Linlin HOU, Xuan MA, Haibin SUN, 2022. Stabilization of switched linear systems under asynchronous switching subject to admissible edge-dependent average dwell time. *Frontiers of Information Technology & Electronic Engineering*, 23(5):810-822. https://doi.org/10.1631/FITEE.2000698

Stabilization of switched linear systems under asynchronous switching subject to admissible edge-dependent average dwell time

Front Inform Technol Electron Eng

Key words: Asynchronous switching; Admissible edge-dependent average dwell time; Multi-Lyapunov function

Corresponding author: Linlin HOU
E-mail: houtingting8706@126.com
ORCID: https://orcid.org/0000-0001-7321-9239

Motivation

- In recent decades, switched systems have been widely studied due to their extensive applications in practical systems.
- In fact, there is a lag between controller switching and system switching, because it takes some time to identify the system mode and apply the corresponding controller. Asynchronous switching may decrease control performance and lead to instability.
- It is difficult to determine the lag time between system switching and the switching of the corresponding controller. Hence, there is still significant research need for removing this restriction in switching signal design.

Front Inform Technol Electron Eng

Contributions

- The switching signal is designed by combining the slow AED-ADT (SAED-ADT) method and fast AED-ADT (FAED-ADT) method, assuming that the maximum asynchronous switching delay is not known a priori.
- The constructed Lyapunov function is associated with both the system mode and controller mode.

Front Inform Technol Electron Eng

Contributions (Cont'd)

- In the literature, it was generally assumed that the controller cannot stabilize the subsystems in asynchronous switching intervals. In this paper, we take a different approach and investigate whether the asynchronous switching controller may be able to stabilize the subsystem in asynchronous switching intervals.
- The stabilization criteria are obtained, and the corresponding algorithm is presented to determine the controller gains and to design the switching signal. In the simulations, two examples are provided to demonstrate the effectiveness of the proposed results.

Front Inform Technol Electron Eng

Method

The effect of the lag time $d(t)$ is that the switching between the system and the controller is not synchronous (Fig. 1).

In synchronous switching intervals $[t_0, t_1)$ and $[t_m+d(t_m), t_{m+1})$, $\sigma(t)=\sigma'(t)$.

In asynchronous switching intervals $[t_m, t_m+d(t_m))$, $\sigma(t)\neq\sigma'(t)$.

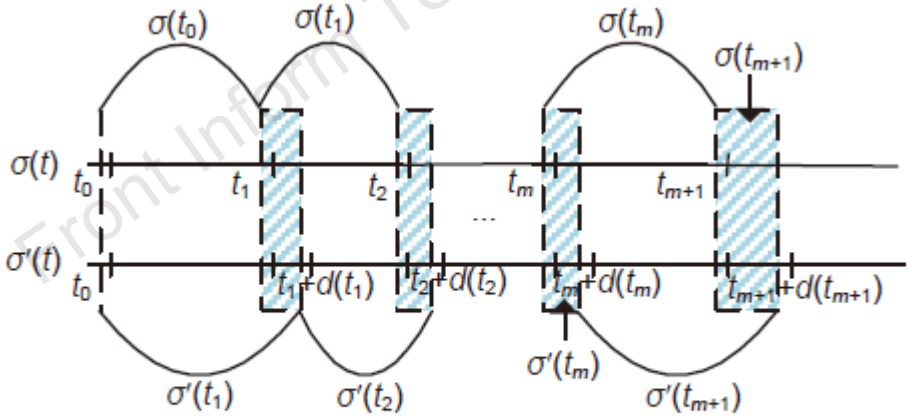


Fig. 1 Switching signals $\sigma(t)$ and $\sigma'(t)$

Front Inform Technol Electron Eng

Method (AED-ADT, Cont'd)

Definition 1 (Hou et al., 2018b) For any $p, q \in \mathcal{M}$ $(p \neq q)$ and $\sigma(t)$ (the switching signal), let $N^{\sigma}_{p,q}(t_1, t_2)$ be the number of switching times from q to p in the interval $[t_1, t_2)$, and $T_{p,q}(t_1, t_2)$ be the total running time of subsystem p in the interval $[t_1, t_2)$ whenever the switching takes place from q to p, where $t_2 \geq t_1 \geq 0$. In this case, $\sigma(t)$ has an SAED-ADT $\tau^{\mathrm{a}}_{p,q}$ and an FAED-ADT $d^{\mathrm{a}}_{p,q}$ if there exist nonnegative numbers $\overline{N}^{0}_{p,q}$ and $\underline{N}^{0}_{p,q}$, and positive numbers $\tau^{\mathrm{a}}_{p,q}$ and $d^{\mathrm{a}}_{p,q}$ such that the following inequalities are true:

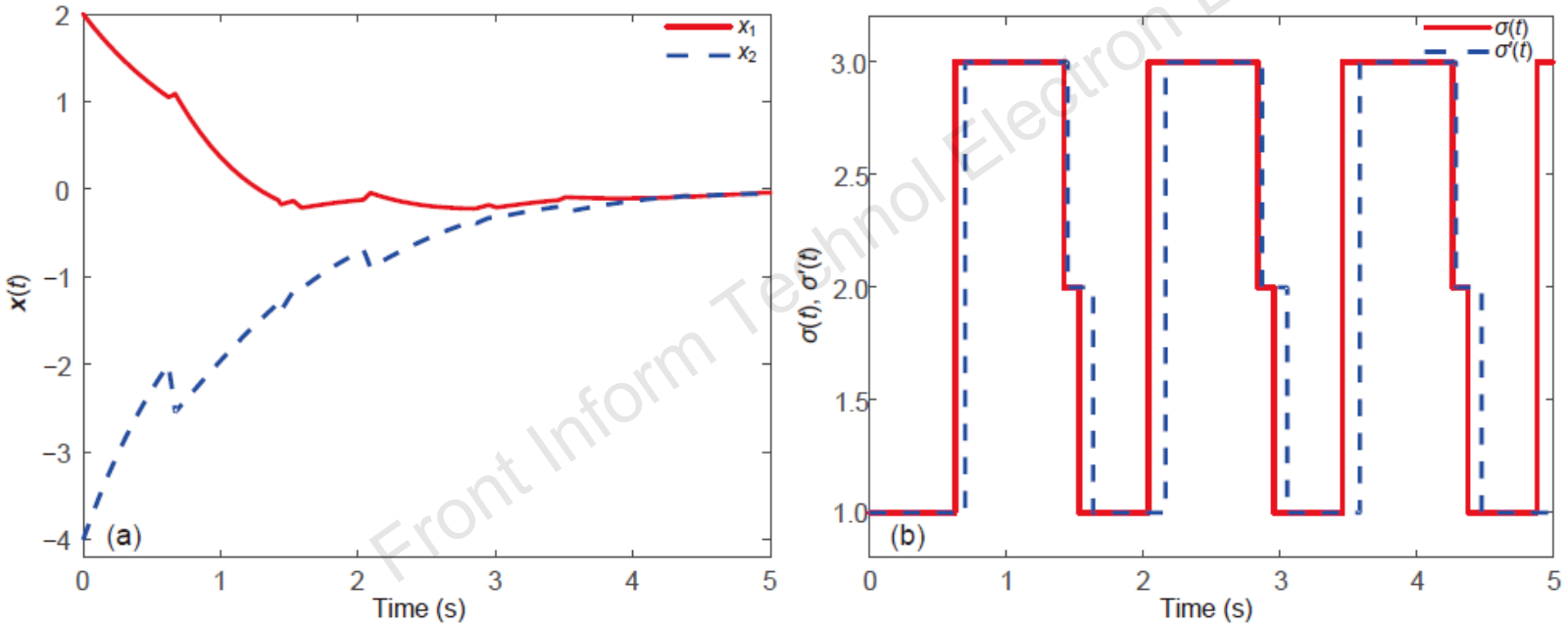
$$N^{\sigma}_{p,q}(t_1, t_2) \leq \underline{N}^{0}_{p,q} + \frac{T_{p,q}(t_1, t_2)}{\tau^{\mathrm{a}}_{p,q}}, \ \forall\, t_2 \geq t_1 \geq 0, \quad (4)$$

$$N^{\sigma}_{p,q}(t_1, t_2) \geq \overline{N}^{0}_{p,q} + \frac{T_{p,q}(t_1, t_2)}{d^{\mathrm{a}}_{p,q}}, \ \forall\, t_2 \geq t_1 \geq 0, \quad (5)$$

where $\overline{N}^{0}_{p,q}$ and $\underline{N}^{0}_{p,q}$ are called the admissible edge-dependent chatter bounds.

Front Inform Technol Electron Eng

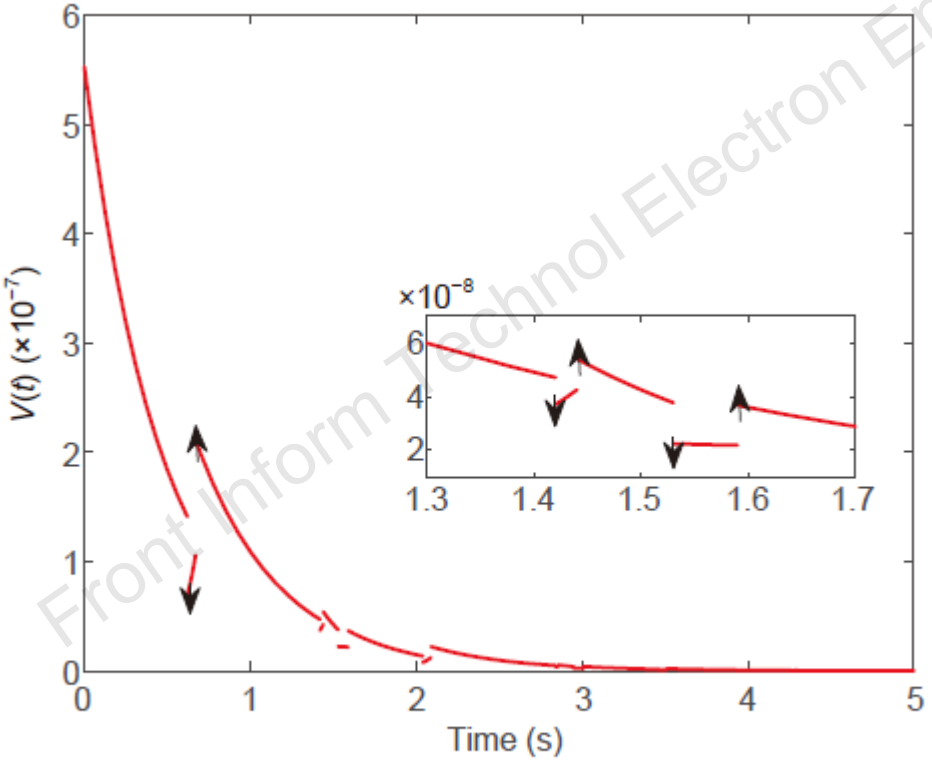
Major results (Example 1)



Front Inform Technol Electron Eng

Fig. 3 Response curves of $x(t)$ (a) and switching signals $\sigma(t)$ and $\sigma'(t)$ (b) for Example 1

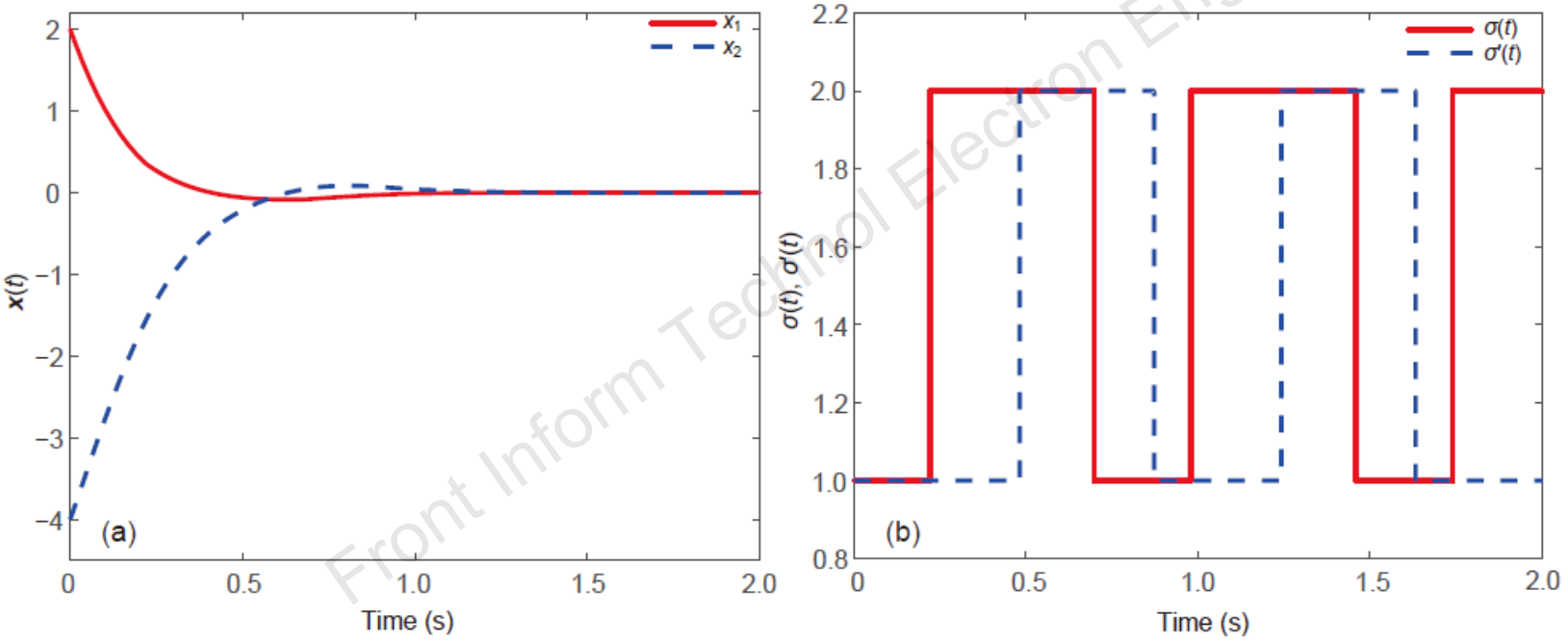
Major results (Example 1, Cont'd)



Front Inform Technol Electron Eng

Fig. 4 Response curve of $V(t)$ for Example 1

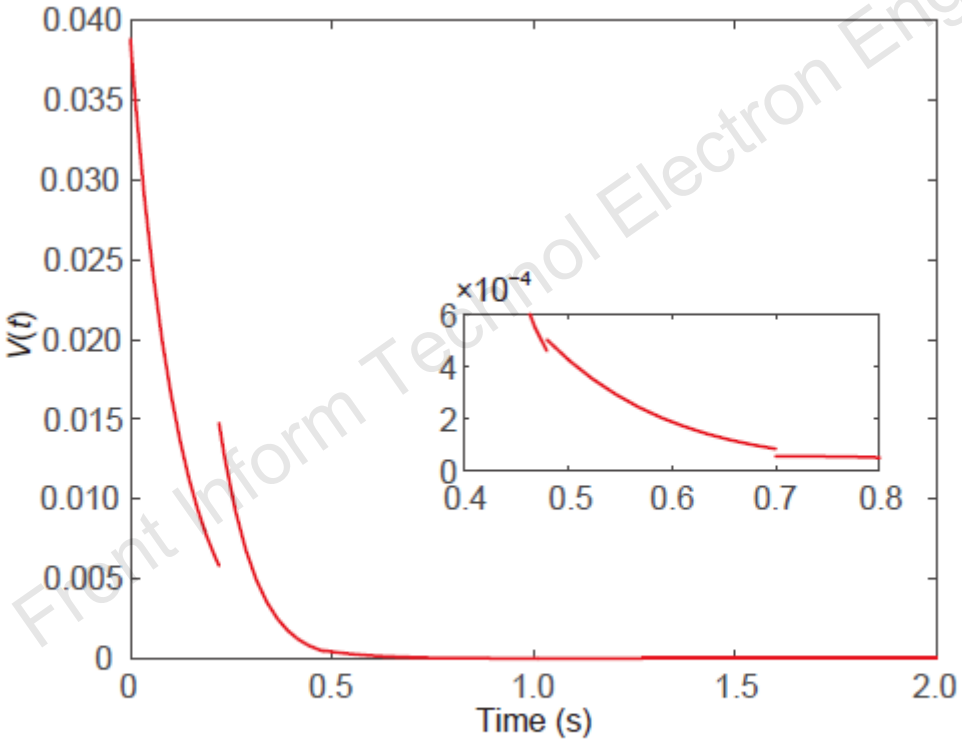
Major results (Example 2)



Front Inform Technol Electron Eng

Fig. 6 Response curves of $x(t)$ (a) and switching signals $\sigma(t)$ and $\sigma'(t)$ (b) for Example 2

Major results (Example 2, Cont'd)



Front Inform Technol Electron Eng

Fig. 7 Response curves of $V(t)$ for Example 2

Conclusions

- This study presents the research on the problem of stabilizing switched linear systems under asynchronous switching.
- SAED-ADT switching and FAED-ADT switching have been applied in designing the switching signal.
- Using the multi-Lyapunov function method, stabilization conditions have been given for switched linear systems.
- An algorithm has been provided to determine the controller gains and to design the switching signals.
- Finally, two examples have been given to show the effectiveness of the proposed results.

Front Inform Technol Electron Eng



Linlin HOU is a professor with the School of Computer Science, Qufu Normal University, Qufu, China. She received her PhD degree in Institute of Automation, Qufu Normal University, in 2012. She was a visiting scholar with the School of Engineering, RMIT University, Melbourne, Australia. Her research interests include analysis and control of switched systems, time-delay systems, and networked control systems.



Xuan MA received her BS degree in School of Information Science and Engineering, Qufu Normal University, in 2019. Her research interests include switching control, network control, and anti-disturbance control.



Haibin SUN is a professor with the School of Engineering, Qufu Normal University. He received his PhD degree in control theory and application from Southeast University in 2013. He was a postdoctoral researcher with the School of Automation, Beihang University, China, from 2013 to 2014. In 2017, he was a visiting scholar with the School of Engineering, RMIT University, Melbourne, Australia. In 2019, he was a visiting scholar with the School of IEEE, Nanyang Technological University, Singapore. His research interests include switched control, anti-disturbance control, and their applications.

Front Inform Technol Electron Eng