Enhancing Robustness of Link Synchronization in Automotive Ethernet at 802.3cy

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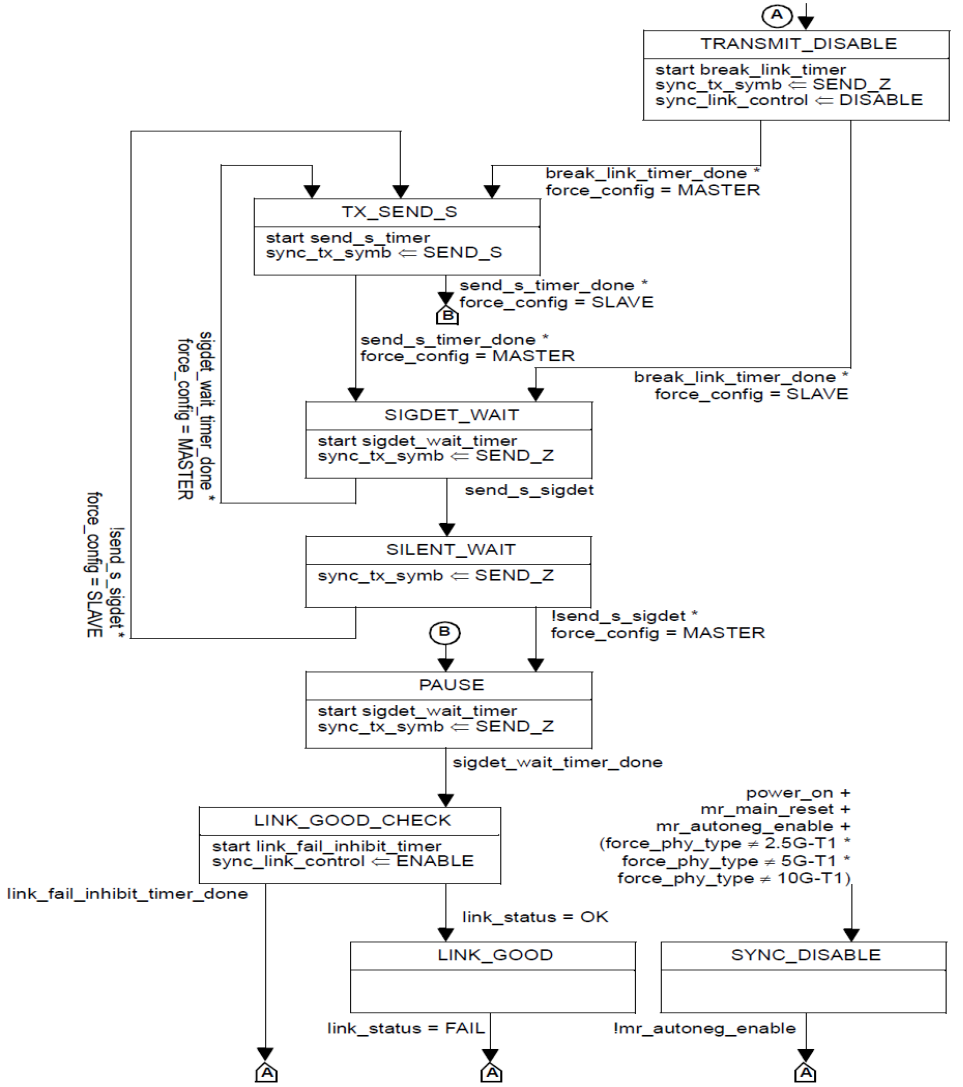
Introduction

- Link synchronization - SEND_S Signal is used by the MASTER and SLAVE to discover the link partner, and synchronize the start of PMA training
- SEND_S – PN sequence with a length of 255, defined at Eqn. 149-10(11)
- It was first adopted at 802.3bp for 1000BASE-T1
- Adopted ay 802.3ch with the same signaling at 703.125MHz for all 3 speed modes
- It has been included in the text draft for 802.3cy, approved to carry from 802.3ch
- In this contribution, the following items are proposed:
  - SEND_S signal working frequency is proposed to run at same rate as in 802ch
    - Repeating 20X PRBS patterns, 703.125MHz (25GBASE-T1)
  - Multiple Frame feedback of SEND_S Pulses at SLAVE.

Link Synchronization in Existing Spec

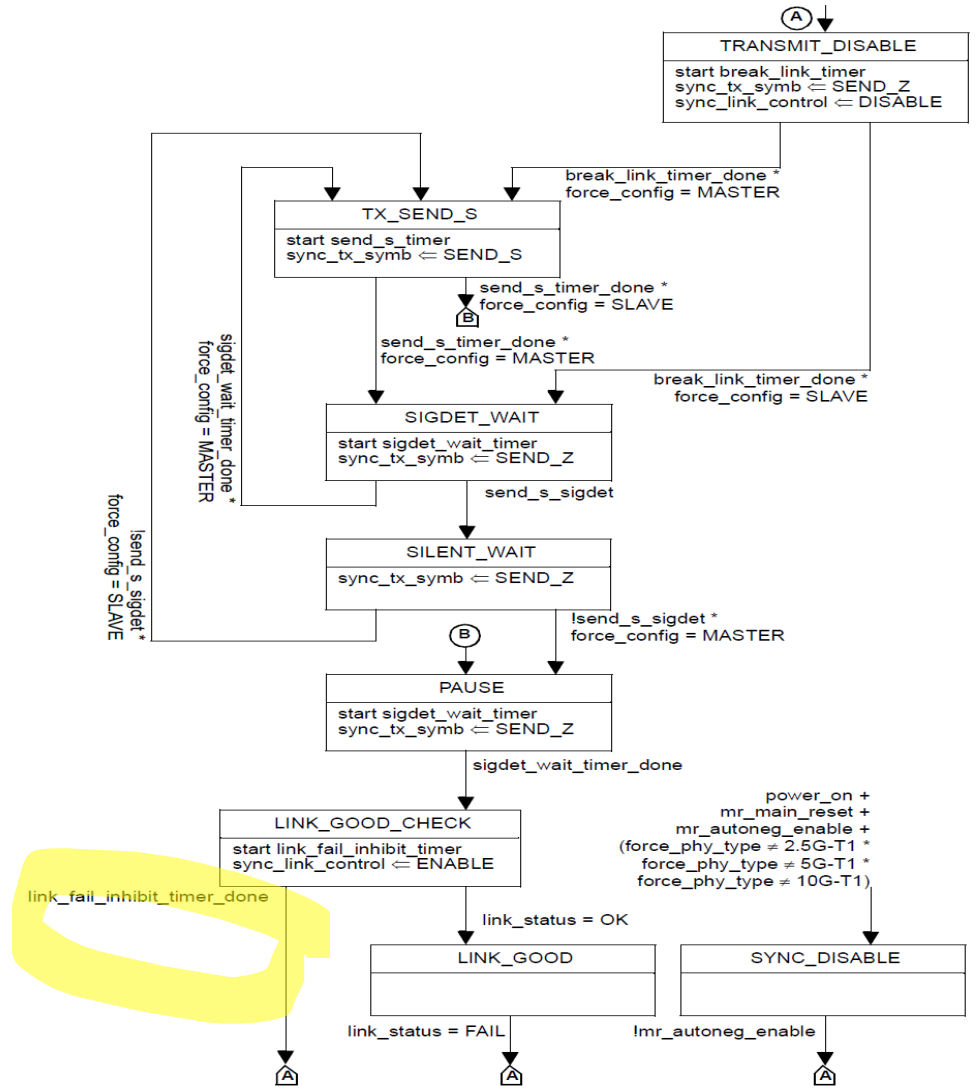
- In current IEEE 802.3bp and IEEE 802.3ch specifications, device configured in master mode will continuously transmit SEND_S frames until it detect and receive a SEND_S frame response from slave mode device
- For slave mode device, once it enter SIGDET_WAIT state it will remain in this state and wait for SEND_S from master.
- Once the Frame detected, it will move to TX_SEND_S to send a single SEND_S frame and move to PAUSE state, marking Link Synchronization completion
- Thus, in current specification, Slave will send one and only one SEND_S frame to Master



IEEE 802.3ch Figure 149-31 - PHY Link Synchronization state diagram

Link Synchronization in Existing Spec-2

- With this SEND_S handshaking, slave device can take as much retry as necessary to detect SEND_S from master
- However, the master side only has single chance to detect and recognize the SEND_S response from slave
- This create a weak point in handshaking where noise corruption can cause link synchronization to fail and result in undesirable slow link where link up time will exceed 100ms as per the IEEE standard and industry requirement

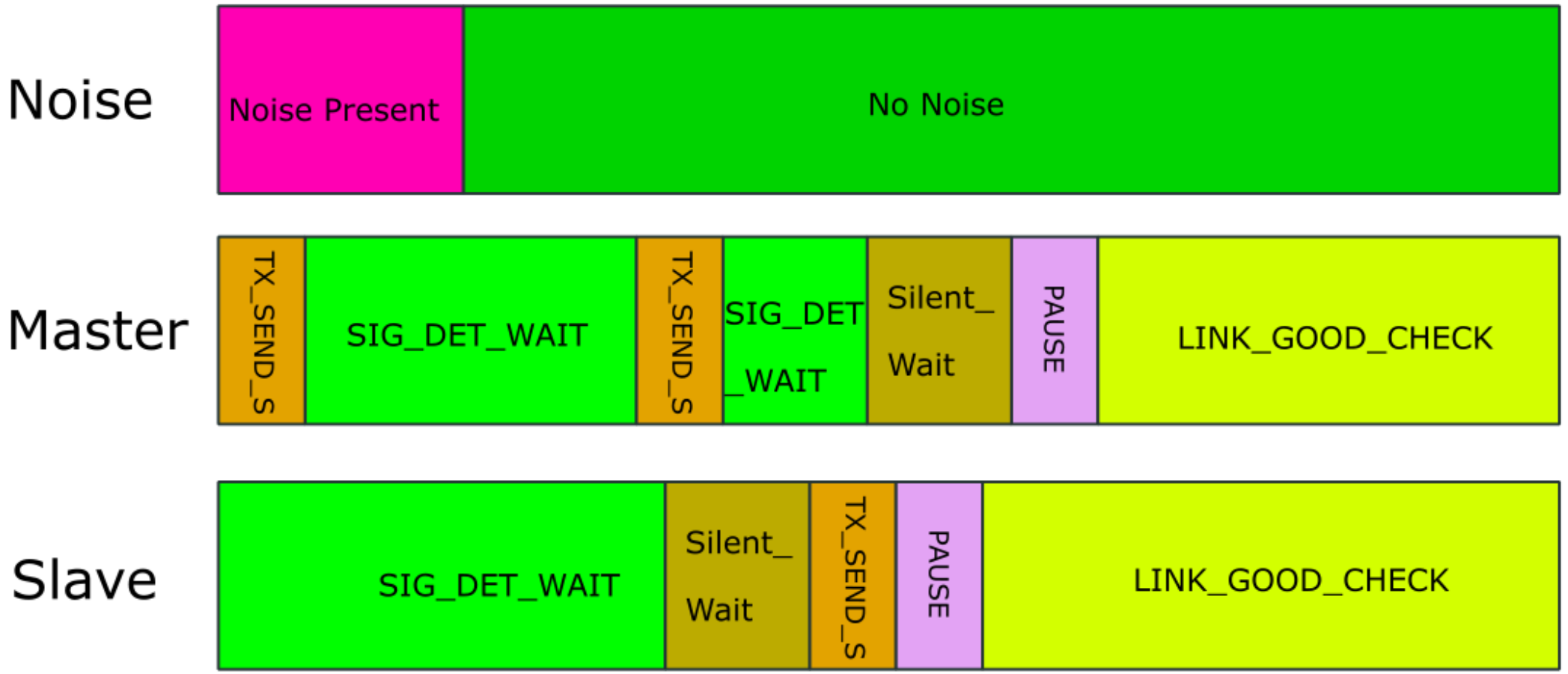


IEEE 802.3ch Figure 149-31 - PHY Link Synchronization state diagram

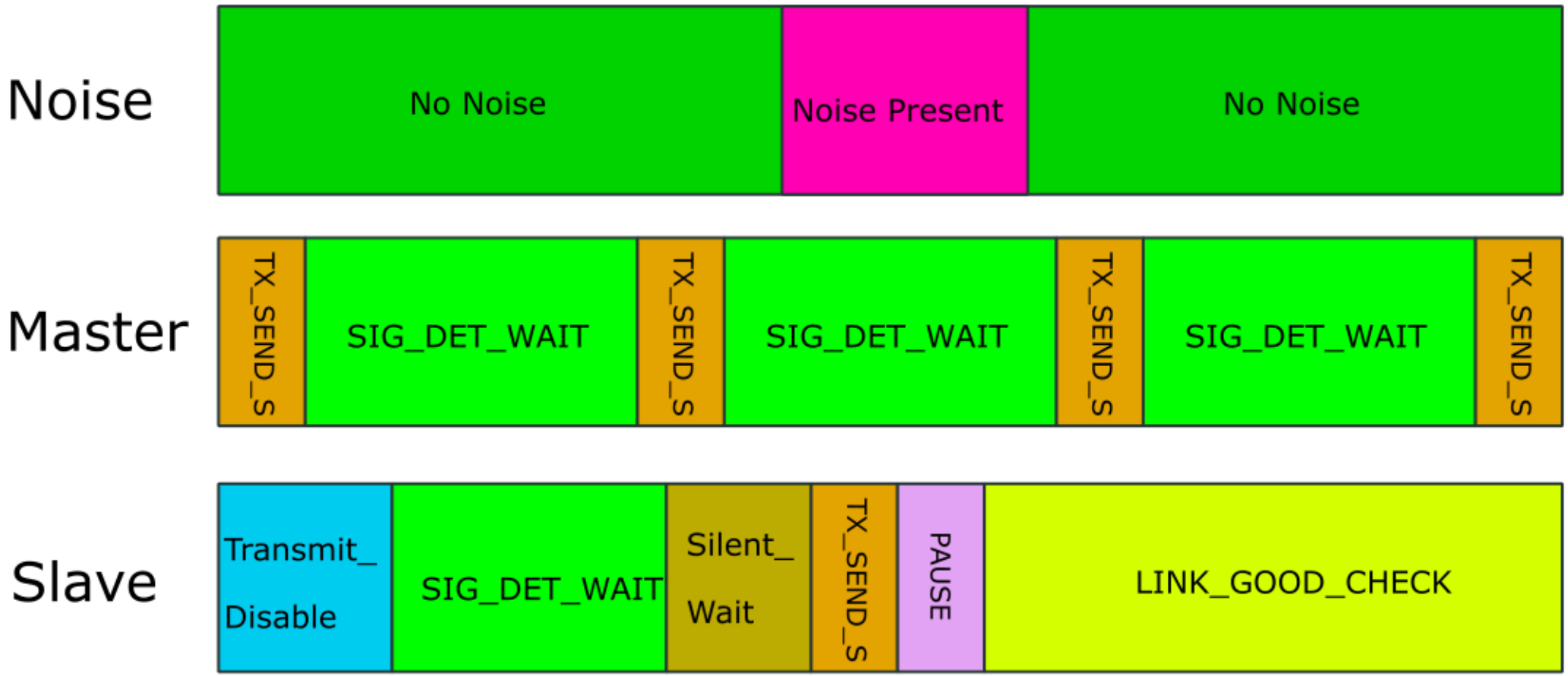
Problem with using existing design

- Single SEND_S frame is susceptible to be corrupted by environmental noise.
- Under existing scheme, the ability of Master device to detect and recognize the single SEND_S frame from slave rely on the resulting pattern correlation level, the corrupted SEND_S frame may be missed.
- Once the single frame missed, MASTER will keep waiting until SLAVE side (stuck at LINK_GOOD_CHECK) time out (link_fail_inhibit_timer= 97-98ms defined in Clause 98.5.2) with PMA training fail(stuck at SILIENT forever) , and start link synchronization again and slow link (>100ms) would happen

Environmental Noise During Slave Detection

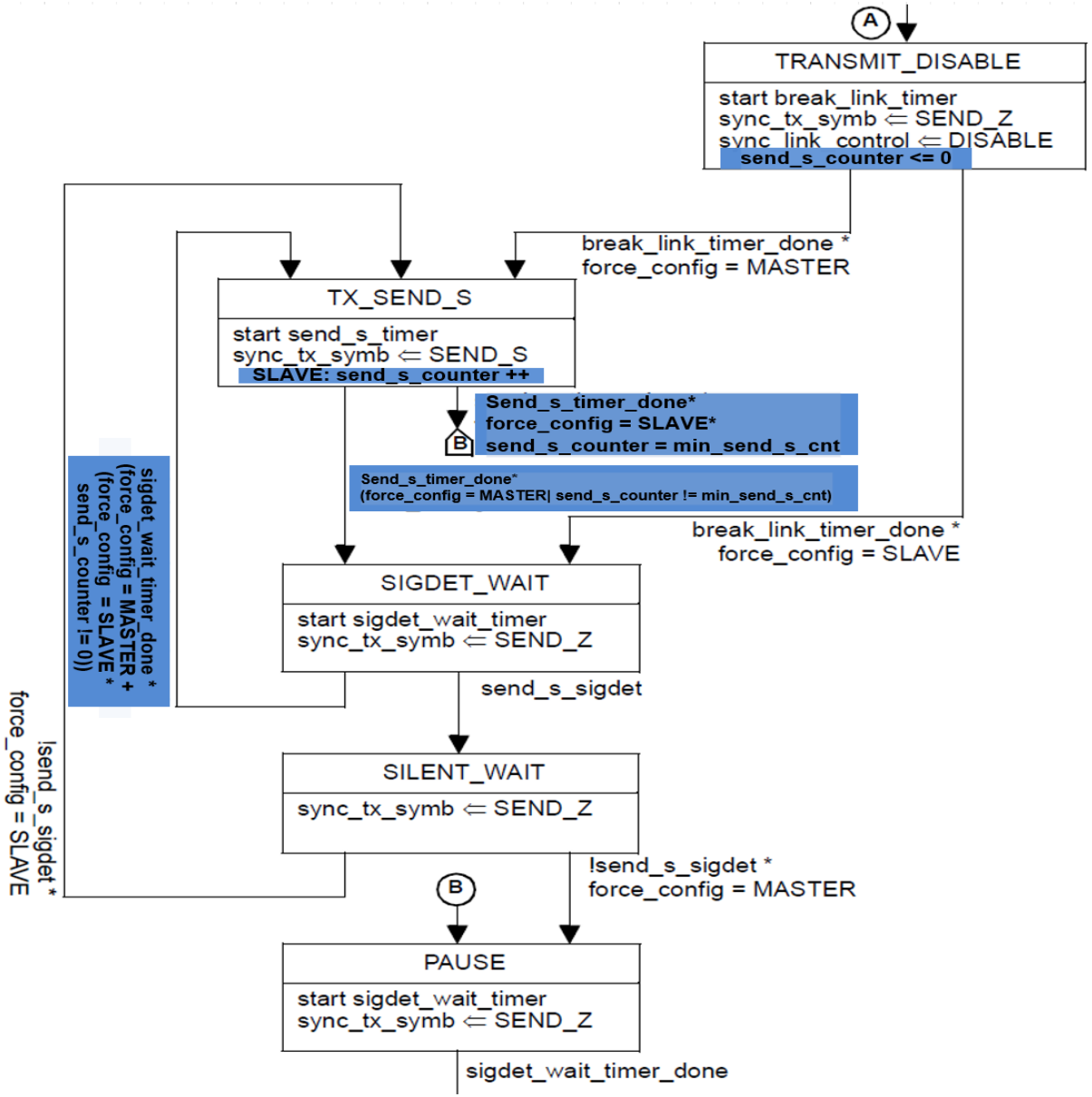


Environmental Noise During Master Detection

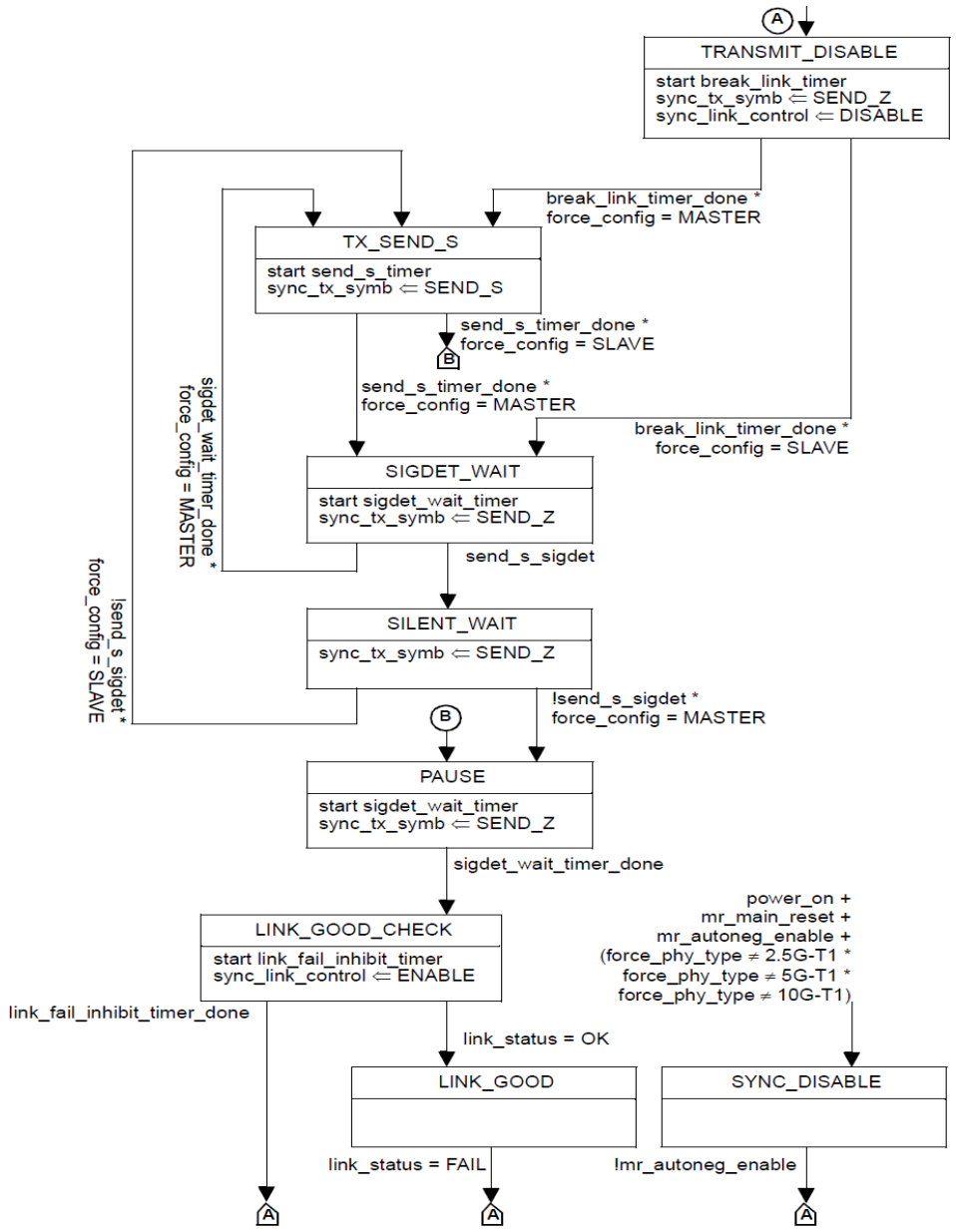


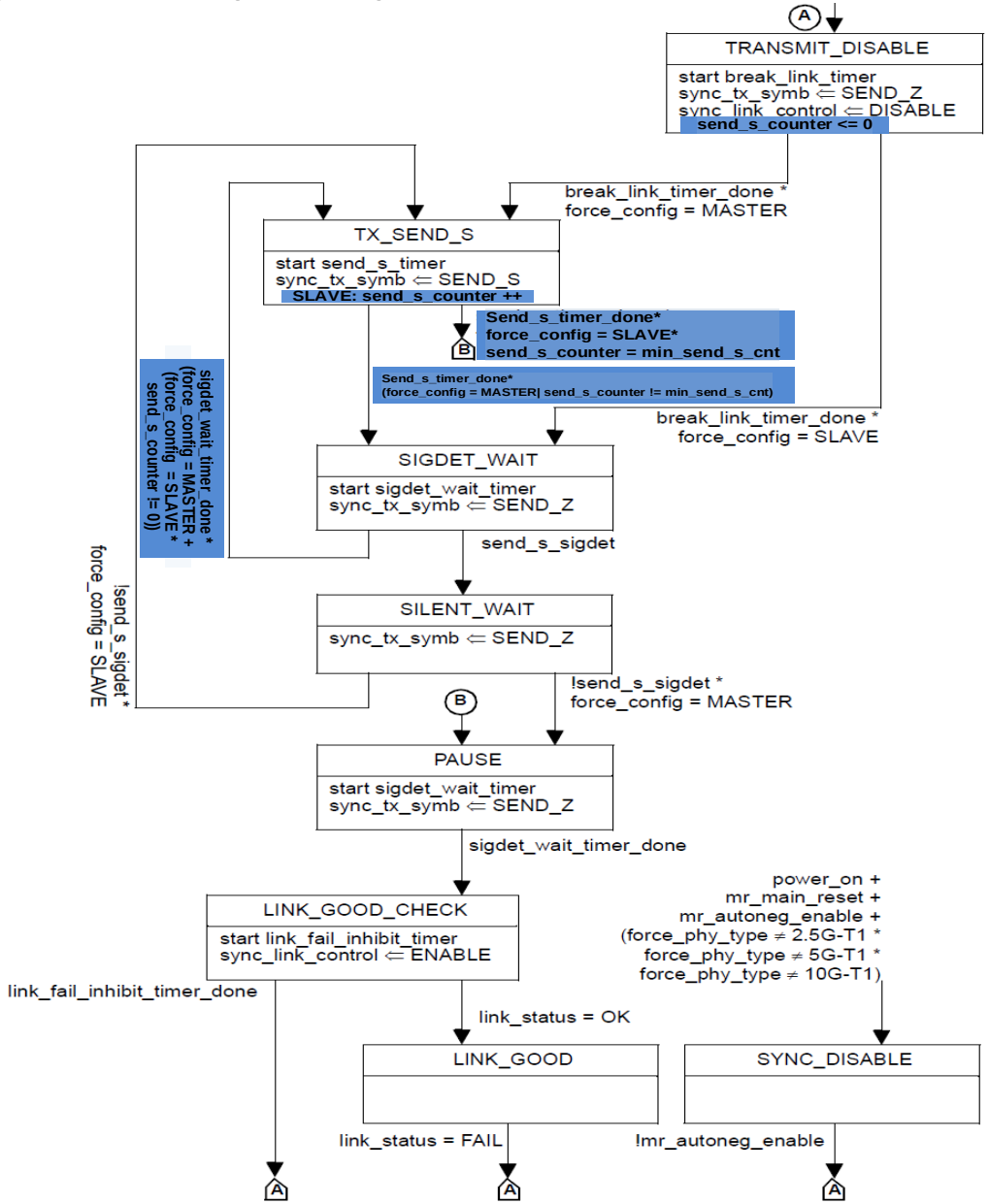
Proposed Solution – Slave Multiple SEND_S Frame

- One scheme to mitigate this behavior is to transmit multiple SEND_S frame from slave side instead of single SEND_S frame
- Slave shall repeat SEND_S frame until it reaches min_send_s_cnt, which is programmable
- min_send_s_cnt = 32



Comparison between existing and proposed solution

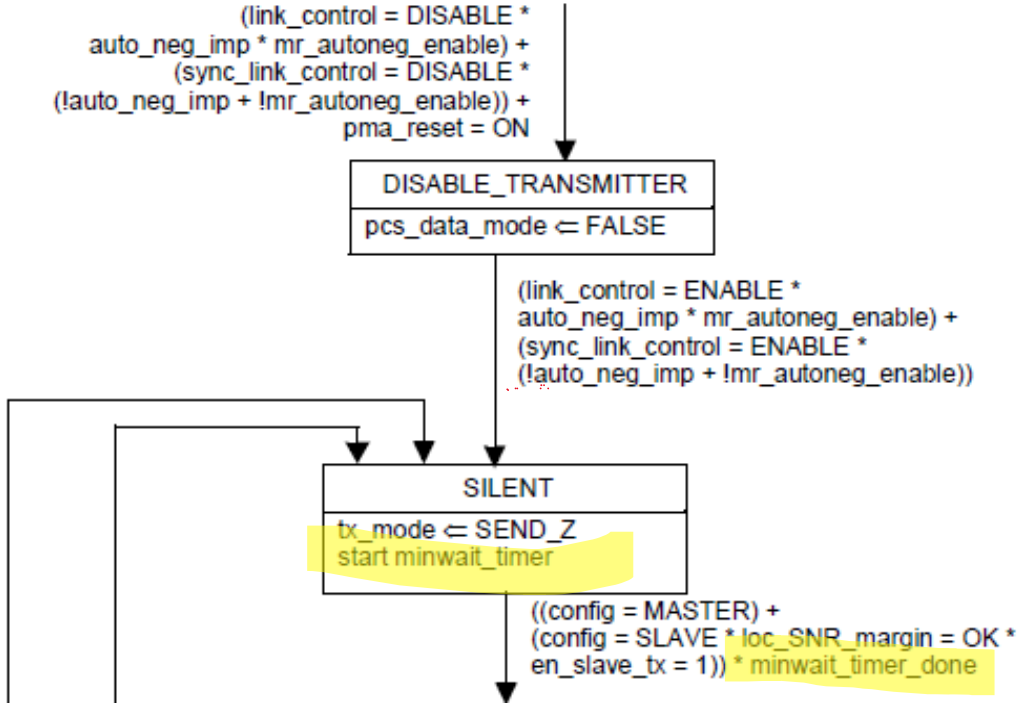




No negative impact to PMA startup

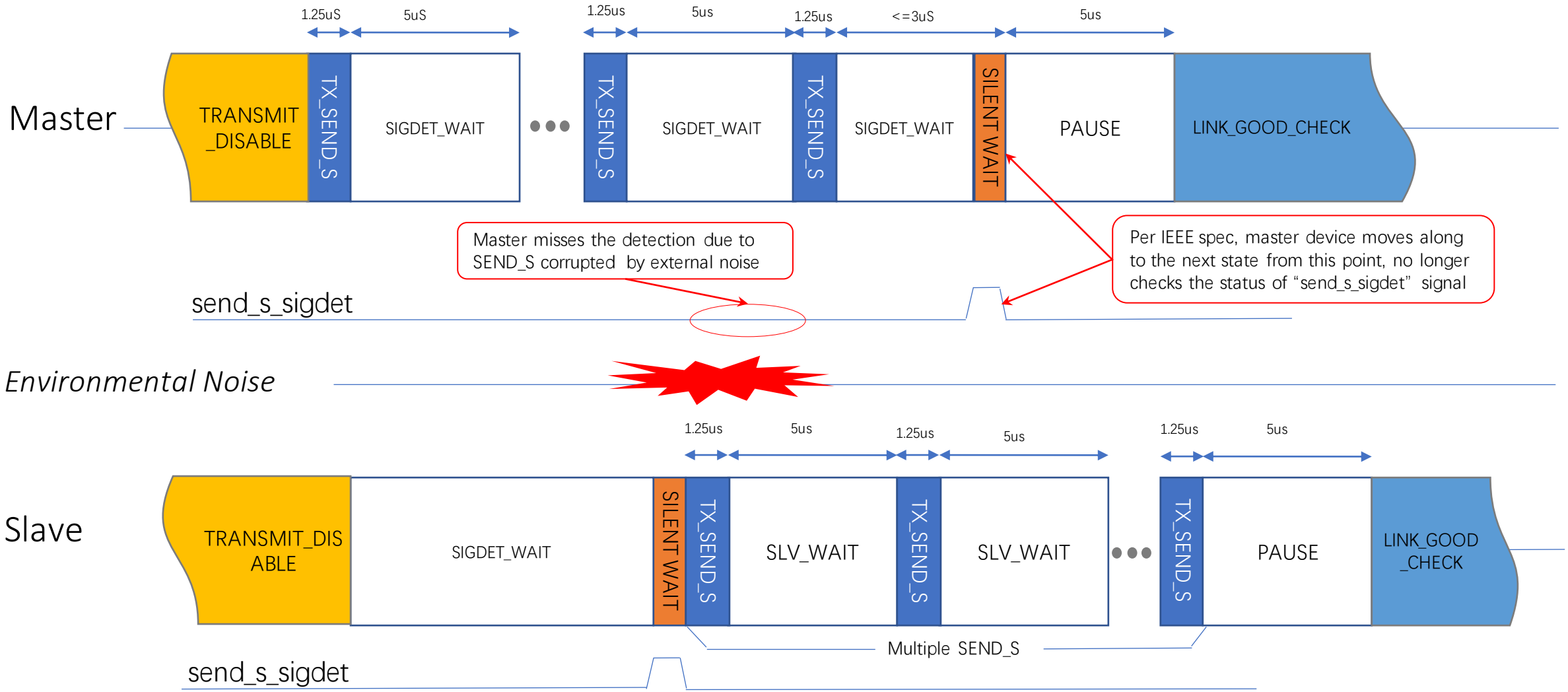
- It has a pre-determined delay from which link synchronization is complete on Master side to when Slave complete its link synchronization
- The relative additional delay is small additional delay compared to the overall link up time (32 frames)
  - Ex: 33 SEND_S frame ~ 206us
- Assuming Master detected the first SEND_S frame, during the additional delay the Master device is in SILENT state for at least 975us (minwait_timer) in the PHY Control State Diagram, hence no signal is coming from Master and Master is not detecting any signal from slave, hence no side effect even when connecting with existing device

149.4.5 State diagrams



IEEE 802.3ch Figure 149-32- PHY Control state diagram

PHY Link Synchronization (Slave Multiple SEND_S Frame)



Benefit of Proposed Solution

- If probability of missing SEND_S frame is p, then with n repeated SEND_S frame the probability of missing all of the SEND_S frame is thereby p^n
  - For example, if failure probability is $p = 10^{-2}$ under strong environmental noise condition, with $n = 10$ repeated SEND_S frame, then the failure probability is $p = 10^{-20}$.
- The multiple SEND_S frame scheme reduces the probability of failing link synchronization
- No change to SEND_S detector, still qualifying detection by 1 single SEND_S frame

Conclusion

- The threat of SEND_S getting corrupted during Link Synchronization in 802.3cy are real under strong environmental noise
- At 802.3cy, We propose multiple SEND_S frame scheme to reduce the probability of failing link synchronization under strong environmental noise
- To simplify the implementation of detector, SEND_S signal can be kept at 703.125MHz, and related parameters stay the same. (Repeating by 20X of PRBS patterns when sent, assuming 14.065GHz baud rate at 25GBASE-T1)
  - send_s_timer: 1.25 µs ± 0.05 µs
  - sigdet_wait_time: 5 µs ± 0.15 µs