power Drain

The DPU POTS Adapter-E may be powered from the local DPU supply, or may be powered directly from the reverse power feed voltage present on the U-O2O interface. In any case, the power ultimately comes from the PSE located at the CPE location, and is specified in terms of power drawn from the U-O interface.

The POTS Adapter-C and Adapter-E shall be powered directly from the local CPE supply to avoid increasing the load on the PSE. They shall draw a limited current from the reverse power feed source while in any operating state and reverse power feed is present on the loop.

The POTS Adapter-D shall be powered from the reverse power feed voltage present on the U-R interface. The POTS Adapter-D current drain changes with the operating state and increases when the telephone is off-hook or ringing. In order to allow detection of a telephone not fitted with a POTS Adapter-D, the current drain shall change gradually over a 5 ms interval when going from on-hook to off-hook. The POTS Adapter-D load current can increase substantially when the telephone goes off-hook during ringing. Measures shall be implemented in the POTS Adapter-D to limit the peak power taken from the U-R interface during this transient interval.

The voltage compliance range and the power consumption shall be measured at the U-O or U-R interface for the DPU and CPE respectively.

The POTS Adapter power drain requirements with reverse power feed active are defined in Table 76 for the cases detailed in clause 9.1.

Table 76: POTS Adapter Power Drain (RPF active)

Parameter	Case 2			Case 3	
	DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
Voltage compliance range	20 V to 60 V	40 V to 60 V	40 V to 60 V	40 V to 60 V	40 V to 60 V
Any operating state	< 0,75 W	≤ 1 mA	N/A	N/A	≤ 1 mA
On-hook no ringing	N/A	N/A	< 0,5 W	< 0,5 W	N/A
Off-hook no ringing	N/A	N/A	< 1,25 W	< 1,25 W	N/A
On-hook with normal ringing (see note 1)	N/A	N/A	< 1,1 W	< 1,1 W	N/A
On-hook with heavy ringing (see note 2)	N/A	N/A	< 2,5 W	< 2,5 W	N/A
Off-hook with ringing (see note 3)	N/A	N/A	< 3 W	< 3 W	N/A

NOTE 1: A telephone has a normal ringing load if > 8 kΩ at the ringing frequency.
NOTE 2: A telephone with a heavy ringing load can be as low as 2 kΩ at the ringing frequency.
NOTE 3: Limited to a maximum duration of 150 ms before exiting the ringing state.
NOTE 4: The maximum loop resistance between the PSE and the POTS Adapter(s) is not specified.

In the case of on-hook, or on-hook with normal ringing, there may be up to four POTS Adapter-D distributed across the house and all drawing current. The total power drain can then be multiplied by a factor of four. In the case of the heavy ringing load, the application will be limited to a single telephone in the house. In the case of an off-hook condition, it is possible that there may be two telephones off-hook simultaneously in addition to two other telephones on-hook.

When configured for case 2 and if the lifeline bypass mode is provided, the various POTS Adapters shall draw a limited current from the exchange line when in the bypass state and with an exchange-provided DC feed voltage in any polarity.

Note that the DC isolation resistance requirement may impose lower current levels.

The POTS Adapter power drain requirements with reverse power feed idle are defined in Table 77 for the cases detailed in clause 9.1.

Table 77: POTS Adapter Power Drain (RPF idle)

Parameter	Case 2			Case 3	
	DPU - E	CPE - C	CPE - D	CPE - D	CPE - E
Voltage compliance range	0 V to 66 V	0 V to 66 V	0 V to 66 V	N/A	N/A
Current drain	≤ 0,1 mA	≤ 0,1 mA	≤ 0,1 mA	N/A	N/A

Annex A (informative): Reverse power backup systems

A.1 Case 1 battery backup in the CPE

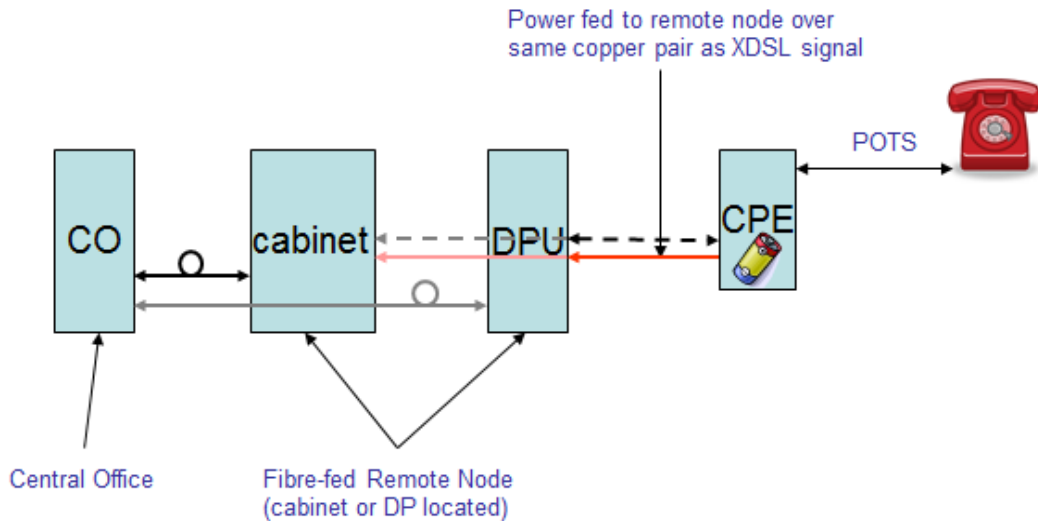


Figure A.1: Battery backup in the CPE Only

Figure A.1 shows the case where battery backup is placed in the CPE, the aim being that if there is a local power failure then lifeline POTS plus OAM support at the remote node can be provided by the battery backup.

A.2 Case 2 battery backup in the DPU and CPE

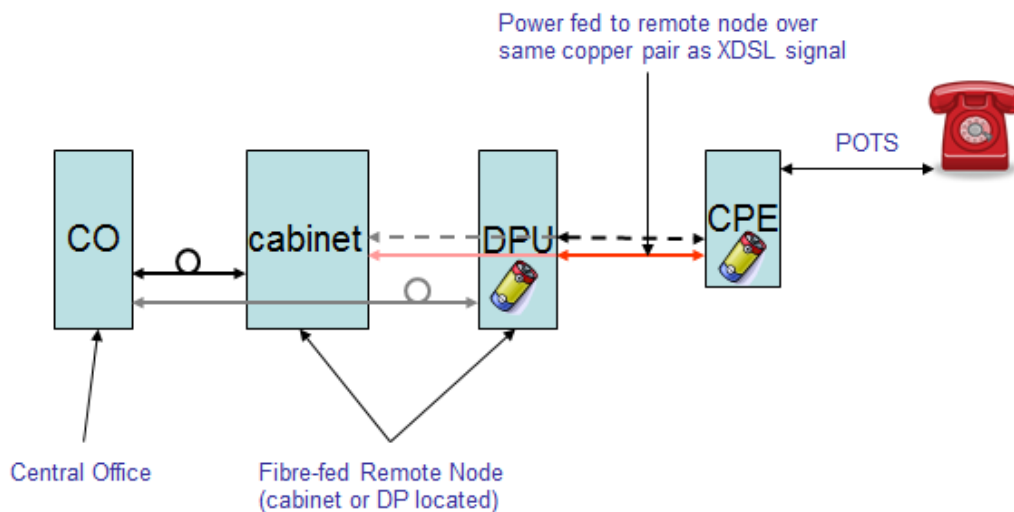


Figure A.2: Battery backup in the DPU and CPE

Figure A.2 shows the addition of another battery backup located in the DPU. This gives the advantage in that equipment located at the DP can remain powered even though no subscribers are connected and thus retaining OAM support.

Annex B (normative): General POTS requirements

This annex is applicable where POTS CPE are compliant with ETSI ES 203 021 [3].

The POTS interface presented by POTSA-C and POTSA-D shall comply with ETSI ES 202 971 [1].

NOTE: In cases where derived POTS is delivered then there is a case to consider a limited subset of requirements (equivalent to providing an analogue POTS presentation via an FTTdp access network). For example one can consider the service and capability features listed in Table 1 and Table 2 given in NICC ND 1645 [i.2].

Annex C (informative): RPF Noise Limits For Common Mode

C.1 Introduction

It is highly likely that differential mode noise at an equipment port will be associated with a strong common mode noise component which may have been the source of the differential mode. The common mode noise signal will encounter unbalance in the access cables as well as equipment connected to the pair in question. Therefore, it is important that both common mode and differential mode noise limits are specified as well as the port balance.

C.2 Derivation

Table C.1 defines a PSD mask for common mode noise measured in a 1 MHz sliding window. The table also demonstrates how the mask is derived from the normative 1 MHz bandwidth differential mode noise limits.

C.3 Cable Balance Model and Common Mode PSD Construction

The conversion factor used to derive the common mode limit mask from the differential mode limit mask has two parts: a "Balance Model" shown in Table C.1; and a factor of 3 dB. The "Balance Model" predicts the power ratio between common mode noise injected from a 150 Ω source impedance and resulting differential mode noise measured in 100 Ω (see Figure C.1), when the common mode signal is injected into a typical telephony distribution cable. An additional 3 dB factor is applied to set the common mode noise limit so as to equally divide the differential mode noise budget between noise coupled by cable unbalance and noise generated directly in the differential mode.

Construction of the Common Mode RPF Noise PSD Mask is shown in Table C.1.

Table C.1: Construction of Common Mode Noise Mask

Parameter	Frequency (MHz)						
	2	4	8	10	20	30	212
10 kHz differential mask (dBm/Hz)	-135	-138	-141	-144	-150	-154	-154
1 MHz differential mask (dBm in 1 MHz RBW)	-75	-78	-81	-84	-90	-94	-94
Balance Model (dB)	40	37	34	33	30	28	20
1 MHz Common Mode Mask (dBm in 1 MHz RBW)	-38	-44	-50	-54	-63	-69	-77

The 10 kHz bandwidth (10 kHz differential) and 1 MHz bandwidth (1 MHz differential) values in Table C.1 are quoted from Table 35.

NOTE: The 10 kHz limit plays no part in derivation of the common mode limit.

C.4 Example of Measurement Environment

It is assumed that the common mode noise power is measured into a 150 Ω load from a 150 Ω source, with respect to the ground plane on which the equipment under test is placed. This would require the equipment under test to have a special measurement mode that freezes start up after RPF initialization. The test set-up is shown in Figure C.1.

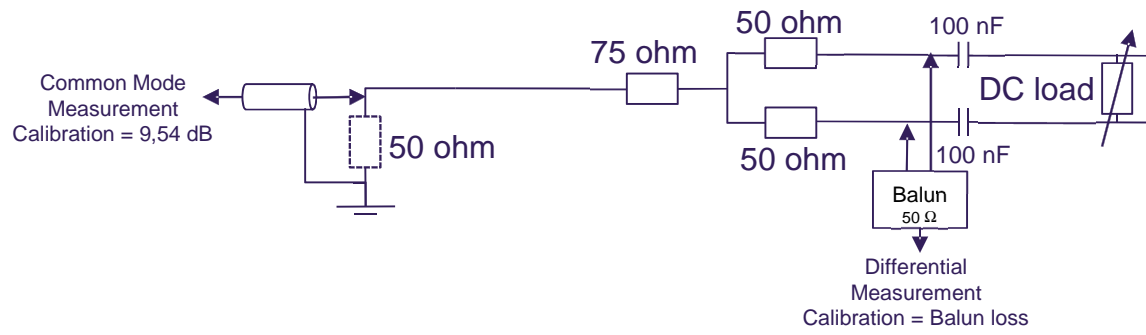


Figure C.1: Example measurement set-up for PSE - termination

Annex D (informative): Out-of-Band Signalling Channel for POTS Adapters

The out-of-band signalling channel implemented between the POTS Adapter-E and the POTS Adapter-C or Adapter-D should:

- Provide a single point to multi-point link from one POTS Adapter-E to a combination of one or zero POTS Adapter-C and one, zero, or many POTS Adapter-D.
- Provide a multi-point to single-point link from a combination of one or zero POTS Adapter-C and one, zero, or many POTS Adapter-D to a single POTS Adapter-E.
- Avoid collisions and message loss when more than one POTS Adapter needs to communicate a signalling command at the same time.
- Transport the signalling information across the copper pair carrying the reverse power feed without being audible to the user at the telephone or at the exchange side of the call. This implies no sustained or temporary tones in the audio band and no switching click.
- Ensure end-to-end communication delay sufficiently short to comply with all POTS signalling requirements.

The following messages should be supported by the out-of-band signalling channel.

POTS Adapter-E → POTS Adapter-C and POTS Adapter-D:

- Start of ringing signal, including the frequency information.
- Start of normal polarity feed.
- Start of reversed polarity feed.
- Start of open feed interval.
- Initiate POTS Adapter-C and Adapter-D detection and ID selection.

POTS Adapter-C and POTS Adapter-D → POTS Adapter-E:

- Start of off-hook, including the adapter ID.
- Start of on-hook, including the adapter ID.
- Reply from a POTS Adapter-C and Adapter-D detection and ID selection command, including the adapter ID.

One option for the out-of-band signalling communication protocol is to use tones in the range of 19 kHz to 21 kHz. One frequency can be used to represent a logical 0 and another one can be used to represent a logical 1. This puts the signalling tones outside of the audio band while allowing the use of common A/D and D/A converters designed for digital audio equipment. Each transmitter would need to monitor for a clear channel before initiating a signal transmission. It would also need to monitor the channel during transmission to guarantee the signal integrity and detect any collision. When detecting a collision, the transmitter should stop transmitting and wait for a random time before making another attempt. The message length should be very short to minimize the probability of a collision and to reduce the transmission delay. The end-to-end messaging delay should be less than 10 ms. When a call is in progress, it may be necessary for the POTS Adapter-E to transmit a continuous tone to maintain the timing synchronization with the POTS Adapter-C and Adapter-D. This would allow faster transmission of any line status change.

The POTS Adapter-C and Adapter-D detection and ID selection command is used by the POTS Adapter-E to identify how many POTS Adapter-C and POTS Adapter-D are present at the CPE location. Upon receiving that command, the POTS Adapter-C and POTS Adapter-D should wait for a random time and reply one at a time including an adapter ID within the reply. They should continue to monitor the channel and identify the adapter IDs that have been selected by other devices. The adapter ID can simply start at 1 and increment in sequence for each adapter responding to the request. From that point on, the adapter ID is retained and used to identify which POTS Adapter C or D originates an off-hook indication.

The out-of-band signalling channel is disabled when configured for POTS from the exchange and operating in the bypass mode because there would be no power available to operate the circuitry.

Annex E (normative): PRP PSE low level flow charts

E.1 General

This annex is applicable to a PSE that supports the optional MDSU extension, PRP, as defined in clause 6.2.5. The top level flow-chart for a PSE supporting PRP is defined in Figure 18. This annex specifies the normative corresponding low-level process flows for PRP.

E.2 Perform MDSU

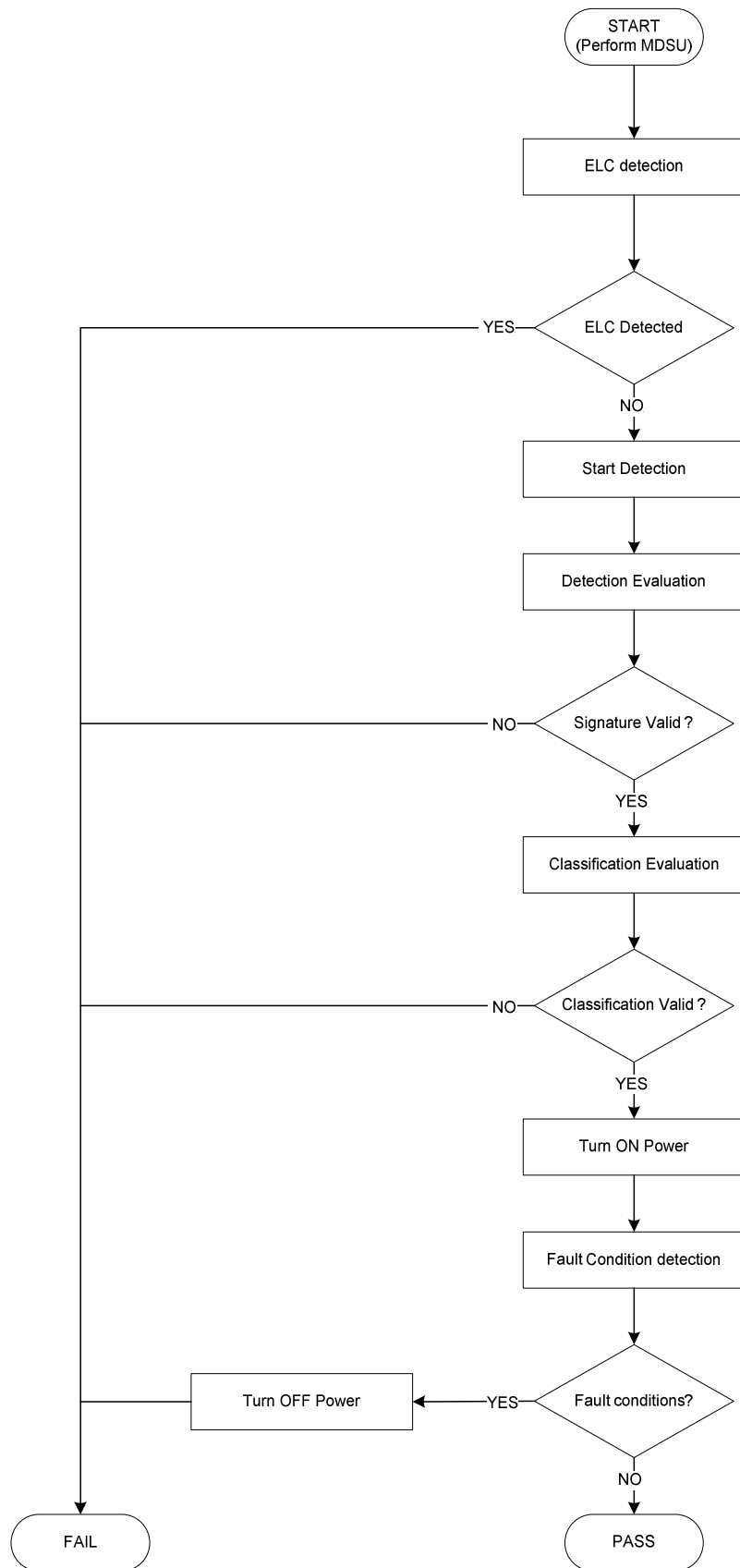


Figure E.1: PRP - Perform MDSU process

E.3 POTS RCR MDSU Error Handler

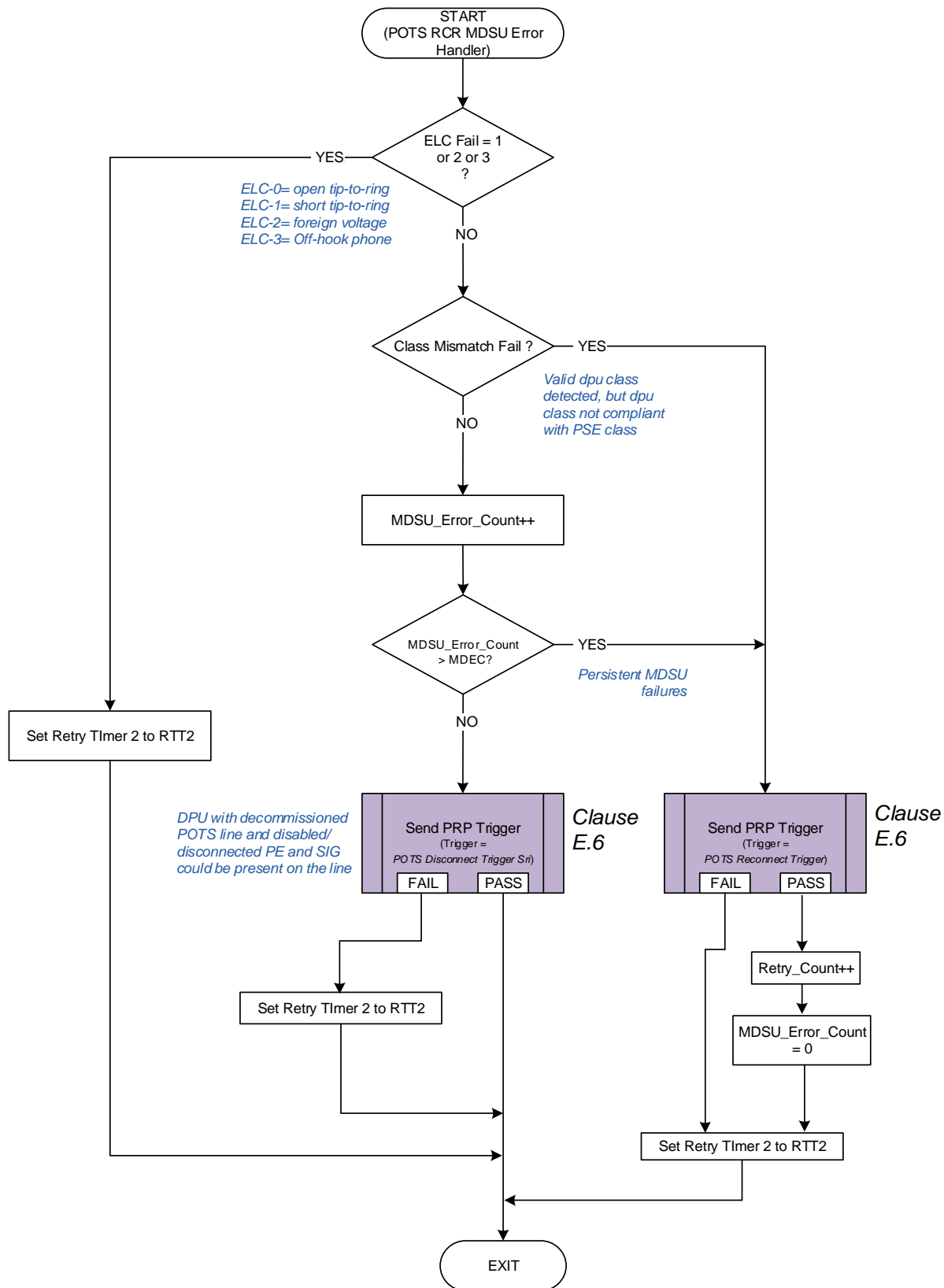


Figure E.2: PRP - POTS RCR MDSU Error handler process

E.4 PSE Reverse Power Active

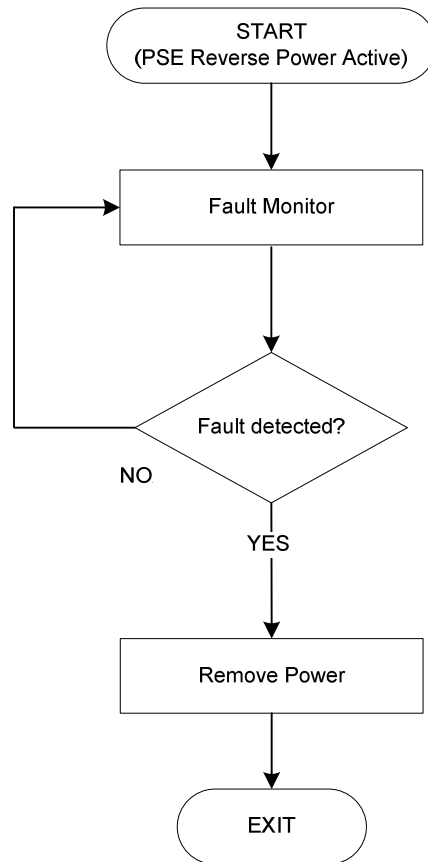


Figure E.3: PRP - PSE Reverse Power Active process

E.5 Perform POTS RCR

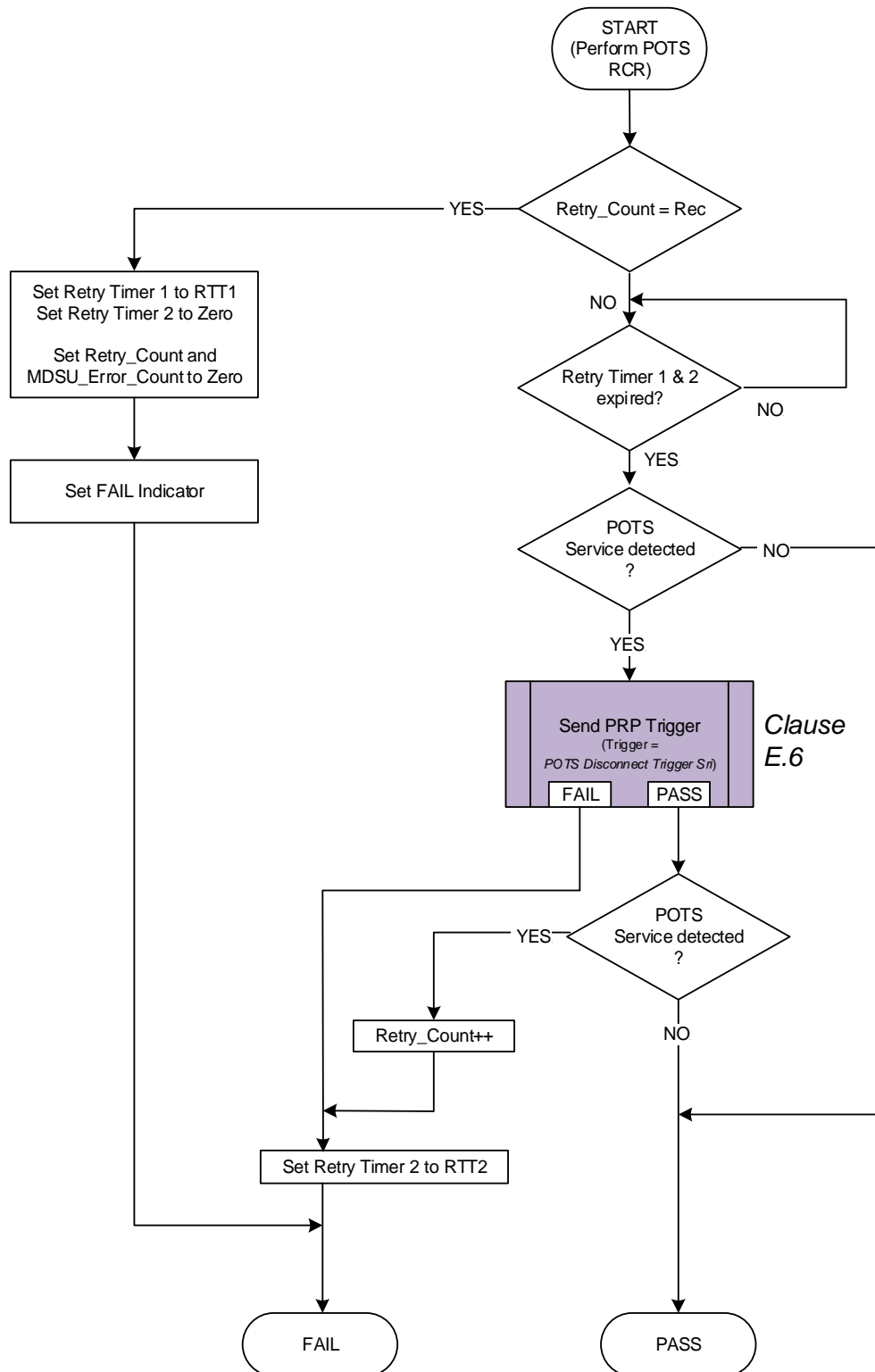


Figure E.4: PRP - PSE Perform POTS RCR flow

E.6 Send PRP Trigger

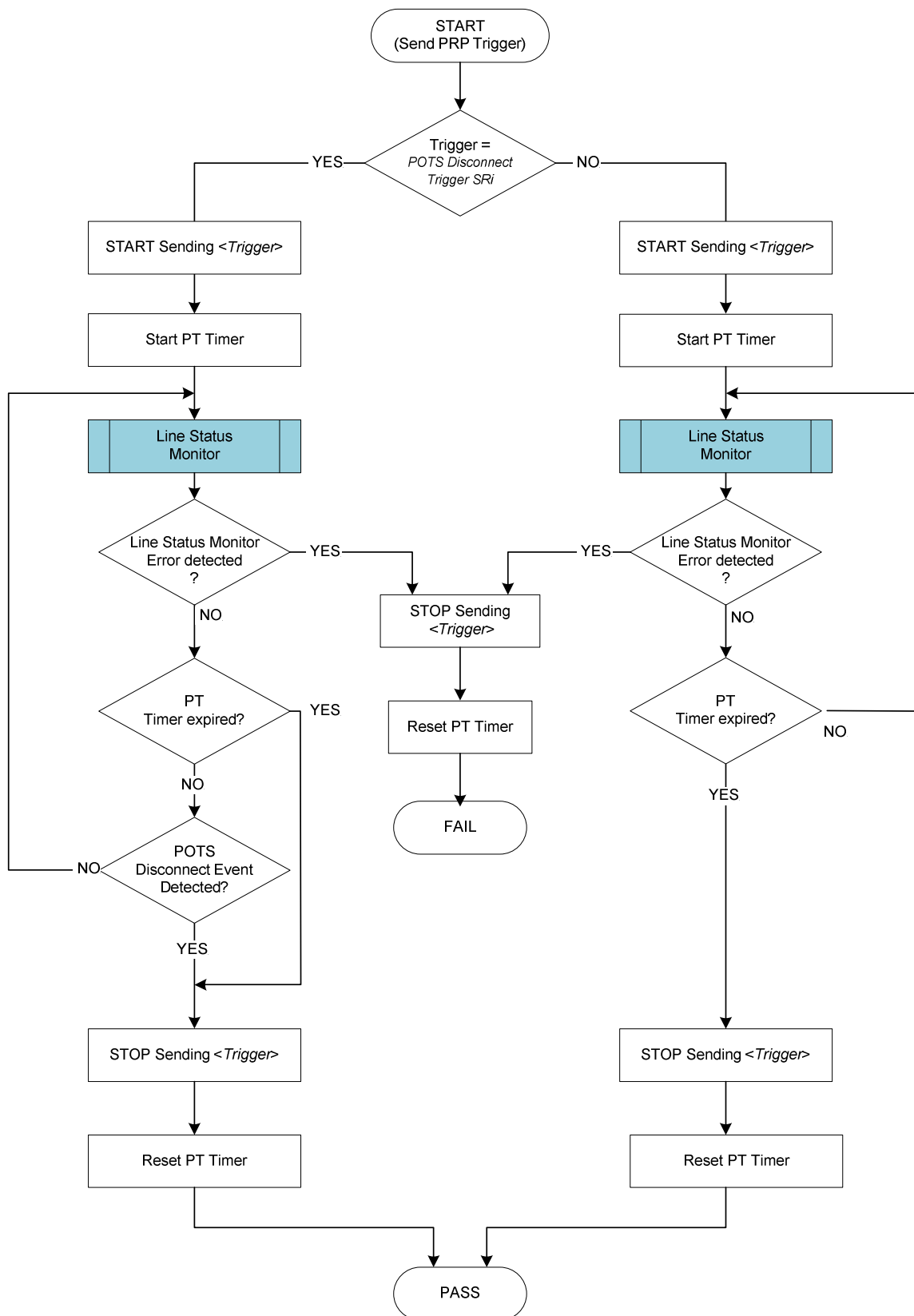


Figure E.5: PRP - Send PRP trigger process

E.7 Set Initial State

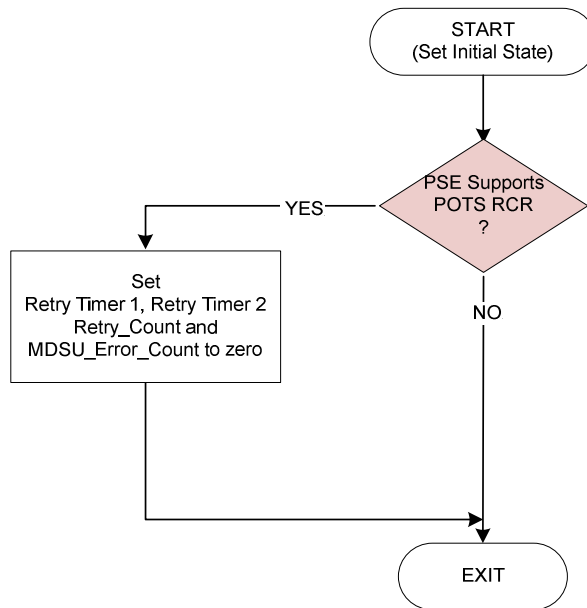


Figure E.6: Set initial State

E.8 Send Enable Trigger to POTS Adapter

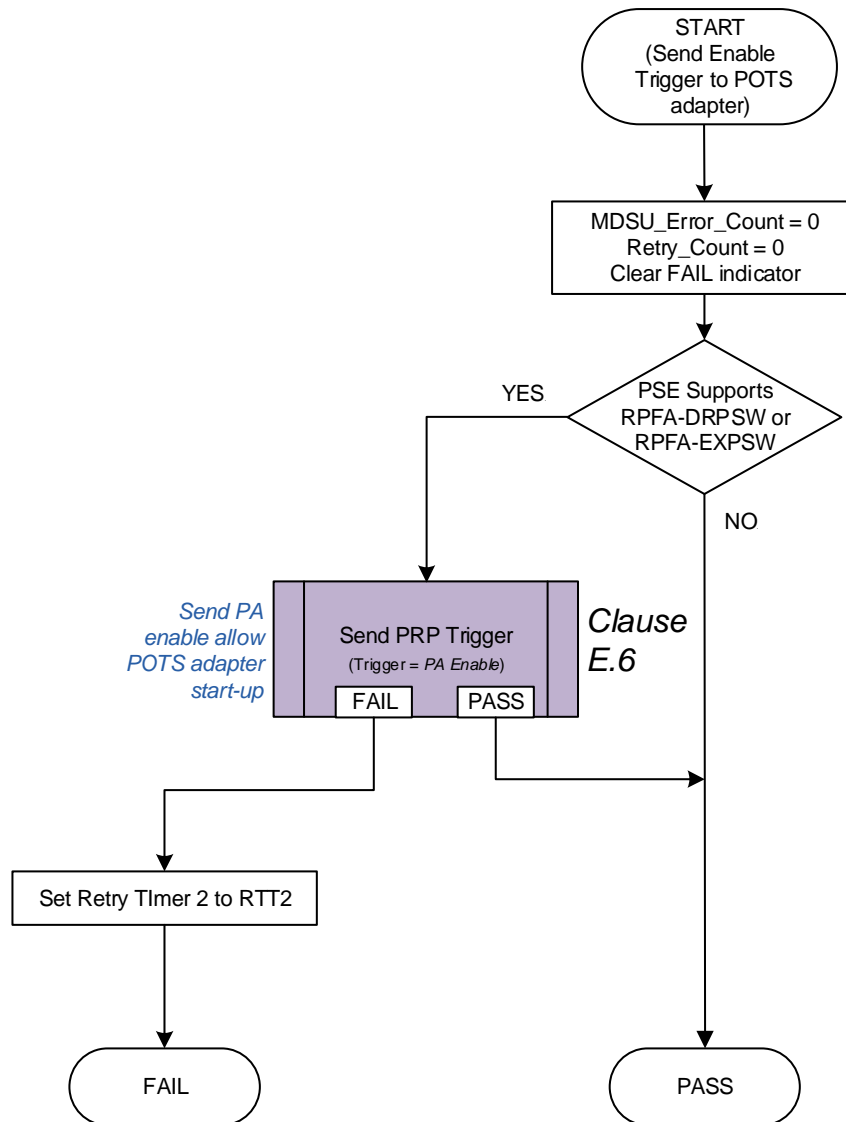


Figure E.7: PRP - Send Enable Trigger to POTS Adapter

Annex F (informative): Long Range RPF Classification

Table F.1 describes two long range RPF classes.

Table F.1: Long range reverse power feed class specifications

Parameter	120 V DC Long Range TNV-3 (CENELEC EN 60950-1 [2]) or ES2 (CENELEC EN 62368-1 [9]) RPF Class LR2 Safety Note (c)	120 V DC Long Range TNV-3 (CENELEC EN 60950-1 [2]) or ES2 (CENELEC EN 62368-1 [9]) RPF Class LR3 Safety Note (d)
Maximum power input at U-R2P	15 VA	21 VA
Maximum DC Voltage on Line	< 120 V	< 120 V
Maximum line current	125 mA	175 mA
Minimum Reach Resistance supported by a DPU (see clause 7.5.2.1)	180 Ω	180 Ω
<p>SAFETY NOTE (c): In general, the DPU should be designed according to specifications defined in CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9] (in this RPF class a single-port DPU will not be subject to a power exceeding 15 W, while a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W). Additionally, when the PSE is installed at end-user premises, it should not be possible for the end-user to access any PSE part or any part of the local network that can carry the voltage on the line (of up to 120 V), as such voltage exceeds the safe value of 60 V.</p> <p>SAFETY NOTE (d): In general, the DPU should be designed according to specifications defined in CENELEC EN 60950-1 [2] or CENELEC EN 62368-1 [9] (a single-port and a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W). Additionally, a single PSE can generate more than 15 VA and should comply with the definition of "limited power source" as per clause 2.5 of CENELEC EN 60950-1 [2] or as per Annex Q of CENELEC EN 62368-1 [9]. Additionally, when the PSE is installed at end-user premises, it should not be possible for the end-user to access any PSE part or any part of the local network that can carry the voltage on the line (of up to 120 V), as such voltage exceeds the safe value of 60 V.</p>		

Annex G (informative): Bibliography

IR Cooper, DW Faulkner: "Reverse Powering Over DSL". Proceedings of the 13th European Conference on Networks and Optical Communications (NOC 2008) 1 - 3 July 2008, Krems, Austria.

ETSI TR 102 614: "Environmental Engineering (EE); Reverse powering of small access network node by end-user equipment: A4 interface".

ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 2: Operated by -48 V direct current (DC)".

ETSI TS 102 533: "Environmental Engineering (EE) Measurement Methods and limits for Energy Consumption in Broadband Telecommunication Networks Equipment".

ETSI TR 102 702: "Access, Terminals, Transmission and Multiplexing (ATTM) Study of issues related to POTS injection in the customer wiring from xDSL VoIP Home Gateway".

ETSI EN 302 099: "Environmental Engineering (EE) Powering of equipment in access network".

Annex H (informative): Change History

Version	Information about changes
2.1.1	Main new functionality/requirements related to the previously published version: <ul style="list-style-type: none"> • Added: Metallic Detection based Start-up (MDSU) protocol • Added: Optional POTS Remote Copper Reconfiguration Start-up protocol (PRP); Removed: CBSU protocol • Added: Interoperability requirements between MDSU and PRP capable devices • Added: RPF architecture without POTS and with "dry DSL" bypass (NOPBB) • Added: RPF Electrical specification • Added: RPF OAM • Added: RPF Noise PSD Requirements • Added: POTS adapter requirements • Added: Power Splitter requirements
2.2.1	<ul style="list-style-type: none"> • Definitions updated • Clause 6.3 updated • Clause 7.5.3 (DPU power modes) added • Various typos corrected • Clause 7.1.1 updated to include reference to CENELEC EN 62368-1. Table 37 and Table G.1 also updated to reflect this • Table 8 updated • Clause 7.5.1.2 (PSE isolation requirements) added • Clause 6.3 updated and Annex F removed • Annex G renamed to Annex F • Clause 7.5.1.1 updated • Comments received during AbC (December 2017) resolved
2.3.1	<ul style="list-style-type: none"> • References updated • Updates to clause 6.3 (RPF Dying Gasp and indication primitives) • Updates to clause 7.3 (Electrical reference model and RPF Noise Limits) • Addition of requirements for PSE Touch Current Limitation and PSE Power frequency common mode immunity clauses 7.5.1.3 and 7.5.1.4 • Updated clause 8.4.4 (Power splitter DSL band noise attenuation) • Updated clause 8.4.10 (Power splitter (POTS band noise attenuation) • Removed placeholder clause 9.4 (Out of Band Signalling Channel)
2.4.1	<ul style="list-style-type: none"> • Corrigendum to V2.3.1

History

Document history		
V1.1.1	September 2014	Publication as ETSI TS 101 548
V1.2.1	November 2014	Publication as ETSI TS 101 548
V2.1.1	September 2016	Publication as ETSI TS 101 548
V2.2.1	June 2018	Publication
V2.3.1	January 2020	Publication
V2.4.1	May 2020	Publication