To: T10 SAS Protocol and Phy Working Groups

From: Brian Day and William Petty

Subject: SAS-2.1 / SPL: 08-439 An Optical OOB Method

Revision History

Revision 0 - Initial draft

Revision 1 - Changed the OOB Idle behavior for optical mode to address EMI concerns raised at the November working group meetings. Added paragraph to descibe negotiation idle in section 6.8.4.

Revision 2 - Editorial changes based on Jan working group feedback. Add new primitive, OOB_IDLE, to be used instead of ALIGN(2), for OOB idle to simplify idle detection in 3GBps environments.

Related Documents

sas2r14f - Serial Attached SCSI - 2 Draft revision 14f

Overview

This proposal provides an alternative OOB method that can be used with commodity optical transceivers. Instead of allowing the differential lines to go to D.C. Idle, specific character sequences (ALIGN(2) and ALIGN(3)) are proposed to provide an "OOB Idle" condition, replacing the D.C. Idle condition.

The proposal has the following main goals:

a) no changes to existing SP state machine operation to significantly leverage the past interoperability testing.
b) be compatible with commodity optical modules/cables used in other interface technologies.
c) define the protocol behavior at the connector interface.

Proposed Changes

In section 3 definitions:

0.0.1 D.C. idle: A differential signal level that is nominally 0 V(P-P)~~, used during the idle time (see 3.1.113) and negation time (see 3.1.150) of an OOB signal (see 3.1.159)~~. See 5.7.4.

0.0.2 D.C. mode : A mode in which D.C. idle is used during the idle time and negation time of an OOB signal, and during the RCDT time of speed negotiation windows (see x.x.x).

0.0.3 idle time: The part of an OOB signal (see 3.1.159) where ~~D.C.~~ OOB idle (see 3.1.47) is being transmitted. See 6.6.

0.0.4 negation time: The part of an OOB signal (see 3.1.159) during which ~~D.C.~~OOB idle (see 3.1.47) is transmitted after the last OOB burst (see 3.1.156). See 6.6.

0.0.5 negotiation idle: The transmission of D.C. idle when D.C mode (see x.x.x) is enabled, or a defined sequence of dwords at a vendor-specific transmit bit rate when optical mode is enabled (see x.x.x).

0.0.6 OOB burst: The transmission of signal transitions~~ ~~or ALIGN(3) primitives for a burst time (see 3.1.25). See 6.6.1.

0.0.7 OOB idle: The transmission of D.C. idle when D.C mode (see x.x.x) is enabled, or a defined sequence of dwords when optical mode is enabled (see x.x.x).

0.0.8 optical mode: A mode in which a defined sequence of dwords is used during the idle time and negation time of an OOB signal, and during the RCDT time of speed negotiation windows (see x.x.x).

0.0.9 speed negotiation transmit time (SNTT): During SNW-1, SNW-2, and Final-SNW, the time after RCDT during which ALIGN (0) or ALIGN (1) is transmitted. During SNW-3, the time after RCDT in which bit cells and ~~D.C.~~ OOB idle are transmitted. See 6.7.4.2.2.

In section 5:

5.7.1 General electrical characteristics

5.7.1.1 General electrical characteristics overview

Table 55 defines the general electrical characteristics, which apply to both transmitter devices and receiver devices..

Table 1 — General electrical characteristics

Characteristic	Units	1.5 Gbps (i.e., G1)	3 Gbps (i.e., G2)	6 Gbps (i.e., G3)
Physical link rate (nominal)	MBps	150	300	600
Unit interval (UI)(nominal) [a]	ps	$666.\overline{6}$	$333.\overline{3}$	$166.\overline{6}$
Baud rate (f_{baud})(nominal)	Gigasymbols/s	1.5	3	6
Maximum A.C. coupling capacitor [b]	nF	12		
Maximum noise during OOB idle time [c] [d]	mV(P-P)	120		

[a] $666.\overline{6}$ equals 2000 / 3. $333.\overline{3}$ equals 1000 / 3. $166.\overline{6}$ equals 500 / 3.
[b] The coupling capacitor value for A.C. coupled transmit and receive pairs. See 5.7.4.2 for A.C. coupling requirements for transmitter devices. See 5.7.5.2 for A.C. coupling requirements for receiver devices. The equivalent series resistance at 3 GHz should be less than 1 ohm.
[c] With a measurement bandwidth of 1.5 × f_{baud} (e.g., 9 GHz for 6 Gbps), no signal level during the idle time shall exceed the specified maximum differential amplitude.
[d] This is not applicable when optical mode is enabled.

5.7.4.3 Transmitter device signal output characteristics for untrained 1.5 Gbps and 3 Gbps as measured with the zero-length test load

Table 2 specifies the signal output characteristics for the transmitter device for untrained 1.5 Gbps and 3 Gbps as measured with the zero-length test load (see 5.5.2) attached at a transmitter device compliance point (i.e., IT or CT). All specifications are based on differential measurements. See 5.7.4.5 for trained 1.5 Gbps, 3 Gbps, and 6 Gbps transmitter device signal output characteristics.

Table 2 — Transmitter device signal output characteristics for untrained 1.5 Gbps and 3 Gbps as measured with the zero-length test load at IT and CT

Signal characteristic [a]	Units	Untrained	
		1.5 Gbps	3 Gbps
Maximum intra-pair skew [b]	ps	20	15
Maximum transmitter device off voltage [c] [f]	mV(P-P)	50	
Maximum rise/fall time [d]	ps	273	137
Minimum rise/fall time [d]	ps	67	
Maximum transmitter output imbalance [e]	%	10	

[a] All tests in this table shall be performed with zero-length test load (see 5.5.2).
[b] The intra-pair skew measurement shall be made at the midpoint of the transition with a repeating 01b or 10b pattern (e.g., D10.2 or D21.5)(see table 242 in 10.2.9.2) on the physical link. The same stable trigger, coherent to the data stream, shall be used for both the Tx+ and Tx- signals. Intra-pair skew is defined as the time difference between the means of the midpoint crossing times of the Tx+ signal and the Tx- signal.
[c] The transmitter device off voltage is the maximum A.C. voltage measured at compliance points IT and CT when the transmitter is unpowered or transmitting D.C. idle (e.g., during idle time of an OOB signal).
[d] Rise/fall times are measured from 20 % to 80 % of the transition with a repeating 01b or 10b pattern (e.g., D10.2 or D21.5)(see table 242 in 10.2.9.2) on the physical link.
[e] The maximum difference between the V+ and V- A.C. rms transmitter device amplitudes measured with CJTPAT (see A.2) into the zero-length test load shown in figure 111 (see 5.5.2), as a percentage of the average of the V+ and V- A.C. rms amplitudes.
[f] This is not applicable when optical mode is enabled.

5.7.4.5 Transmitter device signal output characteristics for trained 1.5 Gbps, 3 Gbps, and 6 Gbps

5.7.4.5.1 Transmitter device signal output characteristics for trained 1.5 Gbps, 3 Gbps, and 6 Gbps overview

Table 3 specifies the signal output characteristics for the transmitter device for trained 1.5 Gbps, 3 Gbps, and 6 Gbps as measured with the zero-length test load (see 5.5.2), unless otherwise specified, attached at a transmitter device compliance point (i.e., IT or CT). All specifications are based on differential measurements.

Table 3 — Transmitter device signal output characteristics for trained 1.5 Gbps, 3 Gbps, and 6 Gbps at IT and CT

Signal characteristic	Units	Minimum	Nominal	Maximum
Peak to peak voltage (V_{P-P}) [a]	mV(P-P)	850		1 200
Transmitter device off voltage [b,m]	mV(P-P)			50
Withstanding voltage (non-operational)	mV(P-P)	2 000		
Rise/fall time [c]	UI	0.25 [d]		
Reference differential impedance [e]	ohm		100	
Reference common mode impedance [e]	ohm		25	
Common mode voltage limit (rms) [f]	mV			30
RJ [g, j]	UI			0.15 [k]
TJ [g, h]	UI			0.25 [d]
TJ - DDJ [g, i]	UI			0.25 [d]
WDP at 6 Gbps [l]	dB			13
WDP at 3 Gbps [l]	dB			7
WDP at 1.5 Gbps [l]	dB			4.5

a See 5.7.4.5.6 for the V_{P-P} measurement method.
b The transmitter device off voltage is the maximum A.C. voltage measured at compliance points IT and CT when the transmitter is unpowered or transmitting D.C. idle (e.g., during idle time of an OOB signal).
c Rise/fall times are measured from 20 % to 80 % of the transition with a repeating 01b or 10b pattern (e.g., D10.2 or D21.5)(see table 242 in 10.2.9.2) on the physical link.
d 0.25 UI is $41.\overline{6}$ ps at 6 Gbps, $83.\overline{3}$ ps at 3 Gbps, and $166.\overline{6}$ ps at 1.5 Gbps.
e See 5.7.4.5.3 for transmitter device S-parameters characteristics.
f This is a broadband limit. For additional limits on spectral content, see figure 130 and table 63.
g The RJ measurement shall be performed with a repeating 0011b or 1100b pattern (e.g., D24.3)(see table 242 in 10.2.9.2) with SSC disabled. RJ is 14 times the RJ 1 sigma value, based on a BER of 10^{-12}. For simulations based on a BER of 10^{-15}, the RJ specified is 17 times the RJ 1 sigma value.
h The TJ measurement shall be performed with a repeating 0011b or 1100b pattern (e.g., D24.3)(see table 242 in 10.2.9.2). If the transmitter device supports SSC, then this test shall be performed with both SSC enabled and SSC disabled.
i The TJ - DDJ measurement should be performed, but is not required. This test shall be performed with CJTPAT (see table 242 in 10.2.9.2). If the transmitter device supports SSC, then this test shall be performed with both SSC enabled and SSC disabled.
j The measurement shall include the effects of the JTF (see 5.7.3.2).
k 0.15 UI is 25 ps at 6 Gbps, 50 ps at 3 Gbps, and 100 ps at 1.5 Gbps.
l See 5.7.4.5.2 for the transmitter device test procedure.
m This is not applicable when optical mode is enabled.

5.7.4.6 Transmitter device signal output characteristics for OOB signals

Transmitter devices supporting SATA shall use SATA Gen1i or Gen2i signal output levels (see SATA) during the first OOB sequence (see 6.7) after a power on or hard reset. If the phy does not receive COMINIT within a hot-plug timeout (see 6.7.5), then the transmitter device shall increase its transmit levels to the OOB signal output levels specified in table 4 and perform the OOB sequence again. If no COMINIT is received within a hot-plug timeout of the second OOB sequence, then the transmitter device shall initiate another OOB sequence using SATA Gen1i or Gen2i signal output levels. The transmitter device shall continue alternating between transmitting COMINIT using SATA Gen1i or Gen2i signal output levels and transmitting COMINIT with SAS signal output levels until the phy receives COMINIT.

If the phy both transmits and receives COMSAS (i.e., a SAS phy or expander phy is attached), then the transmitter device shall set its transmit levels to the SAS signal output levels (see 5.7.4.3, 5.7.4.5, and 5.7.4.5) prior to beginning the SAS speed negotiation sequence (see 6.7.4.2). If it had been using SATA Gen1i or Gen2i signal output levels, this mode transition (i.e., output voltage change) may result in a transient (see 5.7.2) during the idle time between COMSAS and the SAS speed negotiation sequence.

If the transmitter device is using SAS signal output levels and the phy does not receive COMSAS (i.e., a SATA phy is attached), then the transmitter device shall set its transmit levels to the SATA Gen1i or Gen2i signal output levels and restart the OOB sequence.

Transmitter devices that do not support SATA shall transmit OOB signals using SAS signal output levels.

Table 4 defines the transmitter device signal output characteristics for OOB signals.

Table 4 — Transmitter device signal output characteristics for OOB signals

Characteristic	Units	IT	CT
Maximum peak to peak voltage (i.e., 2 × Z2 in figure 127) [a]	mV(P-P)	1 600	
OOB offset delta [b,g]	mV	± 25	
OOB common mode delta [c,g]	mV	± 50	
Minimum OOB burst amplitude [d], if SATA is not supported	mV(P-P)	240	
Minimum OOB burst amplitude [d], if SATA is supported	mV(P-P)	240 [e, f]	N/A

[a] The recommended maximum peak to peak voltage is 1 200 mV(P-P).
[b] The maximum difference in the average differential voltage (D.C. offset) component between the burst times and the idle times of an OOB signal.
[c] The maximum difference in the average of the common-mode voltage between the burst times and the idle times of an OOB signal.
[d] With a measurement bandwidth of 4.5 GHz, each signal level during the OOB burst shall exceed the specified minimum differential amplitude before transitioning to the opposite bit value or before termination of the OOB burst as measured with each test load at IT and CT.
[e] Amplitude measurement methodologies of SATA and this standard differ. Under conditions of maximum rise/fall time and jitter, eye diagram methodologies used in this standard may indicate less signal amplitude than the technique specified by SATA. Implementers of designs supporting SATA are required to ensure interoperability and should perform additional system characterization with an eye diagram methodology using SATA devices.
[f] The OOB burst contains either 1.5 Gbps D24.3 characters, 1.5 Gbps ALIGN (0) primitives, or 3 Gbps ALIGN (0) primitives (see 6.6 and SATA).
[g] This is not applicable when optical mode is enabled.

5.7.6 Spread spectrum clocking (SSC)

5.7.6.1 SSC overview

Spread spectrum clocking (SSC) is the technique of modulating the operating frequency of a transmitted signal to reduce the measured peak amplitude of radiated emissions.

Phys transmit with SSC as defined in and receive with SSC as defined in 5.7.6.3.

NOTE 1 - Phys compliant with previous versions of this standard do not transmit with SSC. Phys compliant with previous versions of this standard that do not support being attached to SATA devices were not required to receive with SSC.

Table 5 defines the SSC modulation types.

Table 5 — SSC modulation types

SSC modulation type	Maximum SSC frequency deviation (SSC_{tol}) [a]
Center-spreading	+2 300 / -2 300 ppm
No-spreading	+0 / -0 ppm
Down-spreading	+0 / -2 300 ppm
SATA down-spreading [b]	+0 / -5 000 ppm

[a] This is in addition to the physical link rate long-term stability and tolerance defined in table 56 and table 58 (see 5.7.1).
[b] This is only used as a receiver parameter.

A phy may be transmitting with a different SSC modulation type than it is receiving (e.g., a phy is transmitting with center-spreading while it is receiving with down-spreading).

If the SSC modulation type is not no-spreading, then the phy shall transmit within the specified maximum SSC frequency deviation with an SSC modulation frequency that is a minimum of 30 kHz and a maximum of 33 kHz.

The SSC modulation profile (e.g., triangular) is vendor-specific, but should provide the maximum amount of electromagnetic interference (EMI) reduction. For center-spreading, the average amount of up-spreading (i.e., > 0 ppm) in the SSC modulation profile shall be the same as the average amount of down-spreading (i.e., < 0 ppm). The amount of asymmetry in the SSC modulation profile shall be less than 288 ppm.

NOTE 2 - 288 ppm is the rate of deletable primitives that are left over after accounting for the physical link rate long-term stability. It is calculated as the deletable primitive rate defined in previous versions of this standard of 1/2 048 (i.e., 488 ppm) minus the width between the extremes of the physical link rate long-term stability of +100/-100 ppm (i.e., 200 ppm).

SSC-induced jitter is included in TJ at the transmitter output. SSC-induced jitter shall be measured using a D30.3 pattern (see table 242 in 10.2.9.2) after the application of the JTF (see 5.7.3.2).

The slope of the frequency deviation should not exceed 850 ppm/µs when computed over any 0.27 ± 0.01 µs interval of the SSC modulation profile, after filtering of the transmitter device jitter output by a single-pole low-pass filter with a cutoff frequency of 3.7 ± 0.2 MHz. Alternatively, the transmitter device jitter may be filtered by the closed-loop transfer function of a measurement equipment's PLL that is compliant with the JTF.

The slope is computed from the difference equation:

slope = (f(t) - f(t - 0.27 µs)) / 0.27 µs

where:

f(t) is the SSC frequency deviation expressed in ppm

NOTE 3 - A ± 2 300 ppm triangular SSC modulation profile has a slope of approximately 310 ppm/µs and meets the informative slope specification. Other SSC modulation profiles (e.g., exponential) may not meet the slope requirement. A modulation profile that has a slope of ± 850 ppm/µs over 0.27 µs creates a residual jitter of approximately 16.7 ps (i.e., 0.10 UI at 6 Gbps) after filtering by the JTF. This consumes the total BUJ budget of the transmitter device, which does not allow the transmitter device to contribute any other type of BUJ.

Activation or deactivation of SSC on a physical link that is not ~~D.C.~~ OOB idle or negotiation idle shall be done without violating TJ at the transmitter device output after application of the JTF.

In Section 6:

6.6 Out of band (OOB) signals

6.6.1 OOB signals overview

~~Out of band (OOB) signals are low-speed signal patterns that do not appear in normal data streams.~~ If D.C. mode (see x.x.x) is enabled, OOB signals are low-speed signal patterns that do not appear in normal data streams. When optical mode is enabled, OOB signals consist of a defined series of dwords. OOB signals consist of defined amounts of idle time followed by defined amounts of burst time. During the idle time, the physical link carries ~~D.C.~~ OOB idle ~~(see 3.1.47)~~(fix xref). During the burst time, the physical link carries ~~signal transitions~~dwords. The signals are differentiated by the length of idle time between the burst times. A phy shall either have D.C. mode enabled or optical mode enabled. The method to enable D.C. mode or optical mode is outside the scope of this standard.

SATA defines two OOB signals: COMINIT/COMRESET and COMWAKE. COMINIT and COMRESET are used in this standard interchangeably. Phys compliant with this standard identify themselves with an additional SAS-specific OOB signal called COMSAS.

Table 6 defines the timing specifications for OOB signals.

Table 6 — OOB signal timing specifications

Parameter	Minimum	Nominal	Maximum	Comments
OOB Interval (OOBI) [a]	$665.0\overline{6}$ ps [b]	$666.\overline{6}$ ps [c]	$668.2\overline{6}$ ps [d]	The time basis for burst times and idle times used to create OOB signals.
COMSAS detect timeout	13.686 µs [e]			The minimum time a receiver device shall allow to detect COMSAS after transmitting COMSAS.

[a] OOBI is different than UI(OOB) defined in SATA (e.g., SAS has tighter physical link rate long-term stability and different SSC frequency deviation). OOBI is based on:
- A) 1.5 Gbps UI (see table 55 in 5.7.1);
- B) physical link rate long-term stability (see table 56 in 5.7.2); and
- C) center-spreading SSC (see table 79 in 5.7.6.1).

[b] $665.0\overline{6}$ ps equals $666.\overline{6} \times (1 - 0.0024)$.
[c] $666.\overline{6}$ equals 2000 / 3.
[d] $668.2\overline{6}$ ps equals $666.\overline{6} \times 1.0024$.
[e] 13.686 µs is 512 × 40 × Maximum OOBI.

To interoperate with interconnects compliant with previous versions of this standard, phys should create OOB burst times and idle times based on the UI for 1.5 Gbps without SSC modulation.

NOTE 4 - Previous versions of this standard defined OOBI based on the nominal UI for 1.5 Gbps with physical link rate long-term stability tolerance (see table 55 in 5.7.1) but not with SSC modulation (see table 79 in 5.7.6.1). Interconnects compliant with previous versions of this standard may have assumed phys had that characteristic.

6.6.2 Transmitting OOB signals

Table 7 describes the OOB signal transmitter requirements for the burst time, idle time, negation times, and signal times that are used to form each OOB signal.

Table 7 — OOB signal transmitter device requirements

Signal	Burst time	Idle time	Negation time	Signal time [a]
COMWAKE	160 OOBI [b]	160 OOBI [b]	280 OOBI [c]	2 200 OOBI [g]
COMINIT/COMRESET	160 OOBI [b]	480 OOBI [d]	800 OOBI [e]	4 640 OOBI [i]
COMSAS	160 OOBI [b]	1 440 OOBI [f]	2 400 OOBI [h]	12 000 OOBI [j]

[a] A signal time is six burst times plus six idle times plus one negation time.
[b] 160 OOBI is nominally 106.$\overline{6}$ ns (see table 6 in 6.6.1).
[c] 280 OOBI is nominally 186.$\overline{6}$ ns.
[d] 480 OOBI is nominally 320 ns.
[e] 800 OOBI is nominally 533.$\overline{3}$ ns.
[f] 1 440 OOBI is nominally 960 ns.
[g] 2 200 OOBI (e.g., COMWAKE) is nominally 1 466.$\overline{6}$ ns.
[h] 2 400 OOBI is nominally 1 600 ns.
[i] 4 640 OOBI (e.g., COMINIT/COMRESET) is nominally 3 093.$\overline{3}$ ns.
[j] 12 000 OOBI (e.g., COMSAS) is nominally 8 000 ns.

If D.C. mode is enabled, an OOB idle consists of the transmission of D.C. idle.

If optical mode is enabled, an OOB idle consists of repetitions of the following steps:

1) transmission of six OOB_IDLE primitives with either starting disparity at 3.0 Gbps; and
2) transmission of up to 1 024 dwords set to 00000000h that are transmitted scrambled and 8b10b encoded at 3.0 Gbps.

An OOB burst consists of:

a) if D.C. mode is enabled, transmission of D24.3 characters or ALIGN (0) primitives with either starting disparity. The OOB burst should consist of D24.3 characters at 1.5 Gbps; or
b) if optical mode is enabled, transmission of ALIGN (3) primitives with either starting disparity at 3.0 Gbps.

To transmit an OOB signal, the transmitter device shall repeat these steps six times:

1) transmit ~~D.C.~~ OOB idle for an idle time; and
2) transmit an OOB burst ~~with either starting disparity consisting of D24.3 characters or ALIGN (0) primitives~~ for a burst time. ~~The OOB burst should consist of D24.3 characters.~~

NOTE 5 - Transmitter devices compliant with future versions of this standard may not transmit OOB bursts consisting of ALIGN (0) primitives.

The transmitter device shall then transmit ~~D.C.~~OOB idle for an OOB signal negation time.

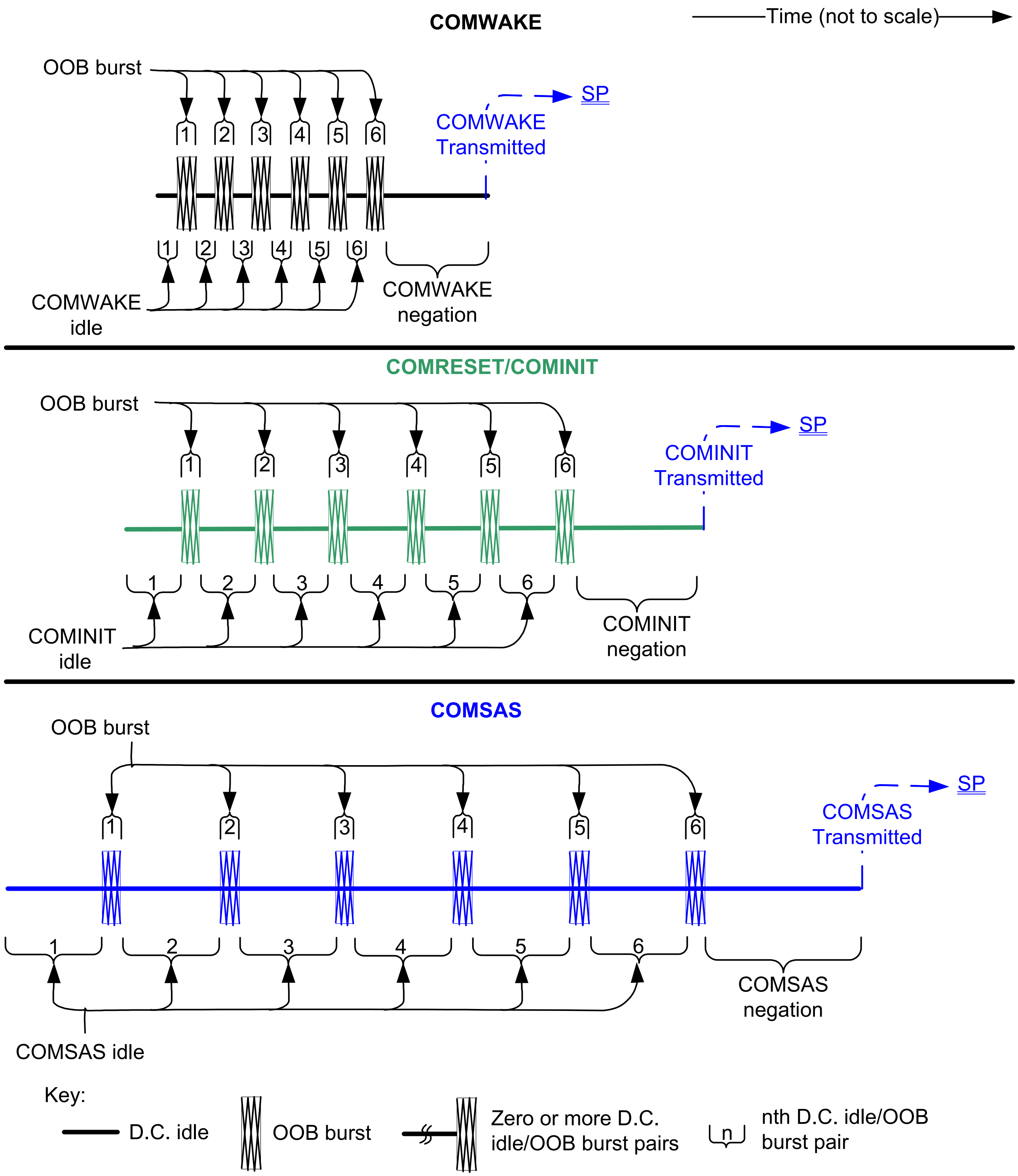
The transmitter device shall use signal output levels during burst time and idle time as described in 5.7.4.6.

When D.C. mode is enabled, ~~T~~the D24.3 characters or ALIGN (0) primitives used in OOB signals shall be transmitted ~~at 1.5 Gbps~~, and~~.~~ t~~T~~he OOB burst is only required to generate an envelope for the detection circuitry, as required for any signaling that may be A.C. coupled. A burst of D24.3 characters at 1.5 Gbps is equivalent to a square wave pattern that has a one for 2 OOBI and a zero for 2 OOBI. A transmitter may use this square wave pattern for the OOB signal. The start of the pattern may be one or zero. The signal rise and fall times:

a) shall be greater than (i.e., slower) or equal to the minimum (i.e., fastest) rise and fall times allowed by the fastest supported physical link rate of the transmitter device (see table 60 in 5.7.4.3); and
b) shall be less than (i.e., faster) or equal to the maximum (i.e., slowest) rise and fall times allowed at 1.5 Gbps.

Editor's Note 1: All figures in section 6 need to replace "D.C. Idle" with "OOB Idle".

Figure 1 describes OOB signal transmission by the SP transmitter (see 6.8). The COMWAKE Transmitted, COMINIT Transmitted, and COMSAS Transmitted messages are sent to the SP state machine (see 6.8).



Note: D.C. idle is shown here as a neutral signal for visual clarity only.

Figure 1 — OOB signal transmission

6.6.3 Receiving OOB signals

Table 8 describes the OOB signal receiver device requirements for detecting burst times, assuming T_{burst} is the length of the detected burst time. The burst time is not used to distinguish between signals.

Table 8 — OOB signal receiver device burst time detection requirements

Signal [a]	may detect	shall detect
COMWAKE	$T_{burst} \le 100$ ns	$T_{burst} > 100$ ns
COMINIT/COMRESET	$T_{burst} \le 100$ ns	$T_{burst} > 100$ ns
COMSAS	$T_{burst} \le 100$ ns	$T_{burst} > 100$ ns

[a] Each burst time is transmitted as 160 OOBI, which is nominally $106.\overline{6}$ ns (see table 7 in 6.6.2).

Table 9 describes the OOB signal receiver device requirements for detecting idle times, assuming T_{idle} is the length of the detected idle time.

Table 9 — OOB signal receiver device idle time detection requirements

Signal	may detect	shall detect	shall not detect
COMWAKE [a]	35 ns $\le T_{idle} <$ 175 ns	101.3 ns $\le T_{idle} \le$ 112 ns	$T_{idle} <$ 35 ns or T_{idle} □ 175 ns
COMINIT/ COMRESET [b]	175 ns $\le T_{idle} <$ 525 ns	304 ns $\le T_{idle} \le$ 336 ns	$T_{idle} <$ 175 ns or T_{idle} □ 525 ns
COMSAS [c]	525 ns $\le T_{idle} <$ 1 575 ns	911.7 ns $\le T_{idle} \le$ 1 008 ns	$T_{idle} <$ 525 ns or T_{idle} □ 1 575 ns

[a] COMWAKE idle time is transmitted as 160 OOBI, which is nominally $106.\overline{6}$ ns (see table 7 in 6.6.2).
[b] COMINIT/COMRESET idle time is transmitted as 480 OOBI, which is nominally 320 ns.
[c] COMSAS idle time is transmitted as 1 440 OOBI, which is nominally 960 ns.

Table 10 describes the OOB signal receiver device requirements for detecting negation times, assuming T_{idle} is the length of the detected idle time.

Table 10 — OOB signal receiver device negation time detection requirements

Signal	shall detect
COMWAKE [a]	$T_{idle} >$ 175 ns
COMINIT/COMRESET [b]	$T_{idle} >$ 525 ns
COMSAS [c]	$T_{idle} >$ 1 575 ns

[a] COMWAKE negation time is transmitted as 280 OOBI, which is nominally $186.\overline{6}$ ns (see table 7 in 6.6.2).
[b] COMINIT/COMRESET negation time is transmitted as 800 OOBI is nominally $533.\overline{3}$ ns.
[c] COMSAS negation time, which is transmitted as 2 400 OOBI, which is nominally 1 600 ns.

A receiver device shall detect an OOB signal after receiving four consecutive idle time/burst time pairs (see figure 2) while the SP_DWS state machine (see 6.9) has not achieved dword synchronization (see 6.8.4.9 and 6.8.5.8), and may, but should not, detect an OOB signal after receiving four consecutive idle time/burst time pairs while the SP_DWS state machine has achieved dword synchronization. It is not an error to receive more than four idle time/burst time pairs. A receiver device shall not detect the same OOB signal again until it has detected the corresponding negation time (e.g., a COMINIT negation time for a COMINIT) or has detected a different OOB signal (e.g., if a receiver device that previously detected COMINIT receives four sets of COMWAKE idle times followed by burst times, then it detects COMWAKE. The receiver device may then detect COMINIT again).

When D.C. mode is enabled, aA SAS receiver device shall detect OOB bursts formed from any of the following:

a) D24.3 characters at 1.5 Gbps;
b) ALIGN (0) primitives at 1.5 Gbps; or
c) ALIGN (0) primitives at 3 Gbps.

NOTE 6 - ALIGN (0) primitives at 3 Gbps provide interoperability with transmitter devices compliant with previous versions of this standard and SATA.

When D.C mode is enabled, aA SAS receiver device shall not qualify the OOB burst based on the characters received.

When optical mode is enabled, a SAS receiver device shall detect OOB bursts formed from ALIGN(3) primitives at 3Gbps.

Editor's Note 2: Throughout section 6.7 and 6.8, replace all references of "D.C. idle" with "OOB idle" for the idle times to transmit OOB signals. Change all references of "D.C. idle" with "negation idle" for the idle time during the speed negotiation window during the RCDT.

Figure 2 describes SAS OOB signal detection by the SP receiver (see 6.8). The COMWAKE Detected, COMWAKE Completed, COMINIT Detected, COMSAS Detected, and COMSAS Completed messages are sent to the SP state machine (see 6.8) to indicate that an OOB signal has been partially or fully detected.

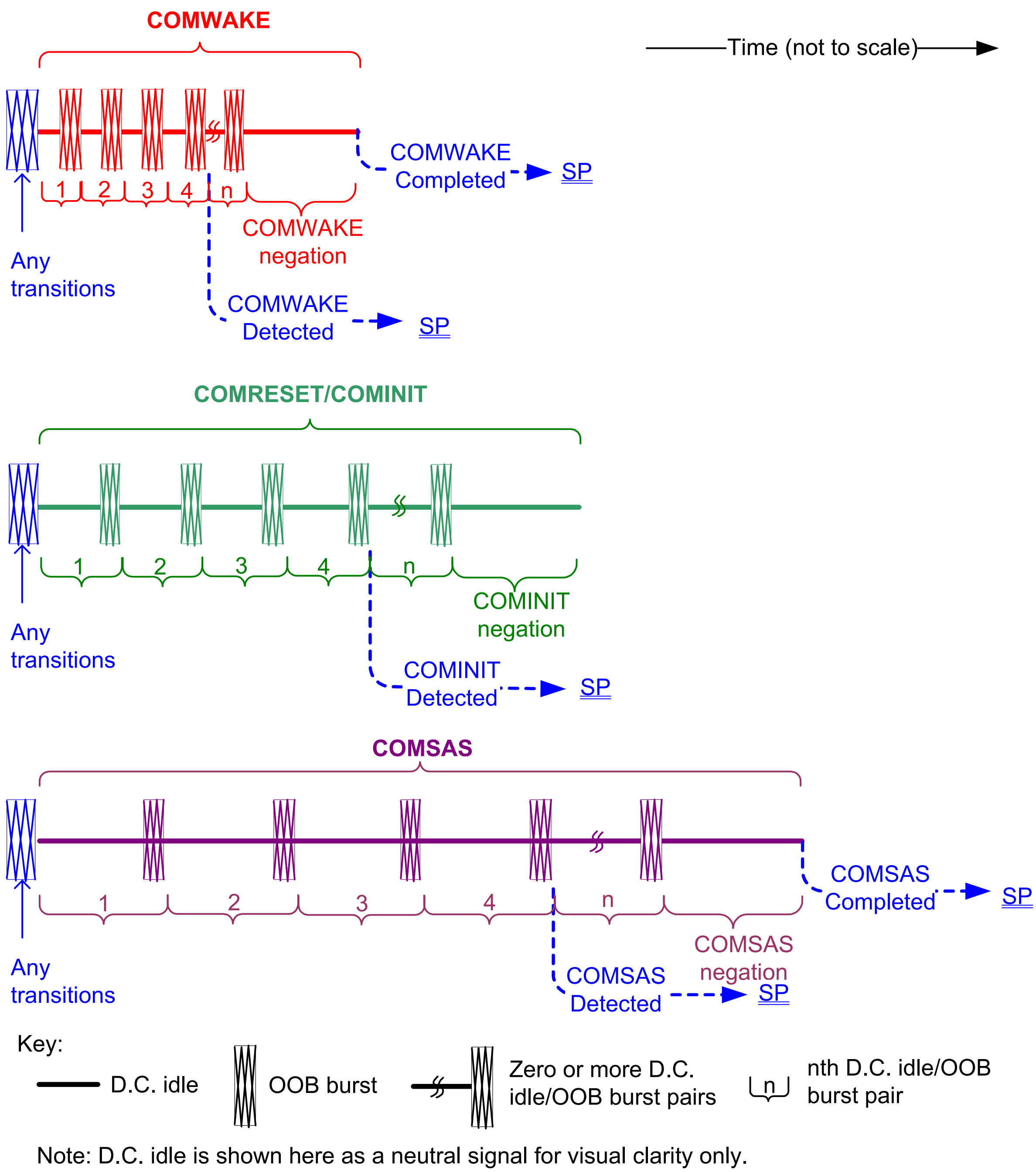


Figure 2 — OOB signal detection

Expander devices shall not forward OOB signals. An expander device shall run the link reset sequence independently on each physical link.

6.6.4 Transmitting the SATA port selection signal

The SATA port selection signal shown in figure 3 causes the attached SATA port selector to select the attached phy (i.e., one of the port selector's host phys) as the active phy (see SATA).

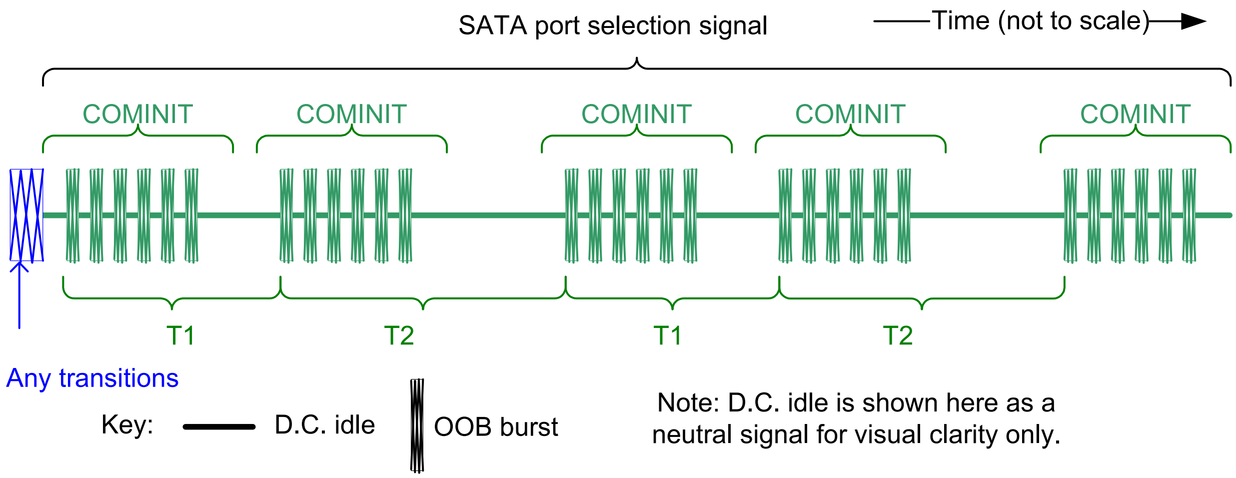


Figure 3 — SATA port selection signal

The SATA port selection signal shall be composed of 5 COMINIT signals, each starting a specified time interval, T1 or T2, as shown in figure 3, after the start of the OOB burst portion of the previous COMINIT signal. The values of T1 and T2 shall be as shown in table 11.

Table 11 — SATA port selection signal transmitter device requirements

Parameter	Time
T1	3×10^6 OOBI [a]
T2	12×10^6 OOBI [b]

[a] 3×10^6 OOBI is nominally 2 ms (see table 6 in 6.6.1).
[b] 12×10^6 OOBI is nominally 8 ms.

See 6.8.6 and 10.4.3.28 for information on usage of the SATA port selection signal.

6.8.4 SAS speed negotiation states

6.8.4.1 SAS speed negotiation OOB idle

SAS speed negotiation states use negotiation idle at the beginning of each speed negotiation window.

If D.C. mode is enabled, an OOB idle consists of the transmission of D.C. idle.

If optical mode is enabled, an OOB idle consists of repetitions of the following steps:

1) transmission of six OOB_IDLE primitives with either starting disparity at a vendor-specific bit rate; and
2) transmission of up to 1 024 dwords set to 00000000h that are transmitted scrambled and 8b10b encoded at a vendor-specific bit rate.

In section 7:

7.2.2 Primitive summary

Table 12 defines the deletable primitives.

Table 12 — Deletable primitives

<table>
<tr><th rowspan="2">Primitive</th><th rowspan="2">Use [a]</th><th colspan="3">From [b]</th><th colspan="3">To [b]</th><th rowspan="2">Primitive sequence type [c]</th></tr>
<tr><th>I</th><th>E</th><th>T</th><th>I</th><th>E</th><th>T</th></tr>
<tr><td>ALIGN (0)</td><td>All, SpNeg</td><td rowspan="4">I</td><td rowspan="4">E</td><td rowspan="4">T</td><td rowspan="4">I</td><td rowspan="4">E</td><td rowspan="4">T</td><td rowspan="4">Single</td></tr>
<tr><td>ALIGN (1)</td><td>SAS, SpNeg</td></tr>
<tr><td>ALIGN (2)</td><td rowspan="2">SAS</td></tr>
<tr><td>ALIGN (3)</td></tr>
<tr><td>MUX (LOGICAL LINK 0)</td><td rowspan="2">SAS</td><td rowspan="2">I</td><td rowspan="2">E</td><td rowspan="2">T</td><td rowspan="2">I</td><td rowspan="2">E</td><td rowspan="2">T</td><td rowspan="2">Single</td></tr>
<tr><td>MUX (LOGICAL LINK 1)</td></tr>
<tr><td>NOTIFY (ENABLE SPINUP)</td><td rowspan="4">SAS</td><td>I</td><td>E</td><td></td><td></td><td></td><td>T</td><td rowspan="4">Single</td></tr>
<tr><td>NOTIFY (POWER LOSS EXPECTED)</td><td>I</td><td>E</td><td></td><td></td><td></td><td>T</td></tr>
<tr><td>NOTIFY (RESERVED 1)</td><td></td><td></td><td></td><td>I</td><td>E</td><td>T</td></tr>
<tr><td>NOTIFY (RESERVED 2)</td><td></td><td></td><td></td><td>I</td><td>E</td><td>T</td></tr>
<tr><td>OOB_IDLE</td><td>SAS, SpNeg</td><td>I</td><td>E</td><td>T</td><td>I</td><td>E</td><td>T</td><td>Single</td></tr>
</table>

[a] The Use column indicates when the primitive is used:
a) All: SAS logical links and SATA physical links;
b) SAS: SAS logical links, both outside connections or inside any type of connection;
c) NoConn: SAS logical links, outside connections;
d) Conn: SAS logical links, inside connections;
e) STP: SAS logical links, inside STP connections; or
f) SpNeg: SAS physical links, during speed negotiation.

[b] The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:
a) I for SAS initiator ports;
b) E for expander ports; and
c) T for SAS target ports.
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

[c] The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 7.2.4).

7.2.3 Primitive encodings

Table 13 defines the primitive encoding for deletable primitives.

Table 13 — Primitive encoding for deletable primitives

Primitive	Character				Hexadecimal
	1st	2nd	3rd	4th (last)	
ALIGN (0)	K28.5	D10.2	D10.2	D27.3	BC4A4A7Bh
ALIGN (1)	K28.5	D07.0	D07.0	D07.0	BC070707h
ALIGN (2)	K28.5	D01.3	D01.3	D01.3	BC616161h
ALIGN (3)	K28.5	D27.3	D27.3	D27.3	BC7B7B7Bh
MUX (LOGICAL LINK 0)	K28.5	D02.0	D16.7	D31.4	BC02F09Fh
MUX (LOGICAL LINK 1)	K28.5	D04.7	D31.4	D27.4	BCE49F9Bh
NOTIFY (ENABLE SPINUP)	K28.5	D31.3	D31.3	D31.3	BC7F7F7Fh
NOTIFY (POWER LOSS EXPECTED)	K28.5	D31.3	D07.0	D01.3	BC7F0761h
NOTIFY (RESERVED 1)	K28.5	D31.3	D01.3	D07.0	BC7F6107h
NOTIFY (RESERVED 2)	K28.5	D31.3	D10.2	D10.2	BC7F4A4Ah
OOB_IDLE	K28.5	D07.3	D01.4	D31.4	BC67819Fh

Editor's Note 3: Make corresponding change in Appendix showing the primitive encodings.

7.2.3.1 OOB_IDLE

OOB_IDLE is used for OOB signals when optical mode is enabled (see x.x.x).

In section 10:

Table 14 — DISCOVER response (part 1 of 4)

Byte\Bit	7	6	5	4	3	2	1	0
0	SMP FRAME TYPE (41h)							
1	FUNCTION (10h)							
2	FUNCTION RESULT							
3	RESPONSE LENGTH (00h or 1Ch)							
4	(MSB)	EXPANDER CHANGE COUNT						
5								(LSB)
6	Reserved							
8								

Table 14 — DISCOVER response (part 2 of 4)

Byte\Bit	7	6	5	4	3	2	1	0
9	PHY IDENTIFIER							
10 … 11	Reserved							
12	Reserved	ATTACHED DEVICE TYPE			ATTACHED REASON			
13	Reserved				NEGOTIATED LOGICAL LINK RATE			
14	Reserved				ATTACHED SSP INITIATOR	ATTACHED STP INITIATOR	ATTACHED SMP INITIATOR	ATTACHED SATA HOST
15	ATTACHED SATA PORT SELECTOR	Reserved			ATTACHED SSP TARGET	ATTACHED STP TARGET	ATTACHED SMP TARGET	ATTACHED SATA DEVICE
16 … 23	SAS ADDRESS							
24 … 31	ATTACHED SAS ADDRESS							
32	ATTACHED PHY IDENTIFIER							
33	Reserved					ATTACHED INSIDE ZPSDS PERSISTENT	ATTACHED REQUESTED INSIDE ZPSDS	ATTACHED BREAK_REPLY CAPABLE
34 … 39	Reserved for IDENTIFY address frame-related fields							
40	PROGRAMMED MINIMUM PHYSICAL LINK RATE				HARDWARE MINIMUM PHYSICAL LINK RATE			
41	PROGRAMMED MAXIMUM PHYSICAL LINK RATE				HARDWARE MAXIMUM PHYSICAL LINK RATE			
42	PHY CHANGE COUNT							
43	VIRTUAL PHY	Reserved			PARTIAL PATHWAY TIMEOUT VALUE			
44	Reserved				ROUTING ATTRIBUTE			
45	Reserved	CONNECTOR TYPE						
46	CONNECTOR ELEMENT INDEX							
47	CONNECTOR PHYSICAL LINK							
48 … 49	Reserved							
50 … 51	Vendor specific							
52 … 59	ATTACHED DEVICE NAME							

Table 14 — DISCOVER response (part 3 of 4)

Byte\Bit	7	6	5	4	3	2	1	0
60	Reserved	REQUESTED INSIDE ZPSDS CHANGED BY EXPANDER	INSIDE ZPSDS PERSISTENT	REQUESTED INSIDE ZPSDS	Reserved	ZONE GROUP PERSISTENT	INSIDE ZPSDS	ZONING ENABLED
61 ... 62	Reserved for zoning-related fields							
63	ZONE GROUP							
64	SELF-CONFIGURATION STATUS							
65	SELF-CONFIGURATION LEVELS COMPLETED							
66 ... 67	Reserved for self-configuration related fields							
68 ... 75	SELF-CONFIGURATION SAS ADDRESS							
76 ... 79	PROGRAMMED PHY CAPABILITIES							
80 ... 83	CURRENT PHY CAPABILITIES							
84 ... 87	ATTACHED PHY CAPABILITIES							
88 ... 93	Reserved							
94	REASON				NEGOTIATED PHYSICAL LINK RATE			
95	Reserved					OPTICAL MODE ENABLED	NEGOTIATED SSC	HARDWARE MUXING SUPPORTED
96	Reserved		DEFAULT INSIDE ZPSDS PERSISTENT	DEFAULT REQUESTED INSIDE ZPSDS	Reserved	DEFAULT ZONE GROUP PERSISTENT	Reserved	DEFAULT ZONING ENABLED
97	Reserved							
98	Reserved							
99	DEFAULT ZONE GROUP							

Table 14 — DISCOVER response (part 4 of 4)

Byte\Bit	7	6	5	4	3	2	1	0
100	Reserved		SAVED INSIDE ZPSDS PERSISTENT	SAVED REQUESTED INSIDE ZPSDS	Reserved	SAVED ZONE GROUP PERSISTENT	Reserved	SAVED ZONING ENABLED
101	Reserved							
102	Reserved							
103	SAVED ZONE GROUP							
104	Reserved		SHADOW INSIDE ZPSDS PERSISTENT	SHADOW REQUESTED INSIDE ZPSDS	Reserved	SHADOW ZONE GROUP PERSISTENT	Reserved	
105	Reserved							
106	Reserved							
107	SHADOW ZONE GROUP							
108	DEVICE SLOT NUMBER							
109	DEVICE SLOT GROUP NUMBER							
110	DEVICE SLOT GROUP OUTPUT CONNECTOR							
115								
116	(MSB) CRC							
119								(LSB)

An OPTICAL MODE ENABLE bit set to one indicates that the phy is operating in optical mode (see x.x.x). An OPTICAL MODE ENABLE bit set to zero indicates that the phy is operating in D.C. mode.

Table 15 — Enhanced phy control mode descriptor

Byte\Bit	7	6	5	4	3	2	1	0
0	Reserved							
1	PHY IDENTIFIER							
2	(MSB) DESCRIPTOR LENGTH (0010h)							
3								(LSB)
4	PROGRAMMED PHY CAPABILITIES							
7								

Table 15 — Enhanced phy control mode descriptor

Byte\Bit	7	6	5	4	3	2	1	0
8 11	CURRENT PHY CAPABILITIES							
12 15	ATTACHED PHY CAPABILITIES							
16 17	Reserved							
18	Reserved		OPTICAL MODE ENABLED	NEGOTIATED SSC	NEGOTIATED PHYSICAL LINK RATE			
19	Reserved							HARDWARE MUXING SUPPORTED