1.1 SAS phy state machine

1.1.1 SAS phy state machine overview

The SAS phy (SP) state machine can be broken down into three sections:

    a) COMINIT/COMSAS handshake states;

    b) SAS speed negotiation states; and

    c) SATA host emulation states.

The SP states are:

    a) SP0: SAS_PWR_ON

    b) SP1: SAS_RESET

    c) SP2: SAS_AWAIT_COMX

    d) SP3: SAS_AWAIT_COMINIT_SENT

    e) SP4: SAS_COMSAS

    f) SP5: SAS_AWAIT_COMSAS_SENT

    g) SP6: SAS_AWAIT_NO_COMSAS

    h) SP7: SAS_AWAIT_COMSAS

    i) SP8: SN_START

    j) SP9: SN_RATE_NOT_SUPPORTED

    k) SP10: SN_AWAIT_ALIGN

    l) SP11: SN_AWAIT_ALIGN

    m) SP12: SN_AWAIT_SNW

    n) SP13:SN_PASS

    o) SP14 SN_FAIL

    p) SP15: SN_FALLBACK

    q) SP16: SN_INC_SPEED

    r) SP17: PHY_CHANGE

    s) SP18: PHY_READY

    t) SP19: SATA_COMWAKE

    u) SP20: SATA_AWAIT_COMWAKE

    v) SP21: SATA_AWAIT_NO_COMWAKE

    w) SP22: SATA_AWAIT_ALIGN

    x) SP23: SATA_ADJUST_SPEED

    y) SP24: SATA_SEND_ALIGN

    z) SP25: SATA_PHY_CHANGE

    aa) SP26: SATA_PHY_READY

    bb) SP27: PM_SLUMBER

    cc) SP28: PM_PARTIAL

    dd) SP29: RESTART

The SP state machine receives the following requests from the link layer:

    a) ResetPhy.

The SP state machine sends no confirmations to the link layer.

The SP state machine sends the following parameters to the DWS state machines:

    a) PhyReady(SAS); and

    b) PhyReady(SATA).

The SAS phy layer shall maintain the following timers:

    a) OOB Timeout timer,

b) Hot Plug Timeout timer;
c) Rate Change Delay (RCD) timer,
d) Speed Negotiation Lock Timeout (SNLT) timer,
e) Speed Negotiation Window Timeout (SNWTO) timer; and
f) COMSAS detect timeout timer.

The SP state machine functions to bring SAS links to a working state. There are multiple entry mechanisms to get the SP state machine to its initial SP0:SAS_PWR_ON state.

A power on event forces the SP state machine into the SP0:SAS_ PWR_ON state..

Upper layers may force a transition to the SP0:SAS_ PWR_ON state. In devices supporting SMP, the PHY CONTROL function may be used to trigger this transition.

The Dword Synchronization state machine (DWS) sets policy on the operational state of the link by monitoring received errors on the link. Entry into the DWS0:AcquireSync state indicates that the link has lost dword synchronization and triggers a counter. If dword synchronization is not re-established in the timeout period, the SP state machine shall change to the SP0:SAS_ PWR_ON state.

The DWS state machine is active after power-up and may be monitored by the SP state machine to help determine receipt of ALIGN and ALIGN1 primitives. The SP state machine actively monitors the DWS state machine int the PhyReady(SATA/SAS) state to determine if it needs to re run OOB.

1.1.2 COMINIT/COMSAS handshaking states

Figure 1 shows the COMINIT/COMSAS handshake states, in which the SAS device transmits an initial COMINIT and COMSAS sequences, and awaits to receive a COMINIT and COMSAS sequences back. These states include a prefix of SAS_ in the state name. Once a COMINIT has been detected, the SAS device transmits a COMSAS sequence instead or in place of the normal SATA calibration pattern, and waits to see if the connected device responds with a COMSAS. If the SAS device does not detect a COMSAS sequence within a COMSAS Detect Timeout period, it assumes that a SATA Device is attached, and jumps to the SATA Host emulation states. Otherwise, a SAS-capable port is attached and the SAS speed negotiation states are entered.

[Editor's note: ResetPhy and PwrOnRst really feed into all states, forcing a transition to SP0:SAS_PWR_ON. They don't feed into SP0:SAS_PWR_ON itself.]
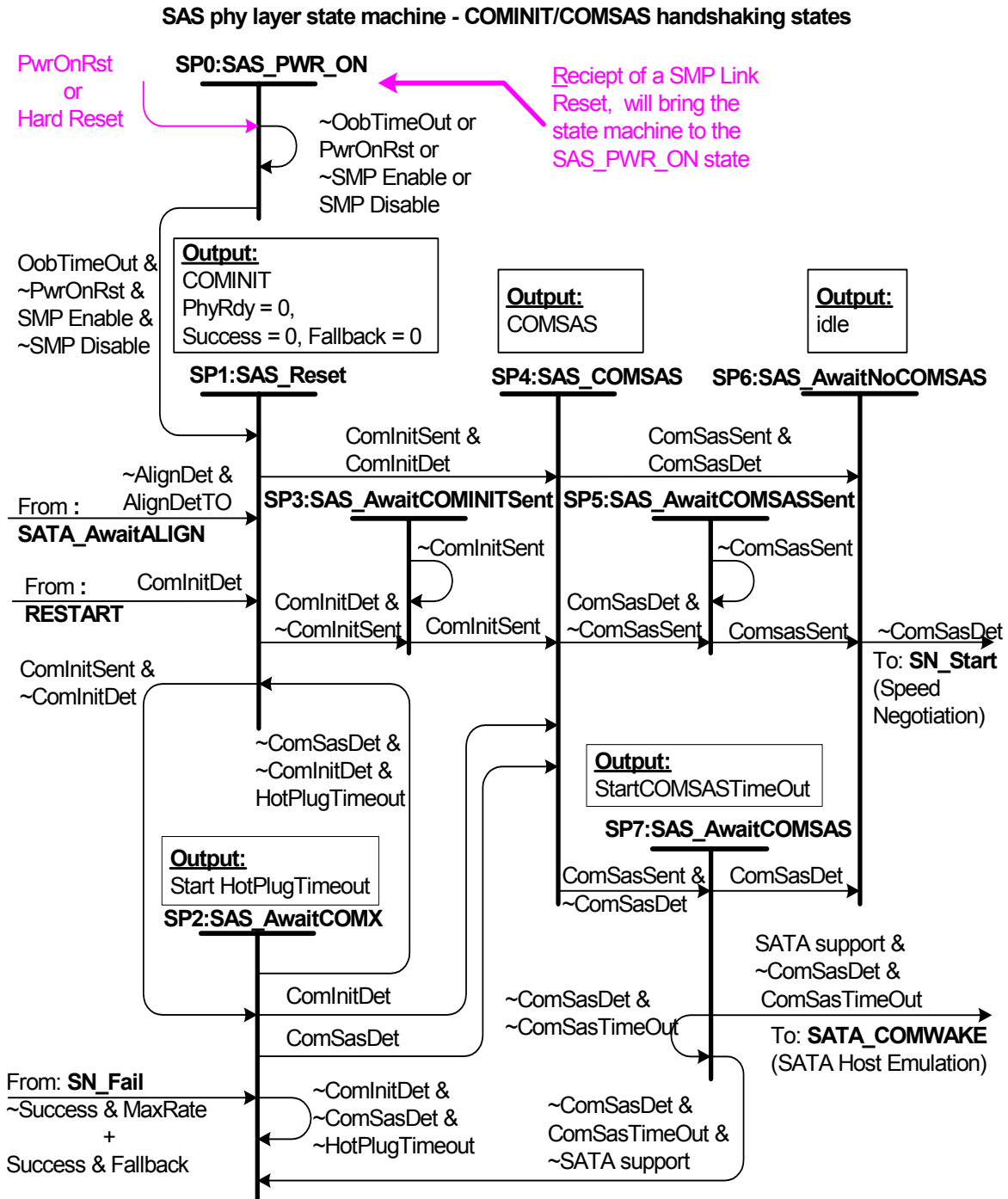
SAS phy layer state machine - COMINIT/COMSAS handshaking states

PwrOnRst or Hard Reset

SP0:SAS_PWR_ON

~OobTimeOut or PwrOnRst or ~SMP Enable or SMP Disable

Reciept of a SMP Link Reset, will bring the state machine to the SAS_PWR_ON state

OobTimeOut & ~PwrOnRst & SMP Enable & ~SMP Disable

Output:
COMINIT
PhyRdy = 0,
Success = 0, Fallback = 0

Output:
COMSAS

Output:
idle

SP1:SAS_Reset

SP4:SAS_COMSAS

SP6:SAS_AwaitNoCOMSAS

ComInitSent & ComInitDet

ComSasSent & ComSasDet

~AlignDet & AlignDetTO

From : **SATA_AwaitALIGN**

SP3:SAS_AwaitCOMINITSent

SP5:SAS_AwaitCOMSASSent

~ComInitSent

~ComSasSent

From : **RESTART**

ComInitDet

ComInitDet & ~ComInitSent

ComInitSent

ComSasDet & ~ComSasSent

ComsasSent

~ComSasDet

To: **SN_Start** (Speed Negotiation)

ComInitSent & ~ComInitDet

~ComSasDet & ~ComInitDet & HotPlugTimeout

Output:
StartCOMSASTimeOut

SP7:SAS_AwaitCOMSAS

Output:
Start HotPlugTimeout

ComSasSent & ~ComSasDet

ComSasDet

SP2:SAS_AwaitCOMX

ComInitDet

ComSasDet

SATA support & ~ComSasDet & ComSasTimeOut

~ComSasDet & ~ComSasTimeOut

To: **SATA_COMWAKE** (SATA Host Emulation)

From: **SN_Fail**
~Success & MaxRate
+
Success & Fallback

~ComInitDet & ~ComSasDet & ~HotPlugTimeout

~ComSasDet & ComSasTimeOut & ~SATA support

Figure 1. SAS phy state machine - COMINIT/COMSAS handshaking states

1.1.2.1 SP0:SAS_PWR_ON

1.1.2.1.1 State description
This state is entered when power-on reset (PwrOnRst) is asserted, or any of the SMP commands affecting the operating status of the phy are received. This state controls the initial start time value. By the SAS specification a device shall wait a period of 1ms before entering into OOB signaling. This state is exited to SP1:SAS_Reset at the expiration of this time after (PwrOnRst) is de-asserted or a SMP command is received enabling the phy.

1.1.2.2 SP1:SAS_Reset state

1.1.2.2.1 State description
This state is entered from SP0:SAS_PWR_ON or when a general reset is requested from the ULP. It is also entered if COMINIT is detected in states SP18:PHY_Ready or SP26:SATA_PHY_Ready or if ALIGN primitives are not detected within an ALIGN Detect Timeout period after entering state SP22:SATA_AwaitALIGN.

The state machine exits this state when it has been determined that a COMINIT burst has been sent or detected, PhyRdy(SAS/SATA) are cleared to 0 upon entering this state. The Fallback and Success flags are also cleared upon entering this state.

1.1.2.2.2 Transition SP1:SAS_Reset to SP2:SAS_AwaitCOMX
Occurs when a COMINIT burst has been sent, a COMINIT was not detected.

1.1.2.2.3 Transition SP1:SAS_Reset to SP3:SAS_AwaitCOMINITSent
Occurs when a COMINIT burst has not been completely transmitted but COMINIT was detected.

1.1.2.2.4 Transition SP1:SAS_Reset to SP4:SAS_COMSAS
Occurs when PwrOnRst is de-asserted, a COMINIT burst has been sent, a COMINIT was detected.

1.1.2.3 SP2:SAS_AwaitCOMX state

1.1.2.3.1 State description
This state is entered when a COMINIT sequence has been sent during state SP0:SAS_RESET and a COMINIT sequence was not detected. Upon entering this state, a Hot-Plug Timeout counter shall be initialized and enabled to count down. The state machine exits this state when it detects a COMINIT, or a COMSAS sequence, or if a Hot-Plug timeout occurs before any of the OOB signals are detected.

This state is also entered from state SP14:SN_Fail if the there was not a previous successful lock and the max frequency has been attempted or there was a successful lock but the fallback speed failed. The state machine shall wait the Hot Plug timeout delay before attempting the connection again.

This state is also entered if COMSAS has been sent and COMSAS is not detected in the timeout window and a SATA connection is not supported.

1.1.2.3.2 Transition SP2:SAS_AwaitCOMX to SP1:SAS_Reset
Occurs when a Hot-Plug timeout occurs before any OOB signals are detected.

1.1.2.3.3 Transition SP2:SAS_AwaitCOMX to SP4:SAS_COMSAS
Occurs when a COMINIT has been sent and received or COMSAS sequence is detected. This indicates that a connection has been detected, so the SAS device transmits a COMSAS sequence to inform the other end of the link that it supports SAS protocol.

1.1.2.4 SP3:SAS_AwaitCOMINITSent state

1.1.2.4.1 State description
This state is entered when a COMINIT sequence has been detected but the COMINIT initiated in SP1:SAS_Reset has not been completely sent. The state machine shall wait in this state until the completion of the COMINIT transmission.

1.1.2.4.2 Transition SP3:SAS_AwaitCOMINITSent to SP4:COMSAS

The state machine shall exit this state at the completion of COMINIT transmission being completed.

1.1.2.5 SP4:SAS_COMSAS state

1.1.2.5.1 State description

1.1.2.6 This state is entered when a COMINIT has been sent and detected. If COMINIT was detected before COMINIT transmission was completed, this state will be entered from the SP3:SAS_AwaitCominitSent state when COMINIT transmission is complete. It can also be entered from SP2:SAS_AwaitCOMX if the full COMINIT handshake is complete or COMSAS has been detected. The state machine remains in this state until the COMSAS sequence is transmitted or detected.

1.1.2.6.1 Transition SP4:SAS_COMSAS to SP5:SAS_AwaitCOMSASSent

Occurs if a COMSAS sequence is detected while COMSAS is still being transmitted. This acknowledges that two SAS ports are connected but COMSAS is not completely sent.

1.1.2.6.2 Transition SP4:SAS_COMSAS to SP6:SAS_AwaitNoCOMSAS

This transition occurs if a COMSAS has been sent and received. This acknowledges that two SAS ports are connected.

1.1.2.6.3 Transition SP4:SAS_COMSAS to SP7:SAS_AwaitCOMSAS

This transition occurs if a COMSAS sequence was not detected while COMSAS was being transmitted. It cannot be determined yet if a SAS or SATA port is connected.

1.1.2.7 SP5:SAS_AwaitCOMSASSent state

1.1.2.7.1 State description

This state is entered when a COMSAS sequence is detected in state SP4:SAS_COMSAS but the full COMSAS sequence has not been completely transmitted.

The state machine remains in this state until the entire COMSAS sequence is transmitted, at which point it will transition to SP6:SAS_AwaitNoCOMSAS to insure that the COMSAS sequence being received is complete.

1.1.2.7.2 Transition SP5:SAS_AwaitCOMSASSent to SP6:SAS_AwaitNoCOMSAS

This transition occurs when the entire COMSAS sequence is transmitted.

1.1.2.8 SP6:SAS_AwaitNoCOMSAS state

1.1.2.8.1 State description

This state is entered when a COMSAS sequence has been transmitted and detected in state SP4:SAS_COMSAS. Entry comes form state SP5:SAS_AwaitCOMSASSent or SP7:SAS_AwaitCOMSAS if a COMSAS sequence has been detected and not full sent of sully sent but not detected respectively.

The state machine remains in this state until the end of the COMSAS sequence is detected, at which point the SAS speed negotiation begins.

1.1.2.8.2 Transition SP6:SAS_AwaitNoCOMSAS to SP8:SN_Start

This transition occurs when the end of the COMSAS sequence is detected.

1.1.2.9 SP7:SAS_AwaitCOMSAS state

1.1.2.9.1 State description

This state is entered when a COMSAS sequence has been transmitted, but a COMSAS has not yet been detected in state SP4:SAS_COMSAS.

Upon entering this state the COMSAS Timeout counter shall be initialized and enabled to count down. The state machine remains in this state until either a COMSAS sequence is detected or a COMSAS detect timeout period occurs.

1.1.2.9.2 Transition SP7:SAS_AwaitCOMSAS to SP6:SAS_AwaitNoCOMSAS

This transition occurs when a COMSAS sequence is detected.

1.1.2.9.3 Transition SP7:SAS_AwaitCOMSAS to SP19:SATA_COMWAKE

All SAS devices that support SATA target attach shall transition to this state when a COMSAS sequence is not detected within the COMSAS detect timeout period..

1.1.2.9.4 Transition SP7:SAS_AwaitCOMSAS to SAS_AwaitNoCOMX

SAS devices that don't support SATA target attach shall transition to this state when a COMSAS sequence is not detected within the COMSAS detect timeout period.

1.1.3 SAS speed negotiation states

[Editor's note: in all state diagrams, make sure that multiple arrows don't meet at the same location]

[Editor's note: these state machines do not look like the others.]

Figure 2 shows the SAS Speed Negotiation states, in which the SAS phy has detected that it is attached to a SAS phy, and engages in the SAS speed negotiation procedure. These states are indicated by state names with a prefix of SN or PHY.

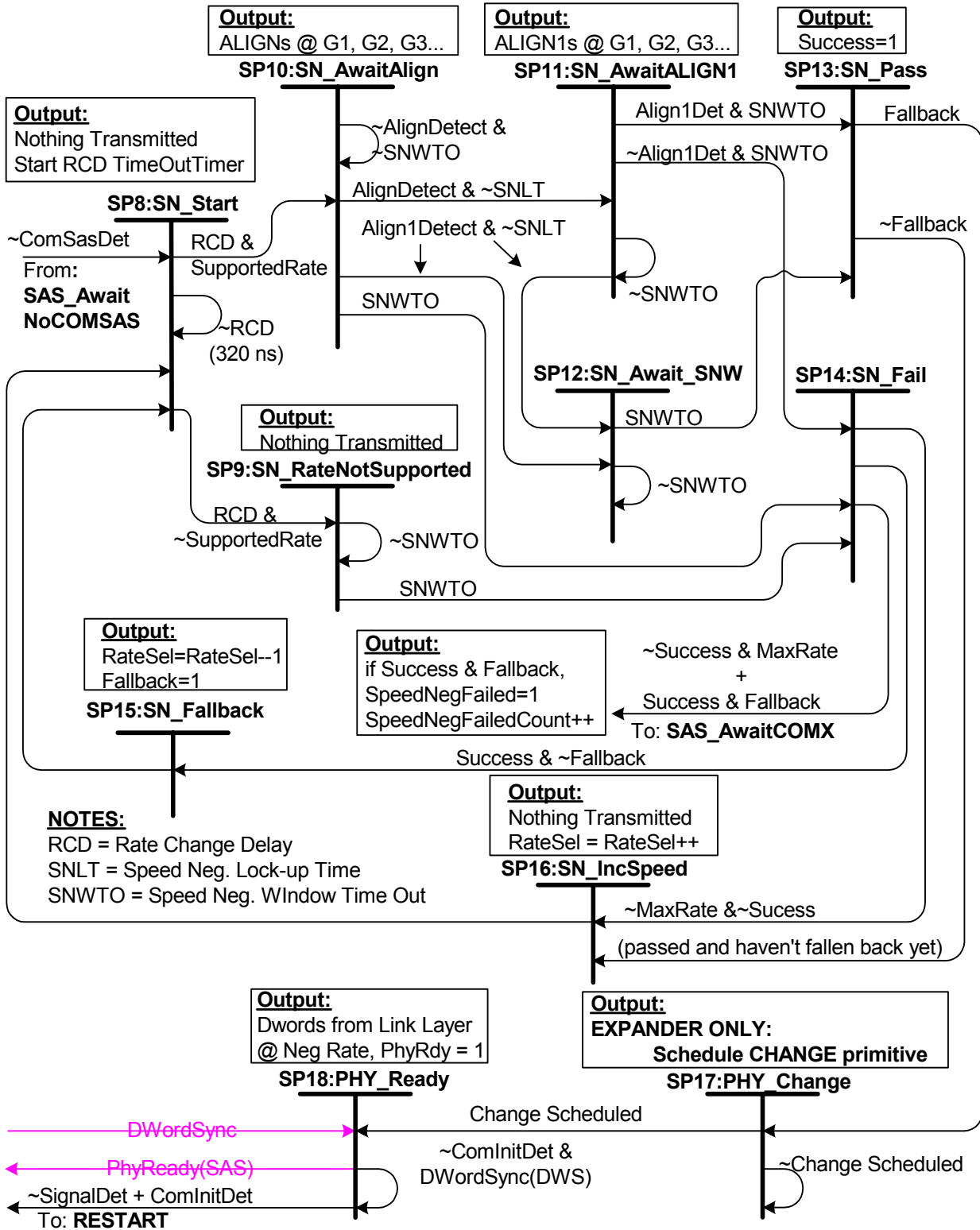# SAS phy layer state machine - SAS speed negotiation states

Output:
ALIGNs @ G1, G2, G3...
SP10:SN_AwaitAlign

Output:
ALIGN1s @ G1, G2, G3...
SP11:SN_AwaitALIGN1

Output:
Success=1
SP13:SN_Pass

~AlignDetect &
~SNWTO

Align1Det & SNWTO

Fallback

Output:
Nothing Transmitted
Start RCD TimeOutTimer

AlignDetect & ~SNLT

~Align1Det & SNWTO

~Fallback

SP8:SN_Start

Align1Detect & ~SNLT

~ComSasDet

RCD &
SupportedRate

From**:**

**SAS_Await
NoCOMSAS**

SNWTO

~SNWTO

~RCD
(320 ns)

SP12:SN_Await_SNW

SP14:SN_Fail

Output:
Nothing Transmitted

SNWTO

SP9:SN_RateNotSupported

~SNWTO

RCD &
~SupportedRate

~SNWTO

SNWTO

Output:
RateSel=RateSel--1
Fallback=1

Output:
if Success & Fallback,
SpeedNegFailed=1
SpeedNegFailedCount++

~Success & MaxRate
+
Success & Fallback
To: **SAS_AwaitCOMX**

SP15:SN_Fallback

Success & ~Fallback

NOTES:
RCD = Rate Change Delay
SNLT = Speed Neg. Lock-up Time
SNWTO = Speed Neg. WIndow Time Out

Output:
Nothing Transmitted
RateSel = RateSel++
SP16:SN_IncSpeed

~MaxRate &~Sucess

(passed and haven't fallen back yet)

Output:
Dwords from Link Layer
@ Neg Rate, PhyRdy = 1
SP18:PHY_Ready

Output:
EXPANDER ONLY:
   Schedule CHANGE primitive
SP17:PHY_Change

Change Scheduled

DWordSync

~ComInitDet &
DWordSync(DWS)

~Change Scheduled

PhyReady(SAS)

~SignalDet + ComInitDet
   To: **RESTART**

Figure 2. SAS phy state machine - SAS speed negotiation states

1.1.3.1 SP8:SN_Start state

1.1.3.1.1 State description
This state marks the beginning of the SAS speed negotiation process. It is used to get the transmit lines to an idle state in between SAS speed negotiation windows. A SAS speed negotiation window is defined to be 109,2 μs (4096 Gen1 UIs). This state is entered from state SP6:SAS_AwaitNoCOMSAS after the end of a COMSAS sequence. It can also be entered from states SP16_Inc Speed or SP15:SN_Fallback for another pass, after a speed negotiation window occurs. Upon entering this state, the Rate Change Delay timer is loaded with an initial value and enabled to count down. This allows time required for a transmitter to switch to either the next higher or next lower supported speed. The state machine remains in this state until a Rate Change Delay (320ns) has elapsed. The transmitter is turned on but nothing is transmitted during this state.
Occurs when the Rate Change Delay timer expires and the current rate is not supported.

1.1.3.1.2 Transition SP8:SN_Start to SP10:SN_AwaitAlign
Occurs when the Rate Change Delay timer expires and the current rate is supported.

1.1.3.1.3 Transition SP8:SN_Start to SP9:SN_RateNotSupported
Occurs when the Rate Change Delay timer expires and the current rate is NOT supported.

1.1.3.2 SP9:SN_RateNotSupported state

1.1.3.2.1 State description
This state is entered after a Rate Change Delay (RCD) from state SP8:SN_Start when the currently selected rate is not supported. During this state nothing is transmitted for an entire speed negotiation window. Upon entering this state the SNWTO counter is loaded and enabled to count down. The state machine exits from this state after the SNWTO counter expires.

1.1.3.2.2 Transition SP9:SN_RateNotSupported to SP14:SN_Fail
Occurs after the SNWTO counter expires.

1.1.3.3 SP10:SN_AwaitAlign state

1.1.3.3.1 State description
The state machine starts transmitting ALIGN characters at the current supported rate (Gen1, Gen2, Gen3…) in this state. Upon entering this state, the Speed Negotiation Window Timeout (SNWTO) counter is loaded and enabled to count down. The state machine exits this state when a SNWTO occurs without the pattern synchronization or if synchronization occurs before the Speed Negotiation Lock Time (SNLT) expires.

1.1.3.3.2 Transition SP10:SN_AwaitAlign to SP11:SN_AwaitALIGN1
Occurs when ALIGNs at the current rate are received and recognized before an SNLT period.

1.1.3.3.3 Transition SP10:SN_AwaitAlign to SP12:SN_Await_SNW
Occurs when ALIGN1s at the current rate are received and recognized before an SNLT period.

1.1.3.3.4 Transition SP10:SN_AwaitAlign to SP14:SN_FAIL
Occurs when the pattern synchronization has not obtained within an SNWTO.

1.1.3.4 SP11:SN_AwaitALIGN1 state

1.1.3.4.1 State description
This state is entered from state SP10:SN_AwaitAlign if the PLL has locked and obtained Dword synchronization and have detected ALIGNs within the SNLT. During this state the ALIGN1 primitive is transmitted. This state is exited when the SNWTO expires or when ALIGN1s are received before the SNLT.
[Editor's note: FIX 010101 text]

1.1.3.4.2 Transition SP11:SN_AwaitALIGN1 to SP13:SN_Pass
Occurs if ALIGN1s are detected at the same time as SNWTO period. This indicates that speed negotiation at this rate was successful.

1.1.3.4.3 Transition SP11:SN_AwaitALIGN1 to SP14:SN_Fail
Occurs if no ALIGN1s were detected within an SNWTO period. This indicates that the other device must not have been able to lock at the current rate.

1.1.3.5 SP12:SN_Await_SNW state

1.1.3.5.1 State description
This state is entered from state SP10:SN_AwaitAlign or SP11:SN_AwaitAlign1 if the PLL has locked and obtained the appropriate pattern synchronization within an SNLT. During this window the state machine latches the fact that ALIGN1s were received, the speed negotiation is successful and now must only wait till the end of the Speed Negotiation Window.

1.1.3.5.2 Transition SP12:SN_AwaitALIGN1 to SP13:SN_Pass
Speed negotiation at this rate was successful and the state machine needs only to wait till the end of the Speed Negotiation window.

1.1.3.6 SP13:SN_Pass state

1.1.3.7 State description
This state is entered from state SP11:SN_AwaitALIGN1 or SP12:SN_Await_SNW after an SNWTO occurs. This is a single clock state that set the Success flag, indicating that there was at least one successful speed negotiation.

1.1.3.7.1 Transition SP13:SN_Pass to SP16:SN_IncSpeed
If the state machine has not fallen back, this means that it has not progressed past the breaking point so the speed is incremented for the next attempt.

1.1.3.7.2 Transition SP13:SN_Pass to SP17:PHY_Change
The transition to the SP17:PHY_Change state is taken if the speed negotiation has completed. This is indicated by the Fallback flag. If this flag is set it indicates that the speed negotiation has progressed to where it failed and then had fallen back to the last negotiated speed and then subsequently passed.

1.1.3.8 SP14:SN_Fail state

1.1.3.8.1 State description
This state is entered from the SP11:SN_AwaitALIGN state or SP11:SN_AwaitALIGN1 state if ALIGN1s are not received indicating that the other end does not support the rate or has NOT locked at this rate.

1.1.3.8.2 Transition SP14:SN_Fail to SP2:SAS_AwaitCOMX
Occurs when the state machine has not been successful, meaning that the max rate has been attempted and there haven't been any successful rate negotiated or when the speed negotiation fails after dropping back to the last working frequency.

1.1.3.8.3 Transition SP14:SN_Fail to SP15:SN_Fallback
Transition to fallback if the speed negotiation has failed and there was a previous success.

1.1.3.8.4 Transition SP14:SN_Fail to SP16:SN_IncSpeed
Transition to SP16:SN_IncSpeed if the speed negotiation has not previously passed and the maximum supported rate has not yet been attempted.

1.1.3.9 SP15:SN_Fallback state

1.1.3.9.1 State description
This state is entered from state SP14:SN_Fail after an SNWTO occurs indicating that the current tested speed failed but there was a former success. This is a one clock state that sets the Fallback flag to indicate that the sequence has progressed through a successful negotiation to one that fails and now needs to fall back to the highest mutually supported speed.

1.1.3.9.2 Transition SP15:SN_Fallback to SP8:SN_Start
Occurs on the next clock.

1.1.3.10 SP16:SN_IncSpeed state

This is a one clock state that increments the speed for the next attempt. This state is entered when the transmitter has not reached its maximum supported rate during the SAS speed negotiation process. This can either be when the previous window has failed with no previous successes or passed but the highest supported rate hasn't been tested.

1.1.3.10.1 Transition SP16:SN_IncSpeed state to SP8:SN_Start

Occurs on the next clock with the transmitter set for the next highest rate.

1.1.3.11 SP17:PHY_Change state

1.1.3.11.1 State description

This state is entered from state SP13:SN_Pass state if the Fallback flag is set, which is an indication that the SAS speed negotiation procedure has completed successfully.

1.1.3.11.2 Transition SP17:PHY_Change to SP18:PHY_Ready

This transition occurs after the CHANGE primitive is scheduled.

1.1.3.12 SP18:PHY_Ready state

1.1.3.12.1 State description

This state is entered from state SP17:PHY_Change state after a CHANGE primitive has been scheduled for transmission. This state enables the SAS phy dword synchronization state machine (DWS) to provide rule checking for dword synchronization and determination of link failure. The input from DWS to indicate that Dword Synchronization is Acquired (DWordSync) and is used in the SP:18:Phy Ready and the SP26:SATA_Phy Ready states to determine if it is necessary to re-run OOB. Until this time the DWS input is ignored.

The state machine remains in this state until a COMINIT sequence is detected or loss of DWordSync.. PhyReady(SAS) is set to one to indicate that the link has been brought up successfully in SAS mode. While in this state, the PhyRdy(SAS) signal to the link layer shall be set to one and dwords from the link layer are transmitted at the negotiated rate

1.1.3.12.2 Transition SP18:PHY_Ready to SP29:RESTART

Transition to SP29:RESTART occurs if DWordSync is de-asserted by the DWS state machine or a COMINIT is detected. This is an indication that a device has been unplugged from the port or reset from the link, and requires the expander to transmit a CHANGE primitive to connected initiators.

1.1.4 SATA host emulation states

Figure 3 shows the SATA Host emulation states, in which the SAS device has detected that it is connected a SATA target and behaves as if it were a SATA Host as far as OOB is concerned, initiating the speed negotiation. These states are indicated by state names with a prefix of SATA_. During SATA Host emulation, the SAS device transmits a COMWAKE sequence and then waits to receive a COMWAKE. Once the COMWAKE sequence is detected, the SAS device follows the speed negotiation sequence defined in the SATA 1.0 specification.

SAS initiator devices, target devices and expander devices should use similar state machines to the one defined in this specification, with the exception that SAS initiators should implement the SATA Host emulation power management states.

The power management states that are defined in this specification are for SAS initiators that intend to attach directly to SATA targets. For SAS-only initiators, these states are not needed. The power management states are prefixed with PM.
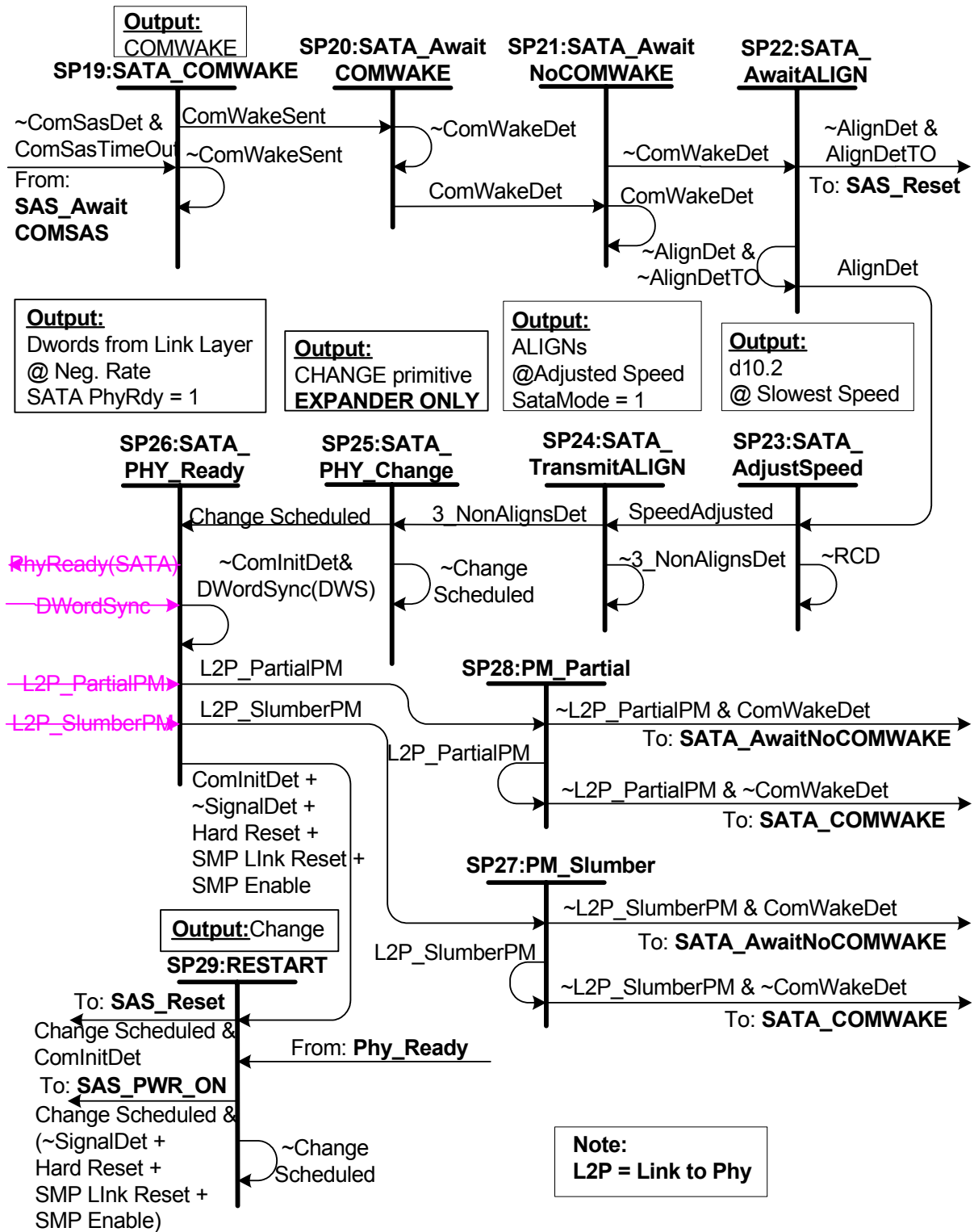
SAS phy layer state machine - SATA host emulation states

Output:
COMWAKE

SP19:SATA_COMWAKE

SP20:SATA_Await COMWAKE

SP21:SATA_Await NoCOMWAKE

SP22:SATA_ AwaitALIGN

~ComSasDet & ComSasTimeOut

ComWakeSent

~ComWakeDet

~AlignDet & AlignDetTO

From: **SAS_Await COMSAS**

~ComWakeSent

To: **SAS_Reset**

~ComWakeDet

ComWakeDet

ComWakeDet

~AlignDet & ~AlignDetTO

AlignDet

Output:
Dwords from Link Layer @ Neg. Rate
SATA PhyRdy = 1

Output:
CHANGE primitive
EXPANDER ONLY

Output:
ALIGNs
@Adjusted Speed
SataMode = 1

Output:
d10.2
@ Slowest Speed

SP26:SATA_ PHY_Ready

SP25:SATA_ PHY_Change

SP24:SATA_ TransmitALIGN

SP23:SATA_ AdjustSpeed

Change Scheduled

3_NonAlignsDet

SpeedAdjusted

PhyReady(SATA)

~ComInitDet& DWordSync(DWS)

~Change Scheduled

~3_NonAlignsDet

~RCD

DWordSync

L2P_PartialPM

SP28:PM_Partial

L2P_PartialPM

L2P_SlumberPM

~L2P_PartialPM & ComWakeDet

To: **SATA_AwaitNoCOMWAKE**

L2P_PartialPM

~L2P_PartialPM & ~ComWakeDet

To: **SATA_COMWAKE**

ComInitDet + ~SignalDet + Hard Reset + SMP LInk Reset + SMP Enable

SP27:PM_Slumber

~L2P_SlumberPM & ComWakeDet

To: **SATA_AwaitNoCOMWAKE**

Output: Change

L2P_SlumberPM

~L2P_SlumberPM & ~ComWakeDet

SP29:RESTART

To: **SATA_COMWAKE**

To: **SAS_Reset**
Change Scheduled & ComInitDet

From: **Phy_Ready**

To: **SAS_PWR_ON**
Change Scheduled & (~SignalDet + Hard Reset + SMP LInk Reset + SMP Enable)

~Change Scheduled

Note:
L2P = Link to Phy

Figure 3. SAS phy state machine - SATA host emulation states

1.1.4.1 SP19:SATA_COMWAKE state

1.1.4.1.1 State description
This is the first state of the SATA Host Emulation states. This state is entered from state SP7:SAS_AwaitCOMSAS when a COMSAS is not detected within a COMSAS detect timeout period of 3,5 µs. The state machine remains in this state until a COMWAKE sequence has been transmitted.

1.1.4.1.2 Transition SP19:SATA_COMWAKE to SP20:SATA_AwaitCOMWAKE
Occurs when the COMWAKE sequence has been transmitted.

1.1.4.2 SP20:SATA_AwaitCOMWAKE state

1.1.4.2.1 State description
This state is entered when a COMWAKE sequence has been sent during state SP19:SATA_COMWAKE. The state machine remains in this state until a COMWAKE sequence has been detected.

1.1.4.2.2 Transition SP20:SATA_AwaitCOMWAKE to SP21:SATA_AawitNoCOMWAKE
Occurs when a COMWAKE sequence is detected.

1.1.4.3 SP21:SATA_AwaitNoCOMWAKE state

1.1.4.3.1 State description
This state is entered when a COMWAKE sequence is detected in state SATA_AwaitCOMX. The state machine remains in this state until the end of the COMWAKE sequence is detected.

1.1.4.3.2 Transition SP21:SATA_AwaitNoCOMWAKE to SP22:SATA_AwaitALIGN
Occurs when the end of the COMWAKE sequence has been detected.

1.1.4.4 SP22:SATA_AwaitALIGN state

1.1.4.4.1 State description
This state is entered from state SP21:SATA_AwaitNoCOMWAKE after the end of a COMWAKE sequence has been detected. While in this state, the SAS device is transmitting D10.2 characters at its slowest supported transmit speed. The state machine remains in this state until either an ALIGN primitive is detected at any of its supported rates, or 880 µs (32K Gen1 dwords) have elapsed without detecting any ALIGN primitives.

The SAS device shall start transmitting D10.2 characters no later than 20 Gen1 dwords (533 ns) after COMWAKE was de-asserted.

1.1.4.4.2 Transition SP22:SATA_AwaitALIGN to SP23:SATA_AdjustSpeed
Occurs when the SAS device detects an ALIGN primitive at any of its supported rates.

1.1.4.4.3 Transition SP22:SATA_AwaitALIGN to SP1:SAS_Reset
Occurs when the SAS device does not detect any ALIGN primitives within 880 µs (32K Gen1 dwords)

1.1.4.5 SP23:SATA_AdjustSpeed state

1.1.4.5.1 State description
This state is entered from state SP22:SATA_AwaitALIGN when the SAS device detects an ALIGN primitive at any of its supported rates. During this state, the SAS device's PHY transmitter circuitry adjusts to the same rate of the ALIGN primitives that were detected by the receiver circuitry. The state machine remains in this state until the transmitter rate has been adjusted appropriately.

1.1.4.5.2 Transition SP23:SATA_AdjustSpeed to SP24:SATA_TransmitALIGN
Occurs when the transmitter rate has been adjusted to the rate of the received ALIGN primitives.

1.1.4.6 SP24:SATA_TransmitALIGN state

1.1.4.6.1 State description

This state is entered from state SP23:SATA_AdjustSpeed after the transmitter rate has been adjusted to the rate of the received ALIGN primitives. While in this state the SAS device transmits ALIGN primitives at the adjusted rate until the receiver circuitry detects three back-to-back non-ALIGN primitives, at which point the state machine transitions to state SP25:SATA_PHY_Change

1.1.4.6.2 Transition SP24:SATA_TransmitALIGN to SP25:SATA_PHY_Change

Occurs when the SAS device's receiver circuitry detects three back-to-back non-ALIGN primitives. The completion of a SATA speed negotiation requires a CHANGE primitive especially since SATA targets do not transmit the IDENTIFY address frame after link initialization.

1.1.4.7 SP25:SATA_PHY_Change state

1.1.4.7.1 State description

This state is entered from state SP24:SATA_TransmitALIGN. In the case of a SATA target, it is the expander's responsibility to request the CHANGE primitive be sent.

1.1.4.7.2 Transition SP25:SATA_PHY_Change to SP26:SATA_PHY_Ready

This transition occurs after the CHANGE primitive is scheduled.

1.1.4.8 SP26:SATA_PHY_Ready state

1.1.4.8.1 State description

This state is entered from state SP25:SATA_PHY_Change state after the CHANGE primitive has been scheduled. This state enables the SAS phy dword synchronization state machine (DWS) to provide rule checking for dword synchronization and determination of link failure. The input from DWS to indicate that Dword Synchronization is Acquired (DWordSync) and is used in the SP:18:Phy Ready and the SP26:SATA_Phy Ready states to determine if it is necessary to re-run OOB. Until this time the DWS input is ignored.

The state machine remains in this state until a COMINIT sequence is detected or loss of DWordSync.. PhyRdy(SATA) is set to one to indicate that the link has been brought up successfully in SATA mode. While in this state, the PhyRdy(SATA) signal to the link layer shall be set to one and dwords from the link layer are transmitted at the negotiated rate

1.1.4.8.2 Transition SP26:SATA_PHY_Ready to SP0:RESTART

Occurs when a COMINIT sequence is detected or loss of DWordSync from the DWS state machine indicating that the incoming signal is not compliant with the encoding defined for SAS/SATA.

1.1.4.9 SP27:PM_Partial state

1.1.4.9.1 State description

This state is entered from SP26:SATA_PHY_Ready if L2P_PartialPM is received from the link layer. Exit from this state is driven from receipt of COMWAKE or de-assertion of the partial signal.

The phy shall remember if COMWAKE was detected during SP27:PM_Partial to determine if the wakeup request was originated from the host or the phy.

1.1.4.9.2 Transition SP27:PM_Partial to SP21:SATA_AwaitNoCOMWAKE

Occurs when the receiver circuitry detects COMWAKE.

1.1.4.9.3 Transition SP27:PM_Partial to SP20:SATA_COMWAKE

The device shall transition to SP20:SATA_COMWAKE if the link layer de-asserts the slumber signal to the PHY interface.

1.1.4.10 SP28:PM_Slumber state

1.1.4.10.1 State description
This state is entered from SP26:SATA_PHY_Ready since the device is operating in SATA mode and L2P_SlumberPM is received from the link layer. Exit from this state is driven from receipt of COMWAKE or de-assertion of the slumber signal.

The phy shall remember if COMWAKE was detected during SP28:PM_Slumber to determine if the wakeup request was originated from the link layer or the phy.

1.1.4.10.2 Transition SP28:PM_Slumber to SP21:SATA_AwaitNoCOMWAKE
Occurs when the receiver circuitry detects COMWAKE from the device at the other end of the link. This transition should not occur until the phy interface is recovered from Slumber mode and is ready to initiate communications.

1.1.4.10.3 Transition SP28:PM_Slumber to SP20:SATA_COMWAKE
The device shall transition to SP20:SATA_COMWAKE if the link layer de-asserts the slumber signal to the PHY interface.

1.1.4.11 SP29:RESTART

1.1.4.11.1 State description
This state is entered from state SP18:PHY_Ready or SP26:Sata_Phy_Ready if dword synchronization is lost. Enable Disable Link Layer(SATA/SAS Disable) are real time indications that dword synchronization has been lost. When asserted, this indicates that a significant problem with the link exists, and shall trigger an Expander to transmit a CHANGE primitive to all of its initiator ports, notifying them of a change in operating status of the link. It is also entered when a COMINIT is detected indication that a reset is being signaled on the link.

1.1.4.11.2 Transition SP29:RESTART to SP0:SAS_PWR_ON
Occurs if a CHANGE primitive has been scheduled for transmission.

1.2 Dword SAS phy dword synchronization state machine

1.2.1 Dword SAS phy dword synchronization state machine overview
A SAS receiver monitors and decodes the incoming data stream and forces K28.5 characters into the first byte position to effectively perform dword alignment. The receiver continues to reestablish dword alignment by forcing received K28.5 characters into the first byte position until a valid SAS primitive is detected. The resultant primitives, dwords and valid dword indicators (encoding error indicators, etc) are sent to the Dword synchronization state machine to enable the state machine to determine the dword synchronization policy.

Upon Power Up or loss of previous synchronization, the DWS0:AcquireSync state is entered. On entry into this state, the Enable Disable Link Layer(SAS Disable) or Enable Disable Link Layer(SATA Disable) confirmation is sent to the link layer qualified by the PhyReady parameter from the SP state machine. When the requirements for dword synchronization are met and the DWS state machine enters the DWS3:SyncAcquired state the Enable Disable Link Layer(SATA Enable or SAS Enable) will be output. These signals will be qualified with the phy initialization state machine output PhyReady(SATA or SAS) and presented to the link layer. The link layer uses this qualified version to enable/disable operation. The phy initialization state machine will use the unqualified version of the Enable Disable Link Layer to determine whether to re-run OOB. The unqualified signal will be monitored only in the PhyReady(SATA or SAS) states and not in the other OOB and speed negotiation states. Upon receipt of the Enable Disable Link Layer (SATA Disable) or Enable Disable Link Layer (SAS Disable), the phy initialization state machine will re-run OOB.

Each SAS phy includes a SAS phy dword synchronization state machine (DWS). The DWS state machine establishes the same dword receive/loss policy. The DWS state machine requires an error free string of dwords to obtain synchronization. The DWS state machine tolerates invalid dwords as defined in the state machine before losing dword synchronization. While not in dword synchronization, information received is invalid and not passed to the SAS link layer state machine.

This state machine may be running continually, initially set in DWS0: AcquireSync by a power on event.

The DWS state machine contains the following states:

- a) DWS0:AcquireSync;
- b) DWS1:Valid1;
- c) DWS2:Valid2;
- d) DWS3:SyncAcquired;
- e) DWS4:Lost1;
- f) DWS4aDWS5:Lost1Recovered;
- g) DWS5DWS6:Lost2;
- h) DWS4aDWS7:Lost2Recovered;
- i) DWS6DWS8:Lost3; and
- j) DWS6aDWS9:Lost3Recovered.

The DWS state machine receives no requests from the link layer.

The DWS state machine sends the following confirmations to the link layer:

- k) Enable Disable Link Layer(SAS Enable);
- l) Enable Disable Link Layer(SATA Enable);
- m) Enable Disable Link Layer(SAS Disable); and
- n) Enable Disable Link Layer(SATA Disable).

The DWS state machine receives the following parameters from the SP state machine:

- o) PhyReady(SAS); and
- p) PhyReady(SATA).

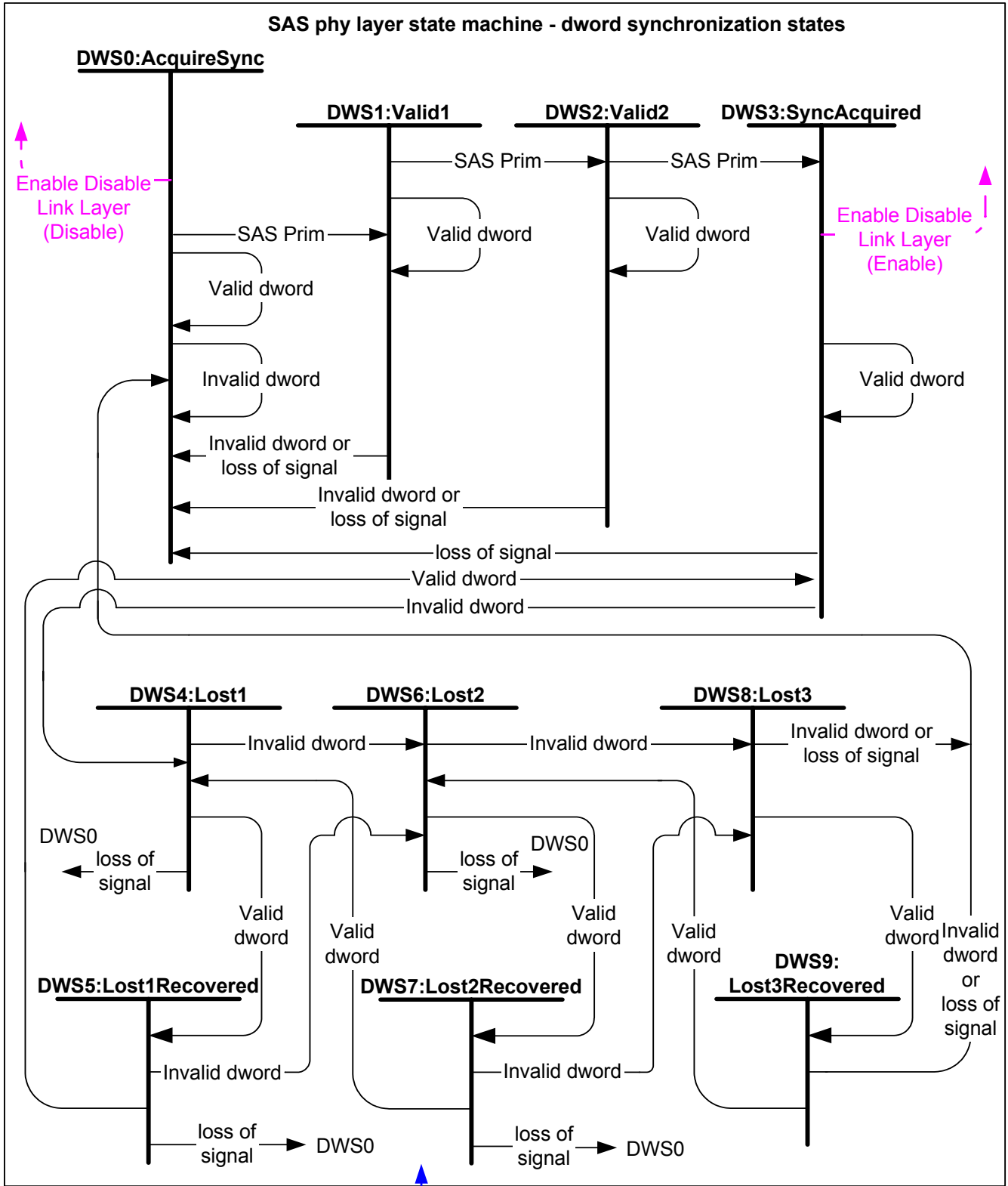**Error! Reference source not found.** shows the DWS state machine.

Figure 4. Dword synchronization state machine

1.2.2 DWS0: ACQ Sync StartDWS0:AcquireSync state

1.2.2.1 State description

Upon power-up or loss of previous dword synchronization, the DWS0:AcquireSync state is entered.

1.2.2.2 Transition DWS0:AcquireSync to DWS1:Valid1

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this word.

1.2.2.3 Transition DWS0:AcquireSync to DWS0a:AcquireSync

This transition shall occur when a valid dword is detected that is not a SAS primitive.

1.2.2.4 Transition DWS0:AcquireSync to DWS0b:AcquireSync

This transition shall occur when an invalid dword or a loss of signal is detected. The receiver continues to monitor information received and forces the first K28.5 character into the first byte position for word alignment.

1.2.3 DWS1:Valid1 state

1.2.3.1 State description

The receiver monitors information received until a valid SAS primitive, an invalid dword, or a loss of signal is detected.

1.2.3.2 Transition DWS1:Valid1 to DWS2:Valid2

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this word.

1.2.3.3 Transition DWS1:Valid1 to DWS1:Valid1

This transition shall occur when a valid dword is detected that is not a SAS primitive.

1.2.3.4 Transition DWS1:Valid1 to DWS0:AcquireSync

This transition shall occur when an invalid dword or a loss of signal is detected. A new attempt at word alignment is started.

1.2.4 DWS2:Valid2 state

1.2.4.1 State description

The receiver has detected Valid2 two valid SAS primitives using the current word alignment. The receiver monitors information received until a valid SAS primitive, an invalid dword, or a loss of signal is detected.

1.2.4.2 Transition DWS2:Valid2 to DWS3:SyncAcquired

This transition shall occur when a valid SAS primitive is detected. This indicates the present dword alignment is valid for this word.

1.2.4.3 Transition DWS2:Valid2 to DWS2:Valid2

This transition shall occur when a valid dword is detected that is not a SAS primitive.

1.2.4.4 Transition DWS2:Valid2 to DWS0:AcquireSync

This transition shall occur when an invalid dword or a loss of signal is detected. A new attempt at word alignment is started.

1.2.5 DWS3:SyncAcquired state

1.2.5.1 State description

Dword synchronization state machine has detected three valid SAS primitives using the current word alignment. The Enable Disable Link Layer(SAS Enable) or Enable Disable Link Layer(SATA Enable) confirmation is sent to the link layer qualified by the PhyReady(SATA/SAS) parameter from the SP state machines. The current SAS

primitive is valid for processing. The receiver monitors information received until an invalid dword is received or a loss of signal is signaled by the receiver.

1.2.5.2 Transition DWS3:SyncAcquired to DWS4:Lost1

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see **Error! Reference source not found.**).

1.2.5.3 Transition DWS3:SyncAcquired to DWS3:SyncAcquired

This transition shall occur when a valid dword is detected.

1.2.5.4 Transition DWS3:SyncAcquired to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at word alignment is started.

1.2.6 DWS4:Lost1 state

1.2.6.1 State description

The receiver has detected an invalid dword. This is the first state in the process that may result in losing dword synchronization. The receiver monitors information received.

1.2.6.2 Transition DWS4:Lost1 to DWS5:Lost1Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment may still be valid for this dword.

1.2.6.3 Transition DWS4:Lost1 to DWS6:Lost2

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see **Error! Reference source not found.**).

1.2.6.4 Transition DWS4:Lost1 to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

1.2.7 DWS5:Lost1Recovered state

1.2.7.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

1.2.7.2 Transition DWS5:Lost1Recovered to DWS3:SyncAcquired

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

1.2.7.3 Transition DWS5:Lost1Recovered to DWS6:Lost2

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see **Error! Reference source not found.**).

1.2.7.4 Transition DWS5:Lost1Recovered to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

1.2.8 DWS6:Lost2 state

1.2.8.1 State description

The receiver has detected an invalid dword without sufficient valid dwords to nullify a previous invalid dwords. The receiver monitors information received for valid dwords, invalid dwords or and loss of signal.

1.2.8.2 Transition DWS6:Lost2 to DWS7:Lost2Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment is still valid for this dword.

1.2.8.3 Transition DWS6:Lost2 to DWS8:Lost3

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see **Error! Reference source not found.**).

1.2.8.4 Transition DWS6:Lost2 to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

1.2.9 DWS7:Lost2Recovered state

1.2.9.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and a loss of signal is detected.

1.2.9.2 Transition DWS7:Lost2Recovered to DWS4:Lost1

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

1.2.9.3 Transition DWS7:Lost2Recovered to DWS8:Lost3

This transition shall occur when an invalid dword is detected. An expander forwarding the dword to another link shall replace the invalid dword with ERROR or SATA_ERROR (see **Error! Reference source not found.**).

1.2.9.4 Transition DWS7:Lost2Recovered to DWS0:AcquireSync

This transition shall occur when a loss of signal is detected. A new attempt at dword alignment is started.

1.2.10 DWS8:Lost3 state

1.2.10.1 State description

The receiver has detected an invalid dword without sufficient valid dwords to nullify a previous invalid dwords. The receiver monitors information received for valid dwords, invalid dwords and a loss of signal.

1.2.10.2 Transition DWS8:Lost3 to DWS9:Lost3Recovered

This transition shall occur when a valid dword is detected. This indicates the present dword alignment may still valid for this dword.

1.2.10.3 Transition DWS8:Lost3 to DWS0:AcquireSync

This transition shall occur when an invalid dword or loss of signal is detected. If an invalid dword is detected, at least four invalid dwords have been received without sufficient intervening valid dwords to nullify their affect. Dword synchronization is lost and must be reacquired; a new attempt at dword alignment is started.

1.2.11 DWS9:Lost3Recovered state

1.2.11.1 State description

The receiver has detected a valid dword after an invalid dword. Dword synchronization may still be valid. The receiver monitors information received for valid dwords, invalid dwords and loss of signal.

1.2.11.2 Transition DWS9:Lost3Recovered to DWS6:Lost2

This transition shall occur when a valid dword is detected. Two valid dwords have been received since the last invalid dword.

1.2.11.3 Transition DWS9:Lost3Recovered to DWS0:AcquireSync

This transition shall occur when an invalid dword or loss of signal is detected. If an invalid dword is detected, at least four invalid dwords have been received without sufficient intervening valid dwords to nullify their affect. Dword synchronization is lost and must be reacquired; a new attempt at dword alignment is started.

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