

Physical human robot interaction

Presentazione elaborati

Antonino Parisi - marzo 2022

Four channel teleoperation

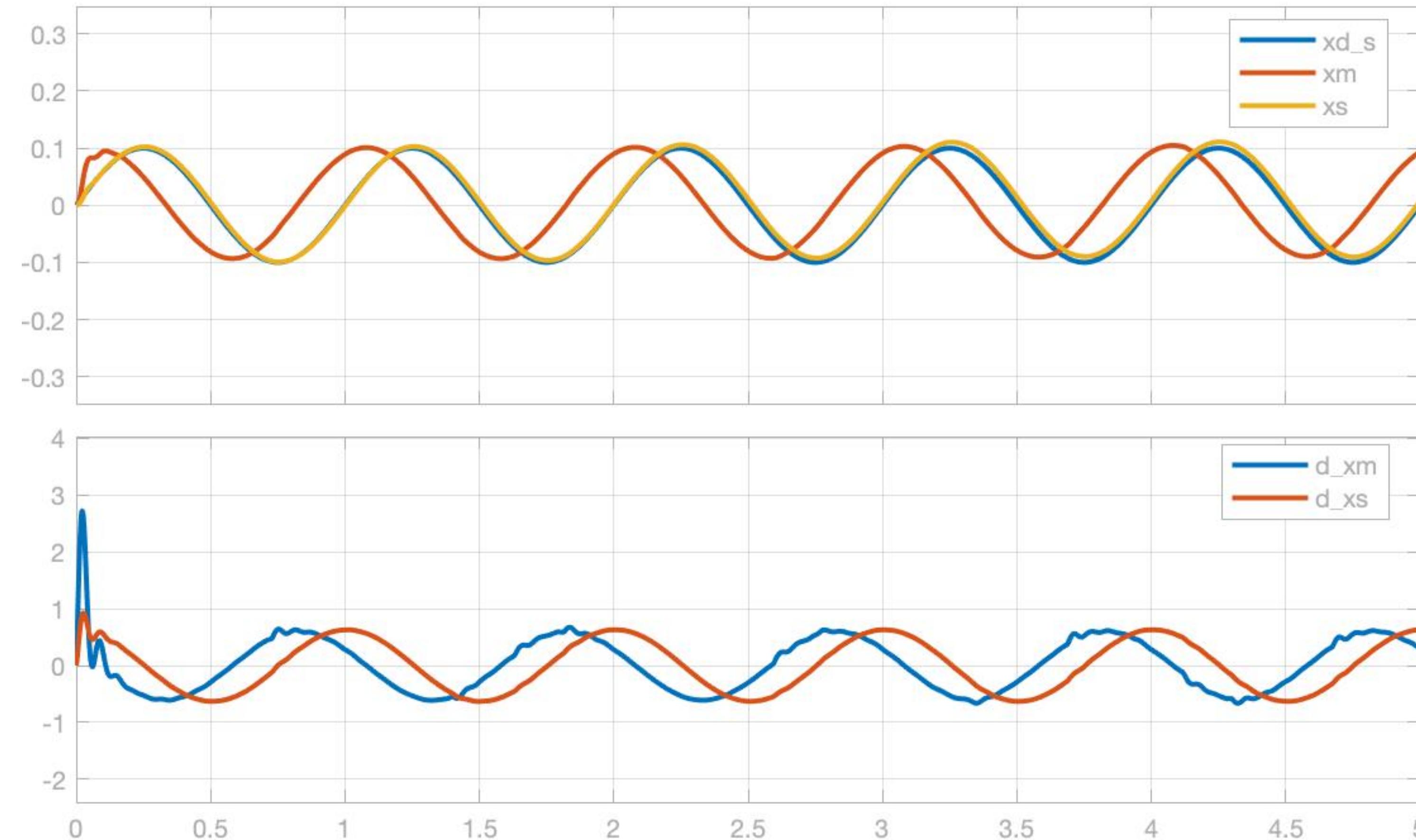
Four channel teleoperation

Descrizione

- Algoritmo FP-FP
- La trasparenza perfetta è data dalla matrice ibrida H (Hannaford o Lawrence)
- C_2 è il controllore in forza che aumenta o diminuisce lo sforzo dell'operatore
- La volontà dell'operatore (X_d) è gestita da C_h , modellato come controllore PD
- L'impedenza dell'operatore è modellata come un sistema del secondo ordine (massa, molla e smorzatore)
- Con loop di forza locali è necessario il tuning online dei parametri dei controllori (ambienti diversi comportano diversi comportamenti)

Four channel teleoperation

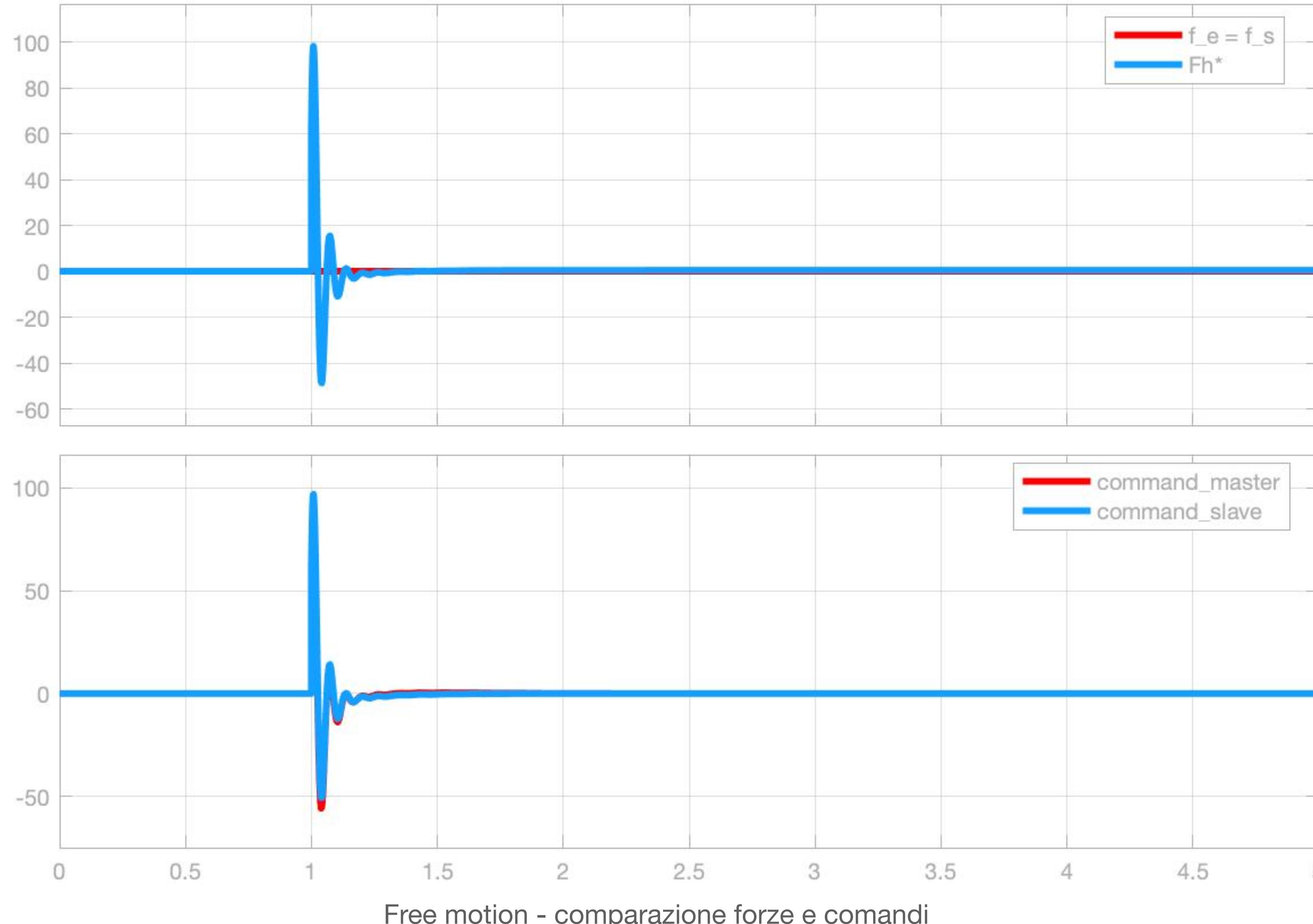
Versione continua



Free motion - Posizioni e velocità

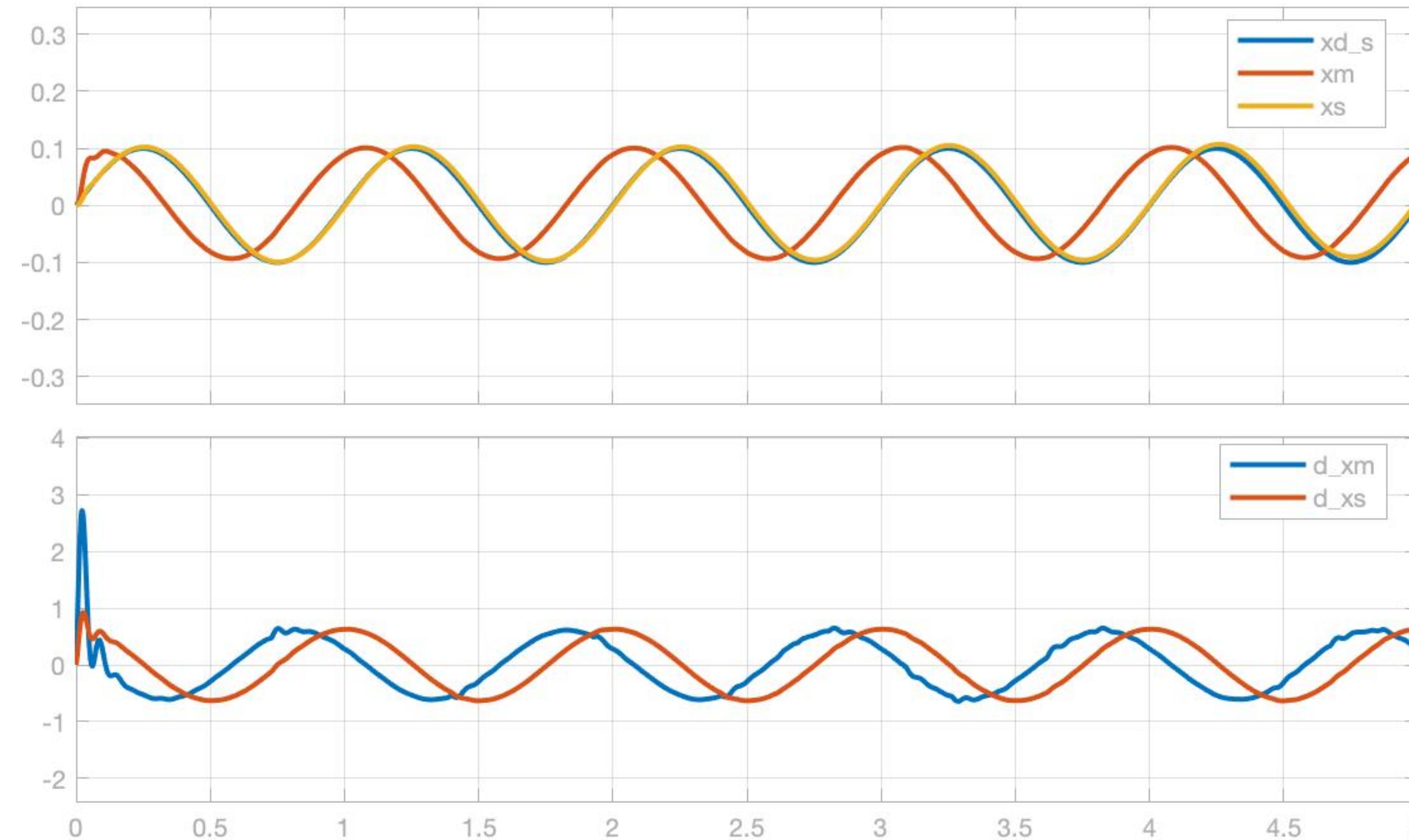
Four channel teleoperation

Versione continua



Four channel teleoperation

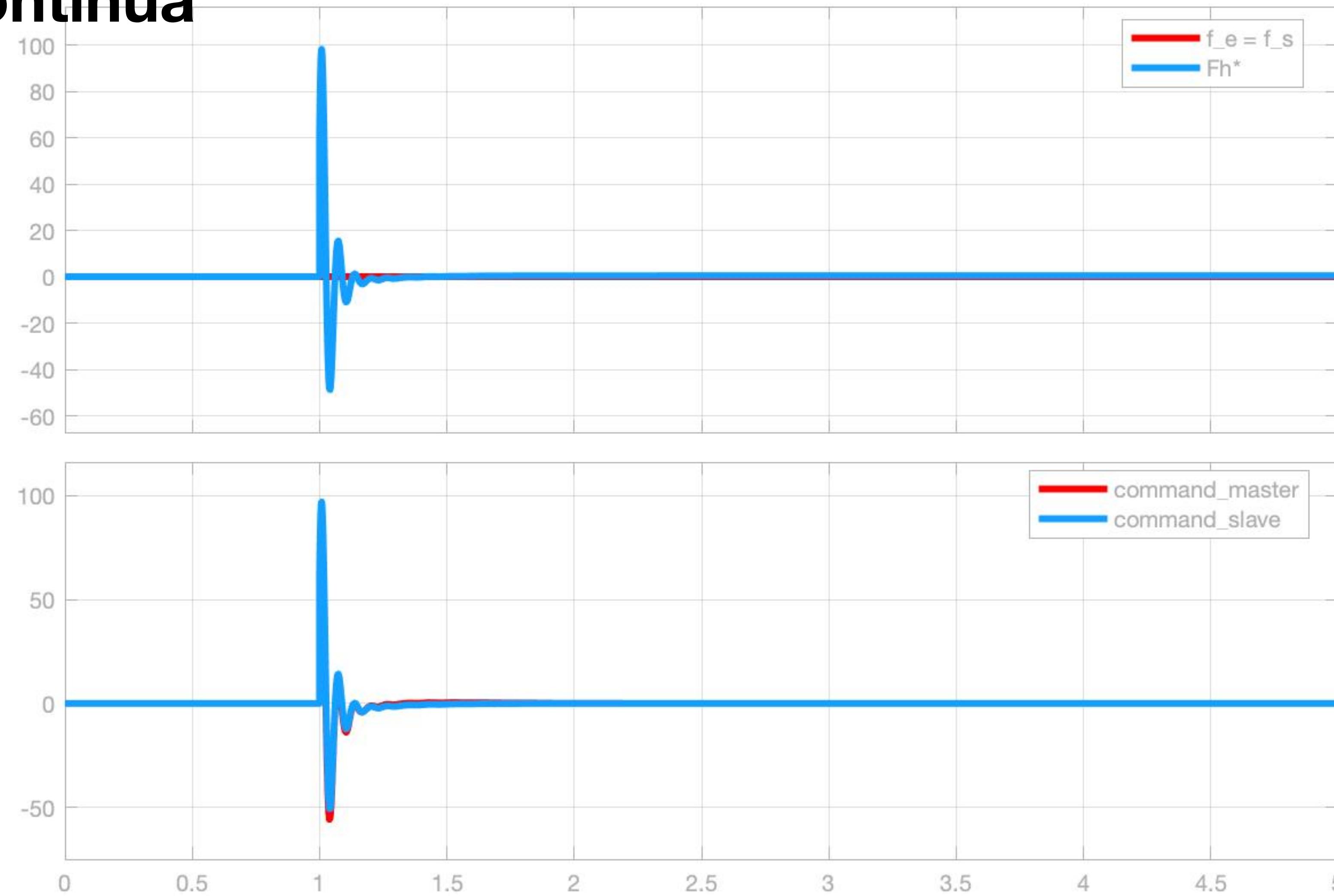
Versione continua



Contatto con l'ambiente - Posizioni e velocità

Four channel teleoperation

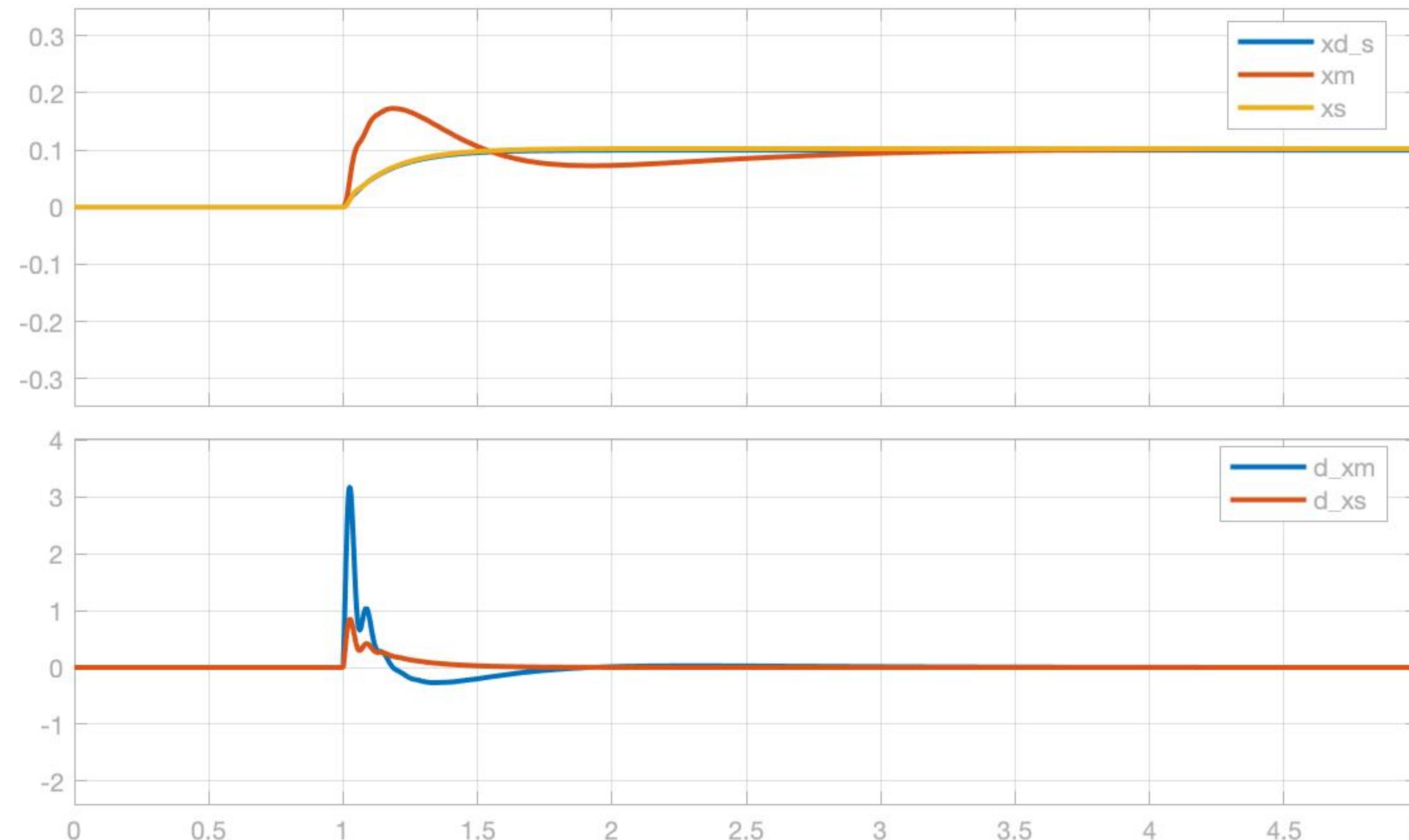
Versione continua



Contact - comparazione forze e comandi

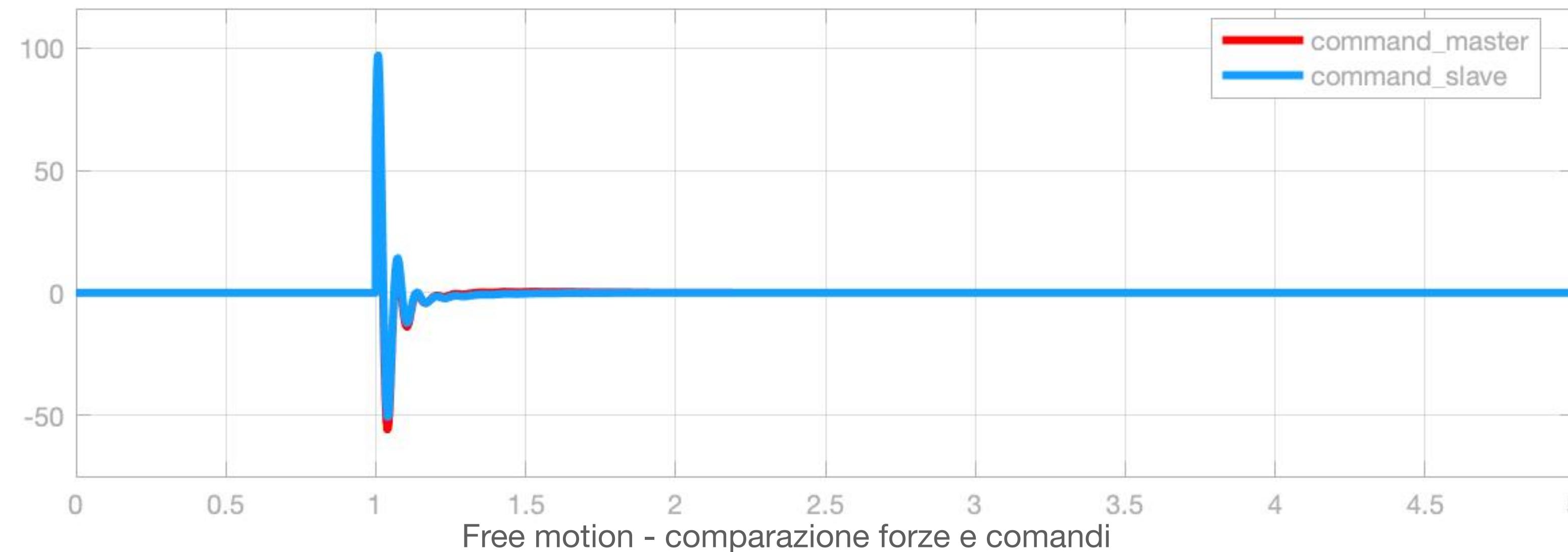
Four channel teleoperation

Versione continua



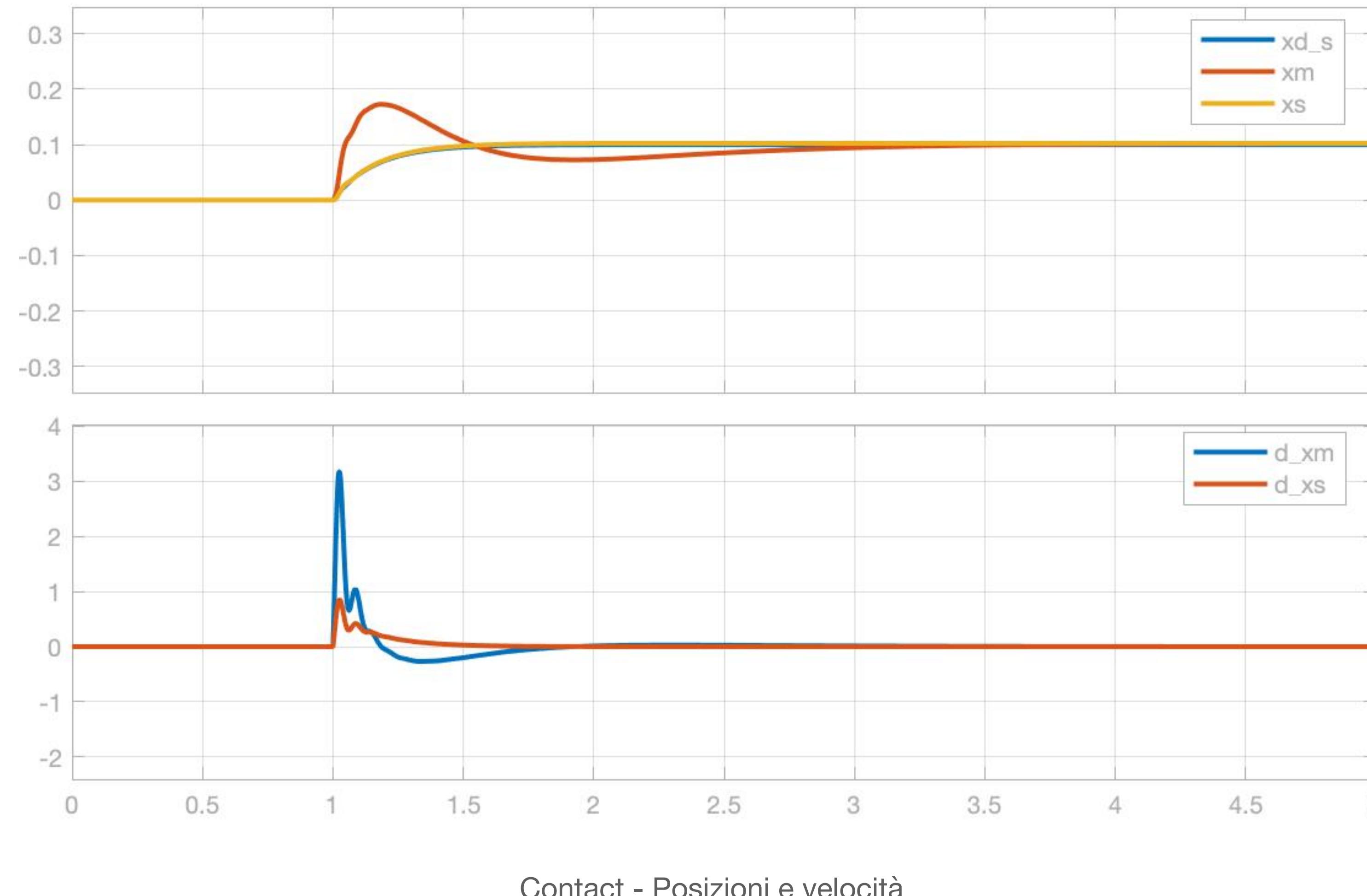
Four channel teleoperation

Versione continua



Four channel teleoperation

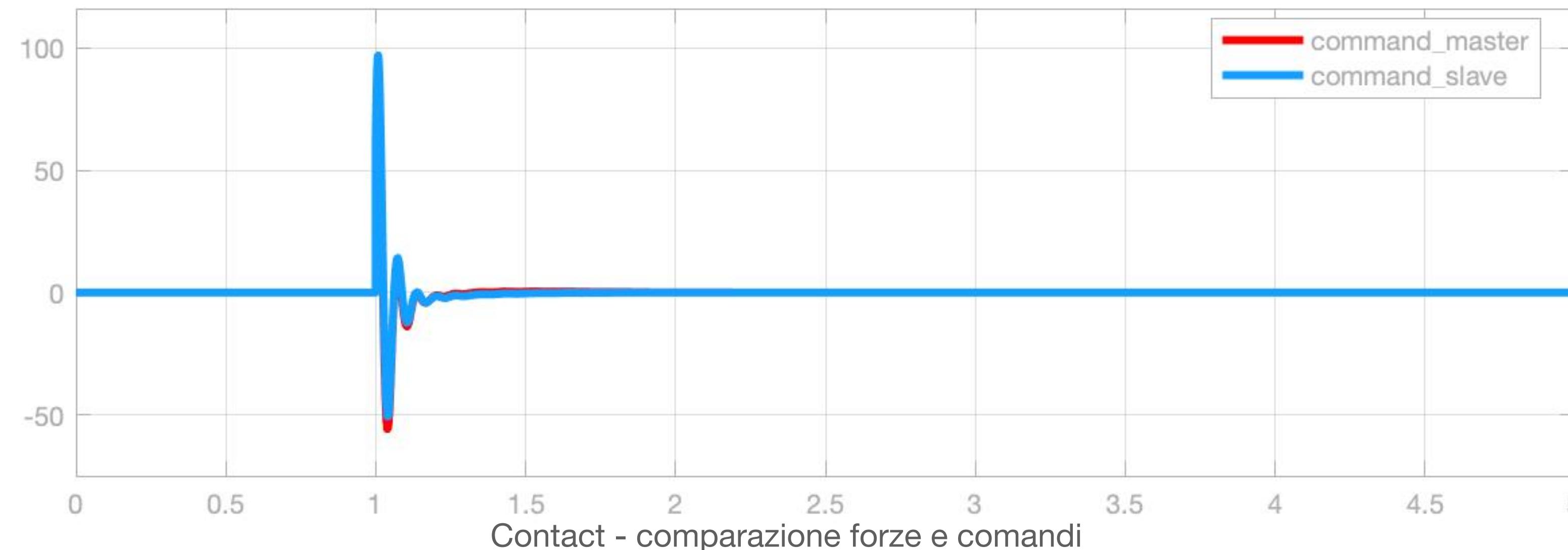
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Contact - Posizioni e velocità

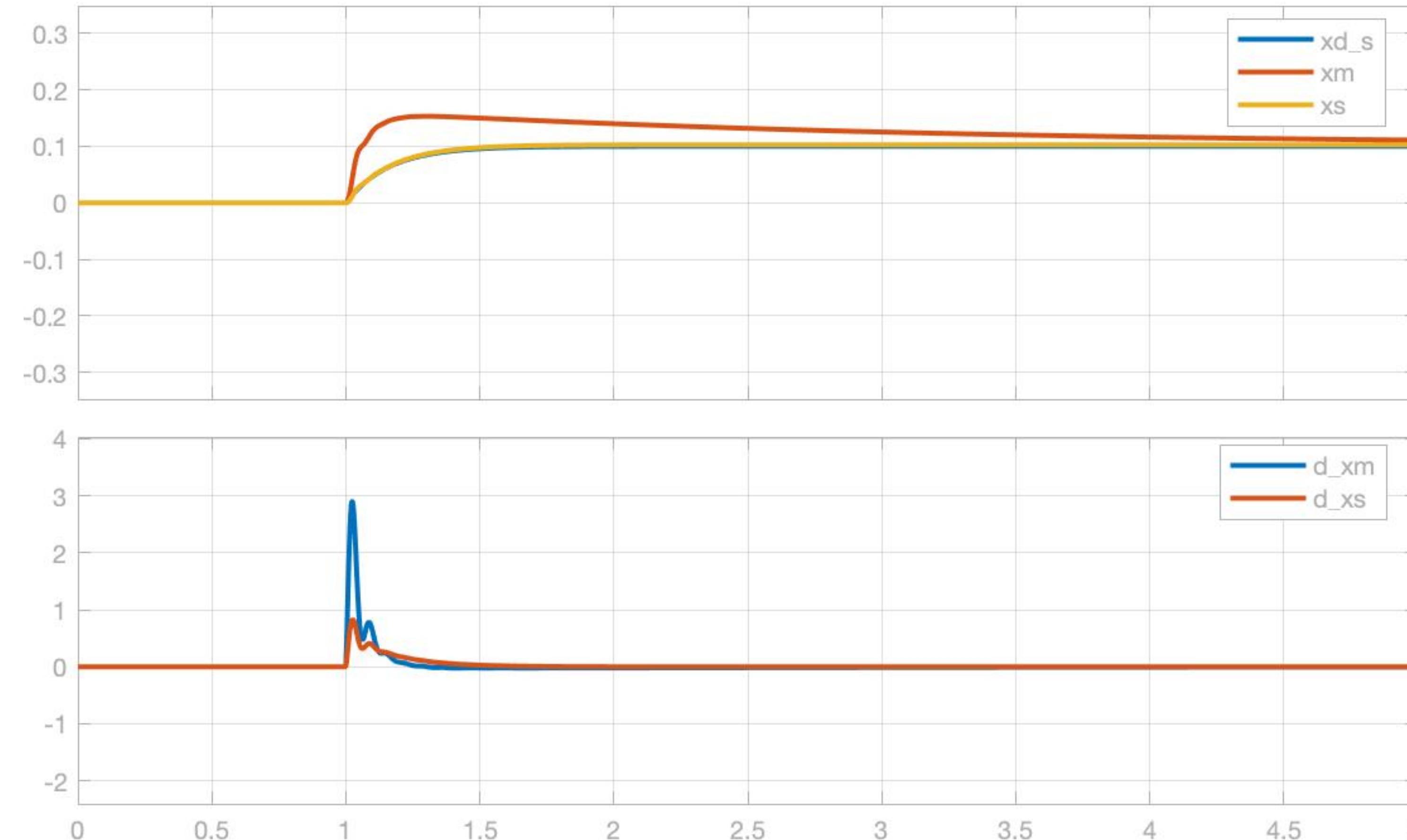
Four channel teleoperation

Versione continua



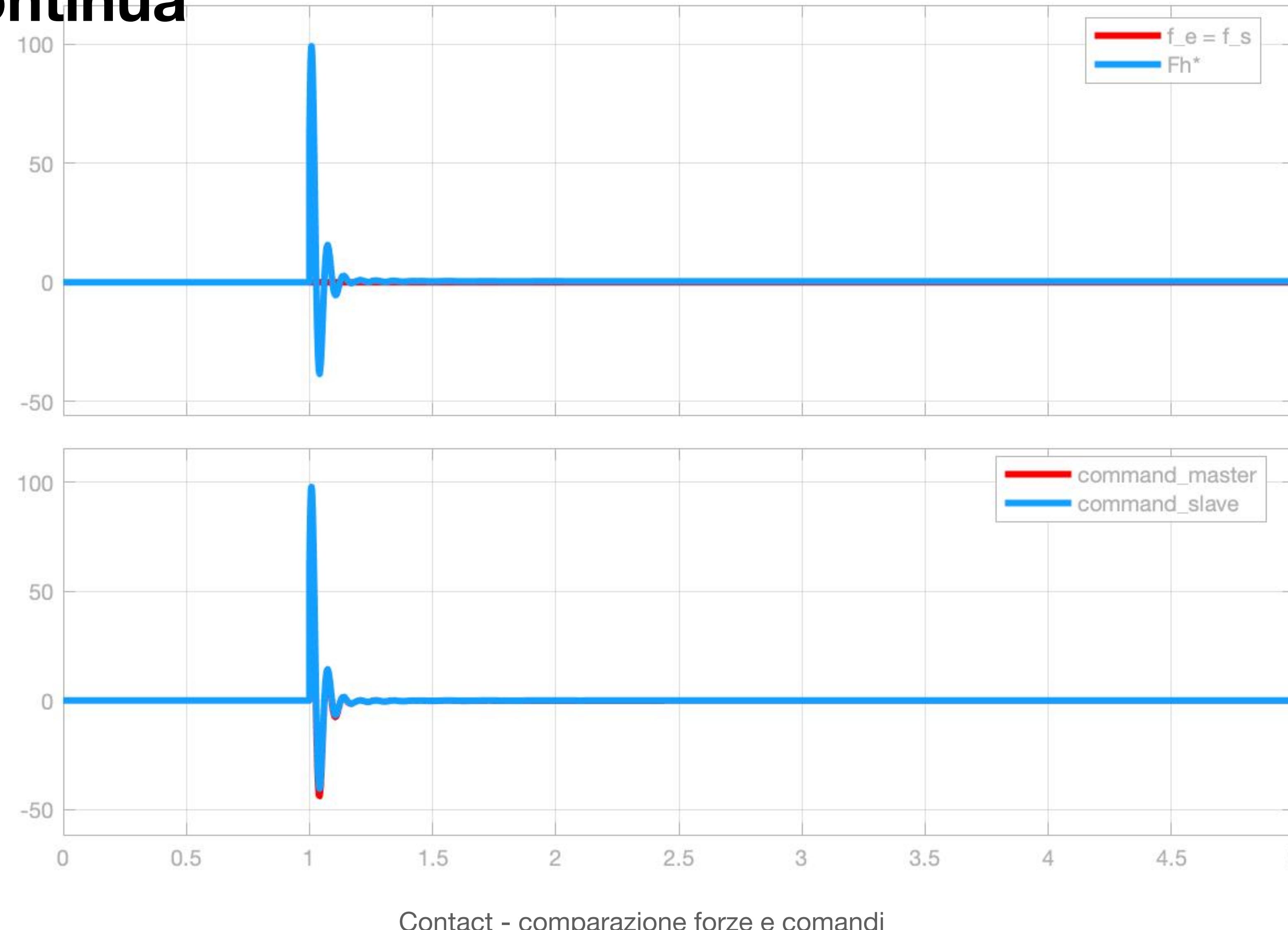
Four channel teleoperation

Versione continua - DM = 5, DS = 10



Four channel teleoperation

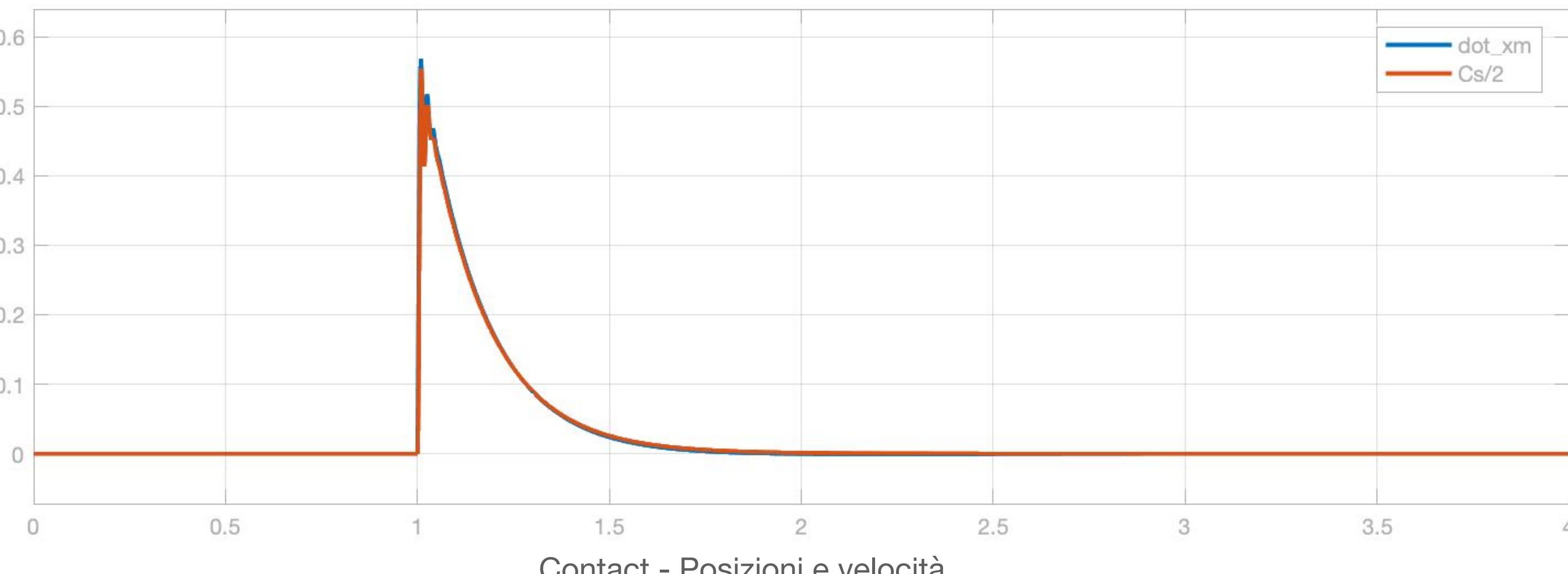
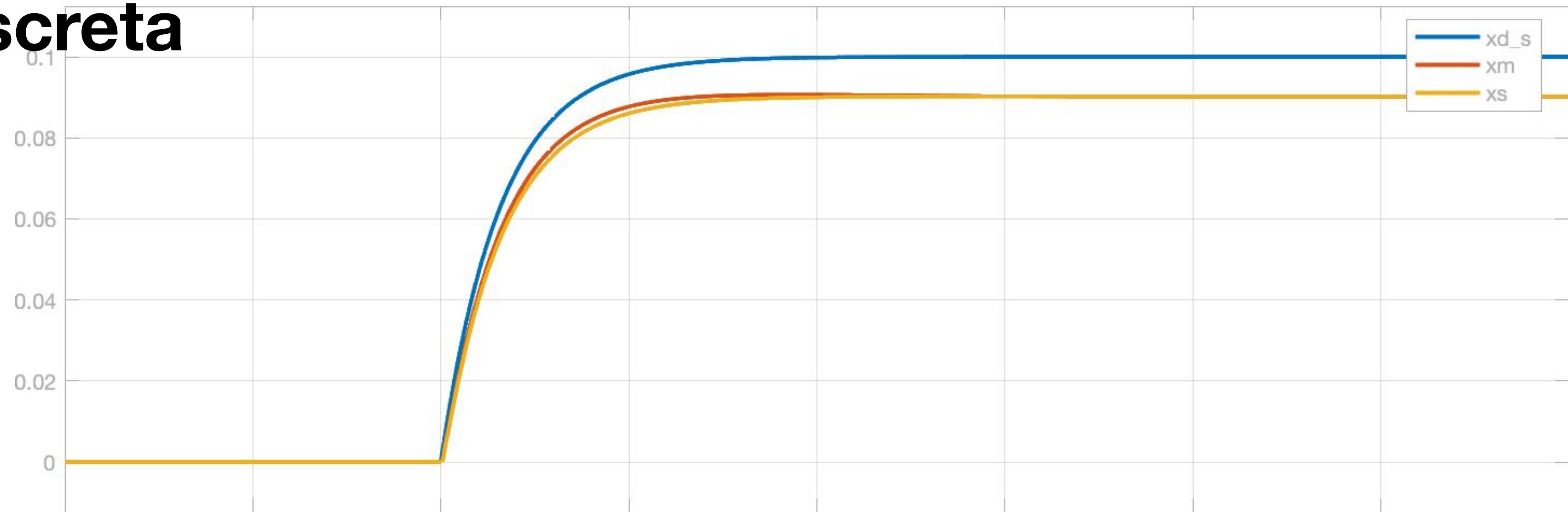
Versione continua



Contact - comparazione forze e comandi

Four channel teleoperation

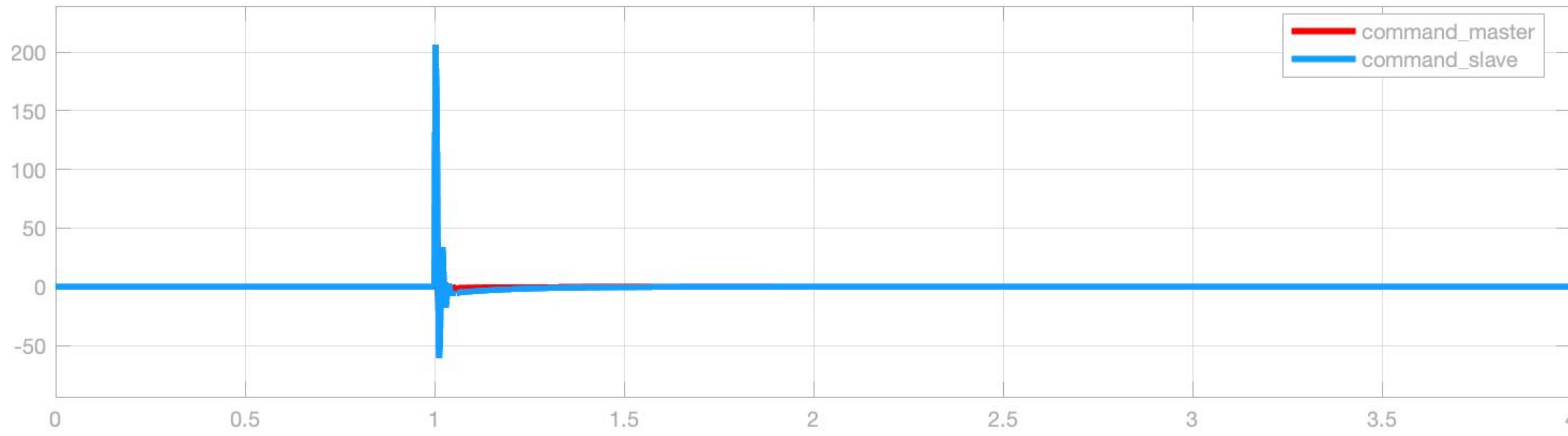
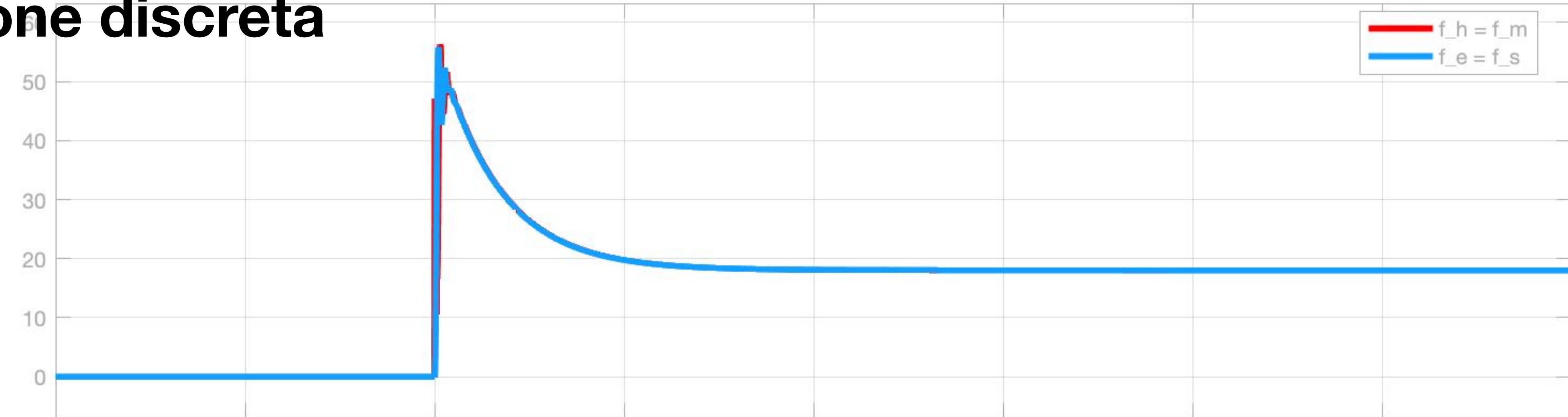
Versione discreta



Contact - Posizioni e velocità

Four channel teleoperation

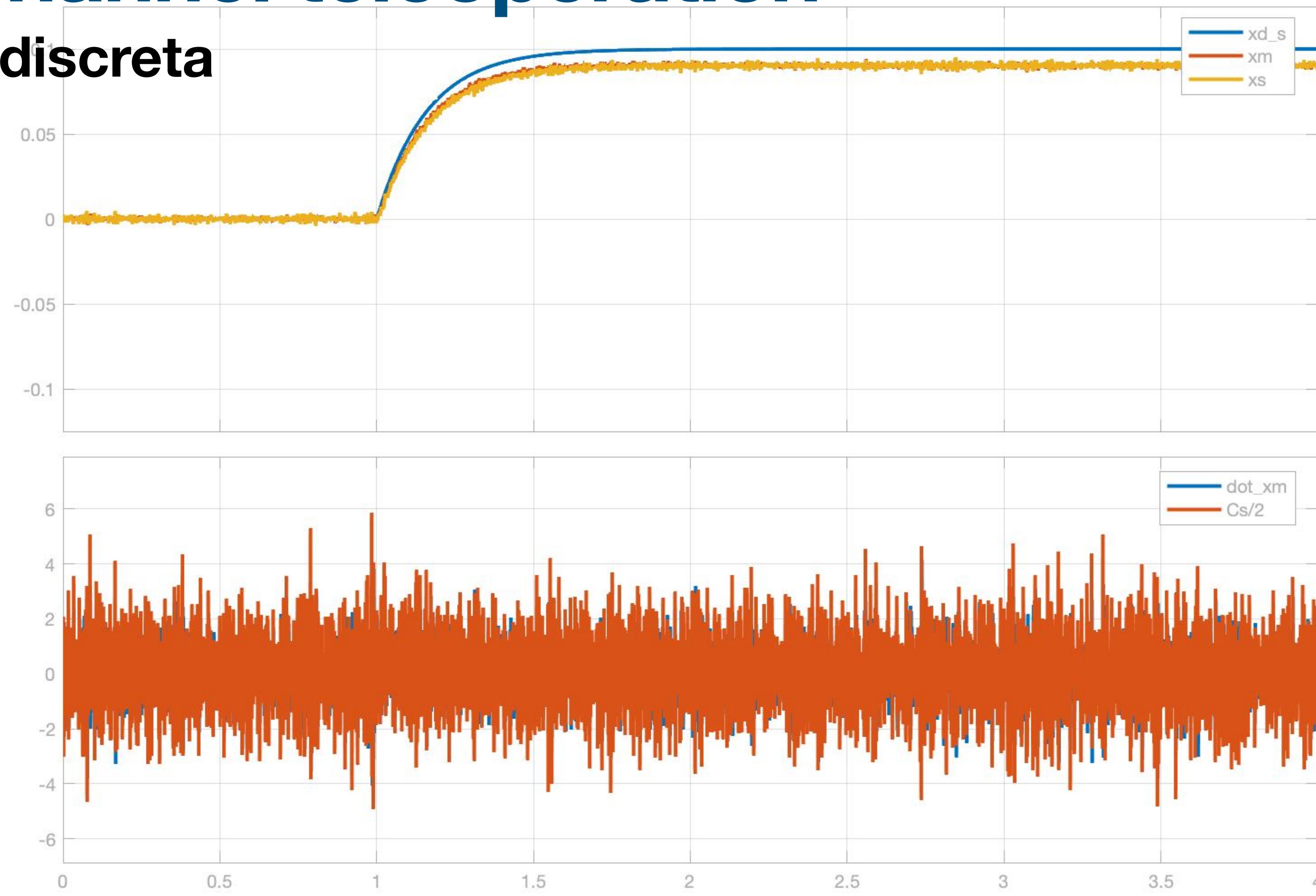
Versione discreta



Contact - comparazione forze e comandi

Four channel teleoperation

Versione discreta



Four channel teleoperation

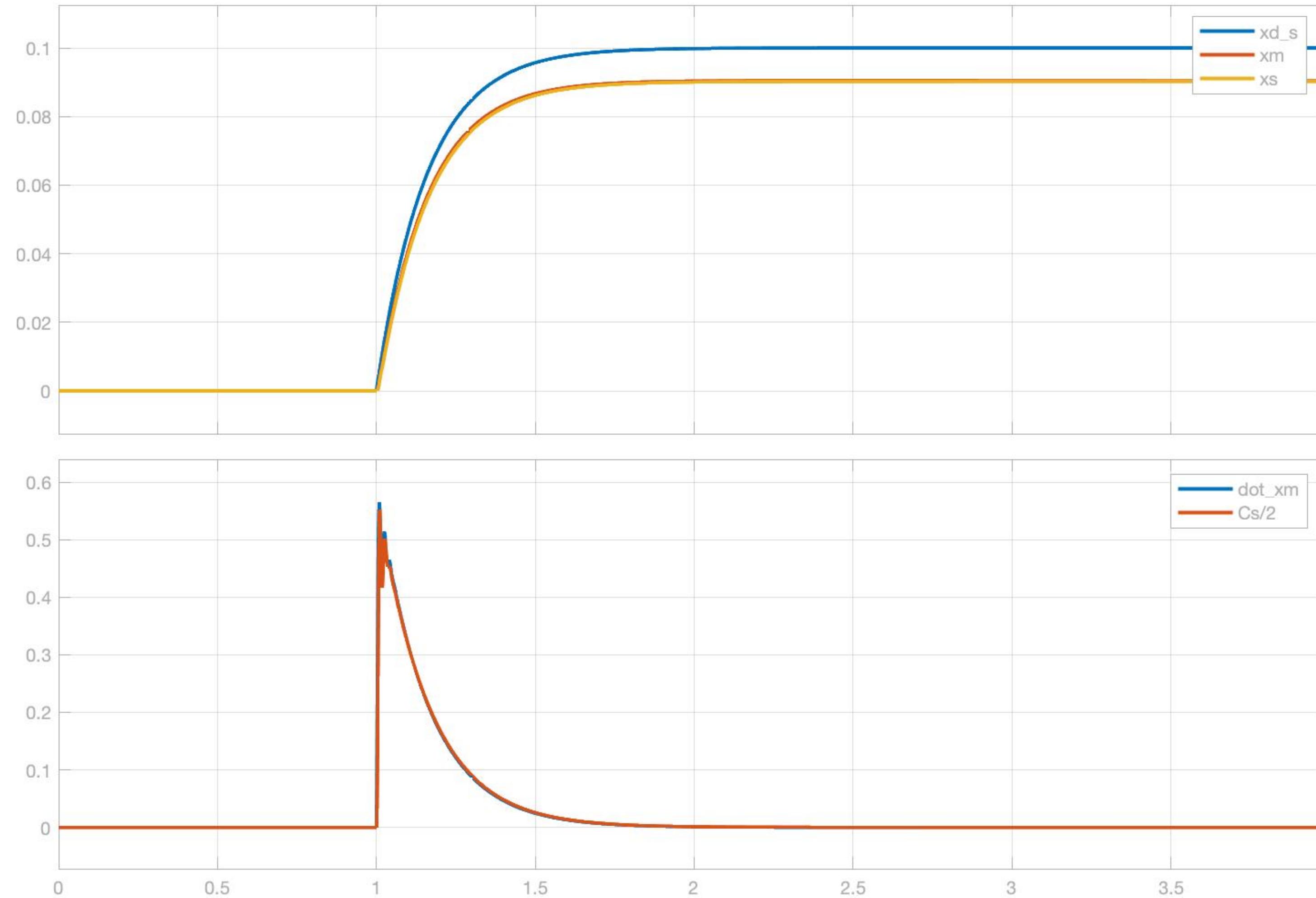
Versione discreta



Contact - comparazione forze e comandi

Four channel teleoperation

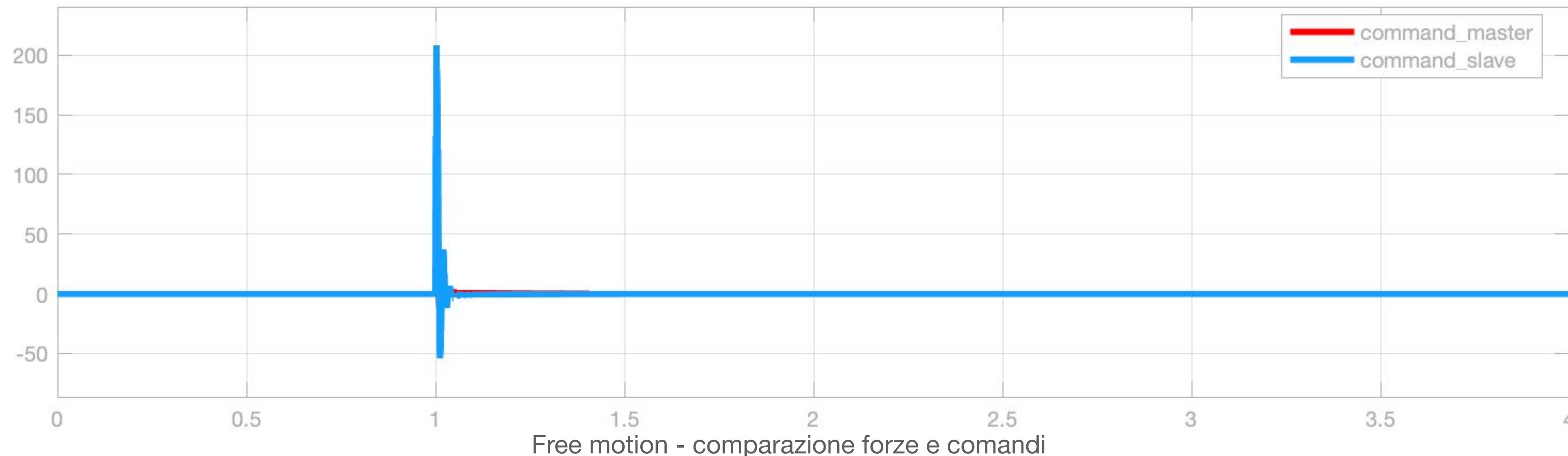
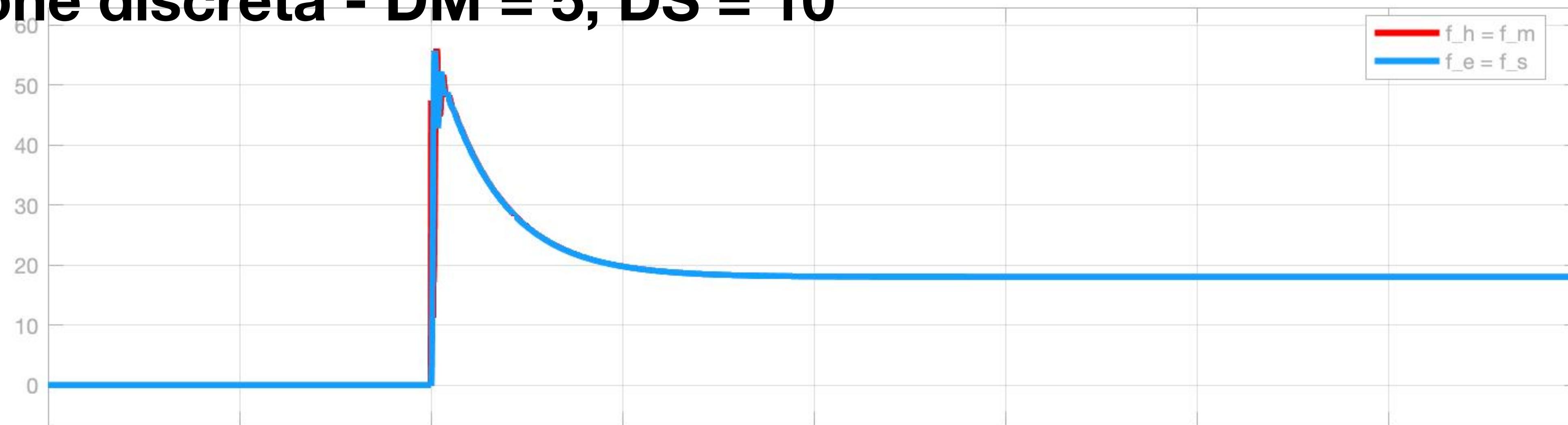
Versione discreta - DM = 5, DS = 10



Free motion - Posizioni e velocità

Four channel teleoperation

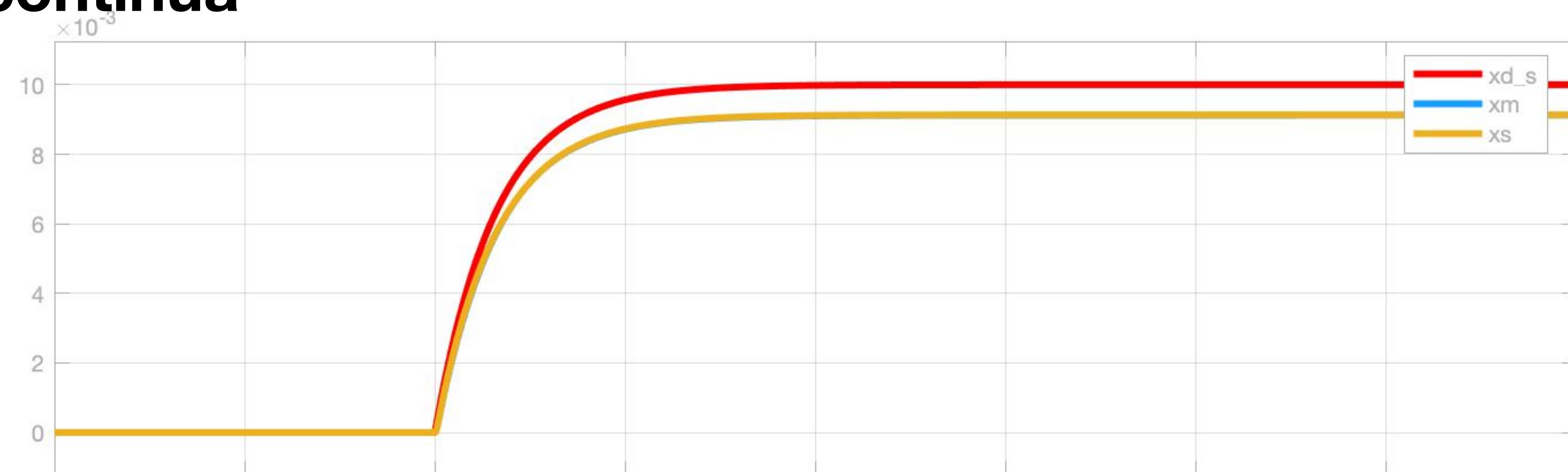
Versione discreta - DM = 5, DS = 10



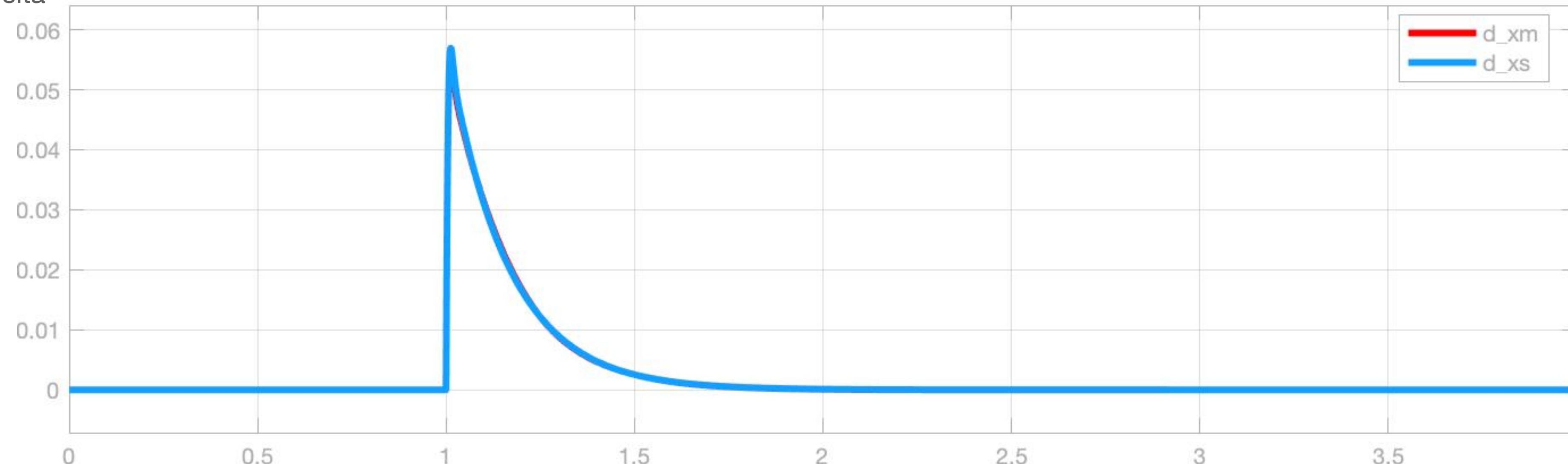
Four channel - inner force loop

Four channel teleoperation

Versione continua

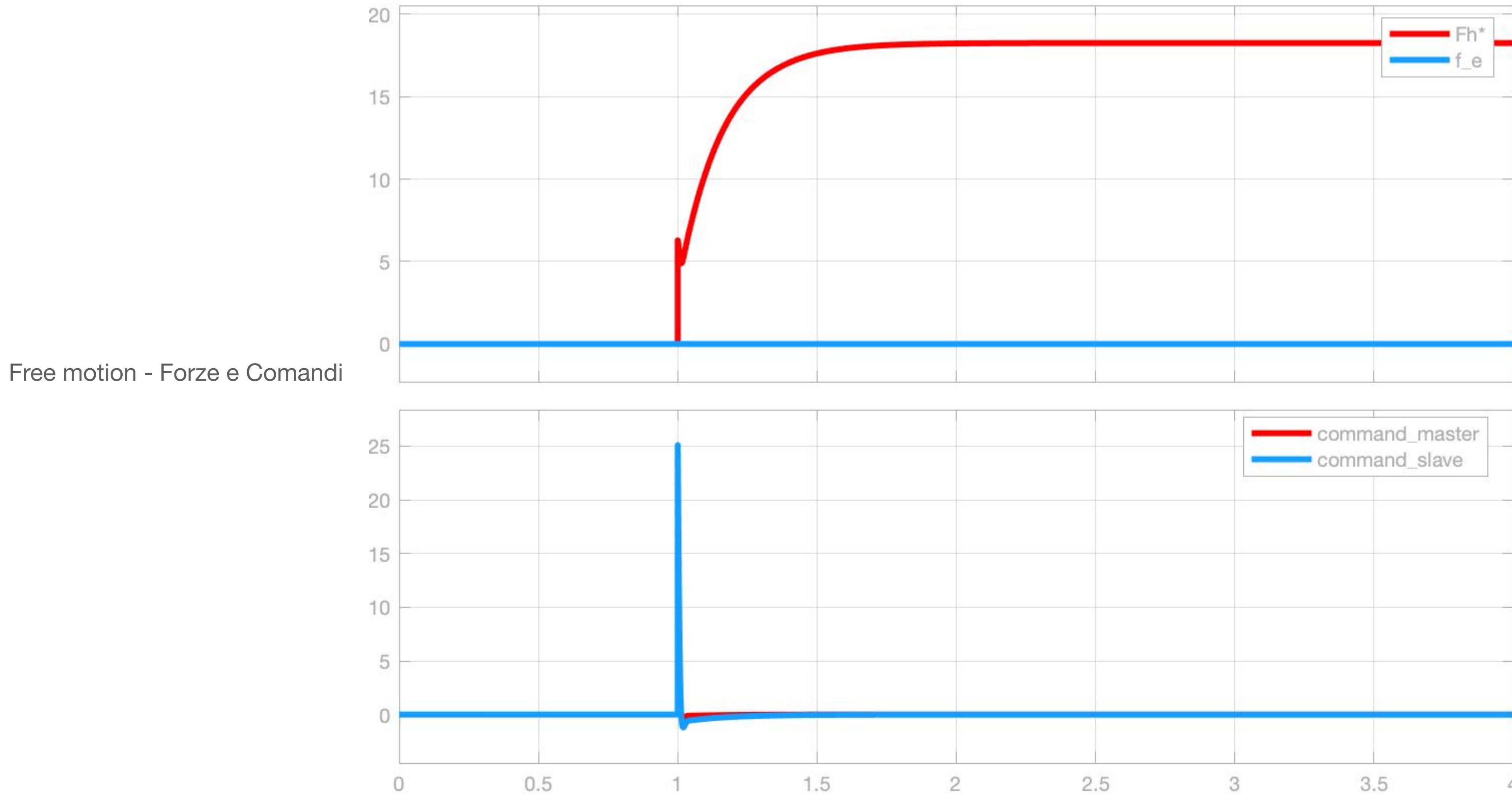


Free motion - Posizioni e velocità



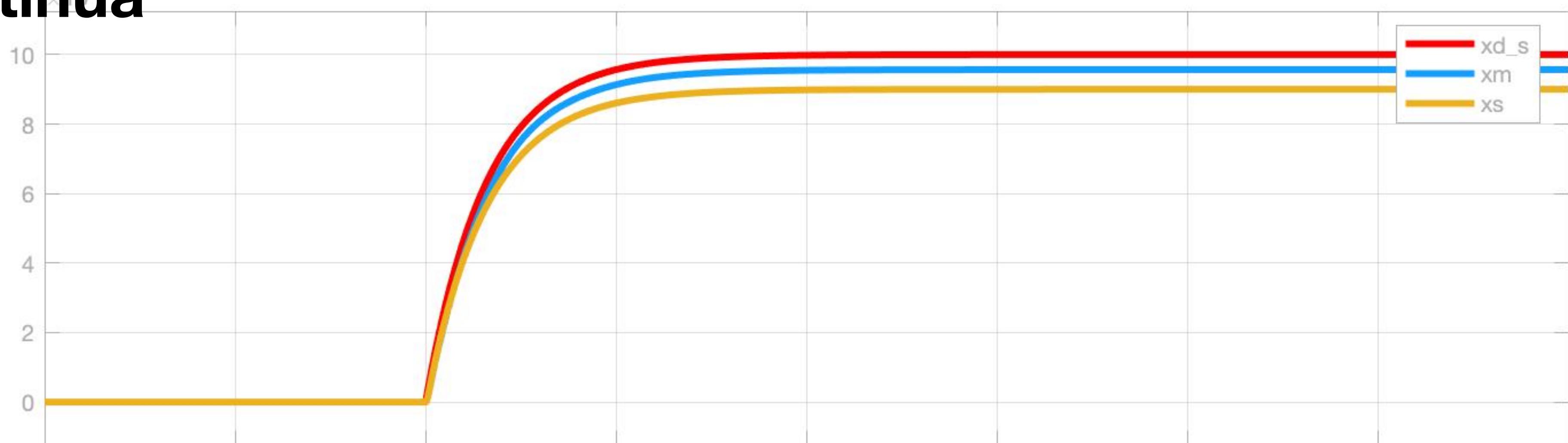
Four channel teleoperation

Versione continua

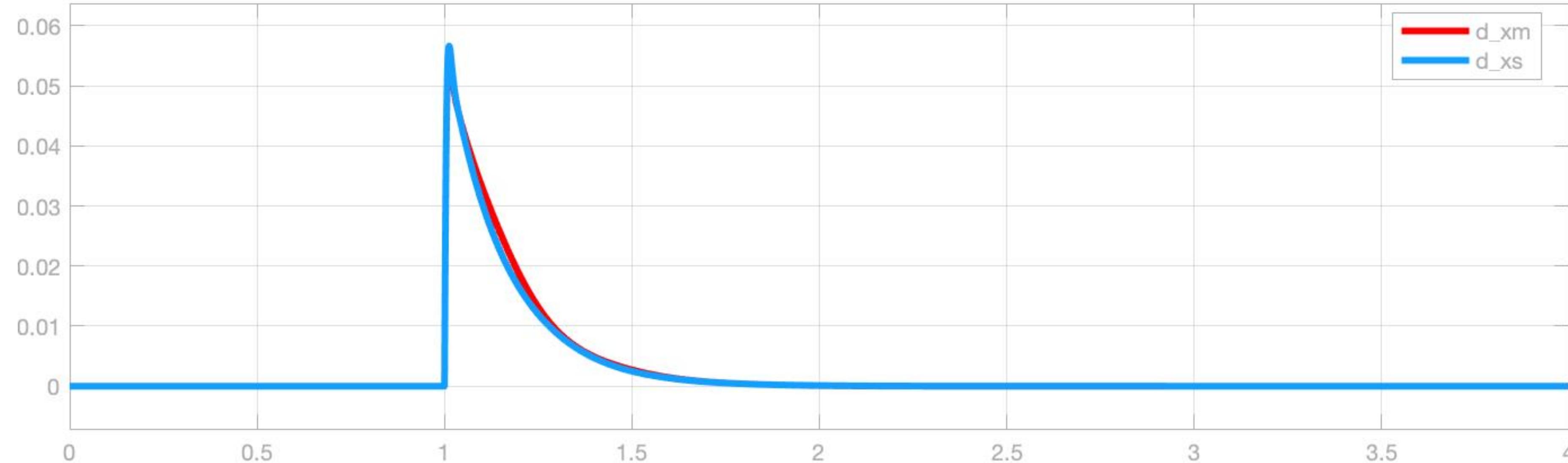


Four channel teleoperation

Versione continua



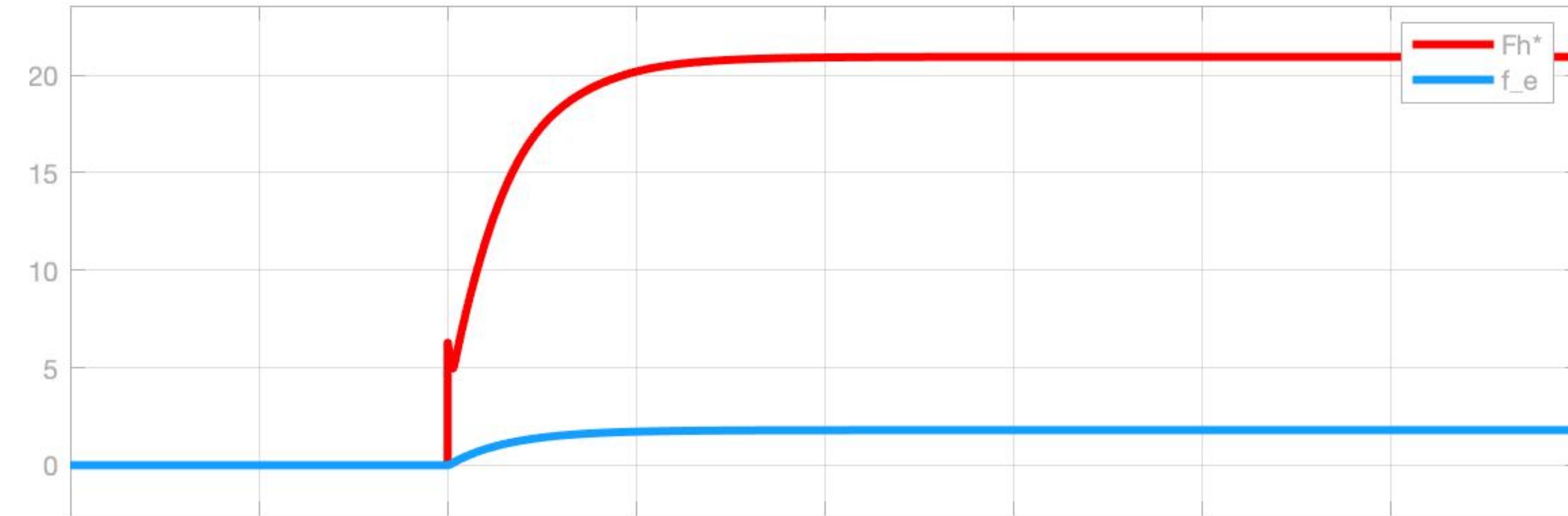
Contact - Posizioni e velocità



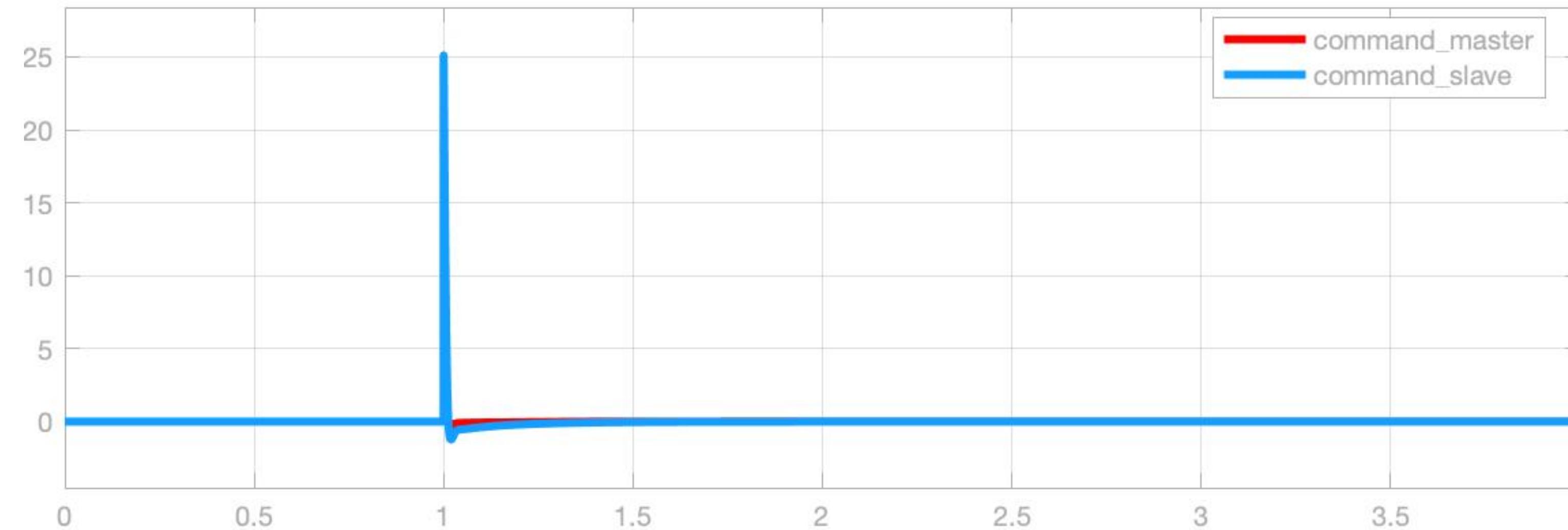
Four channel teleoperation

Versione continua

Contact - Forze e Comandi

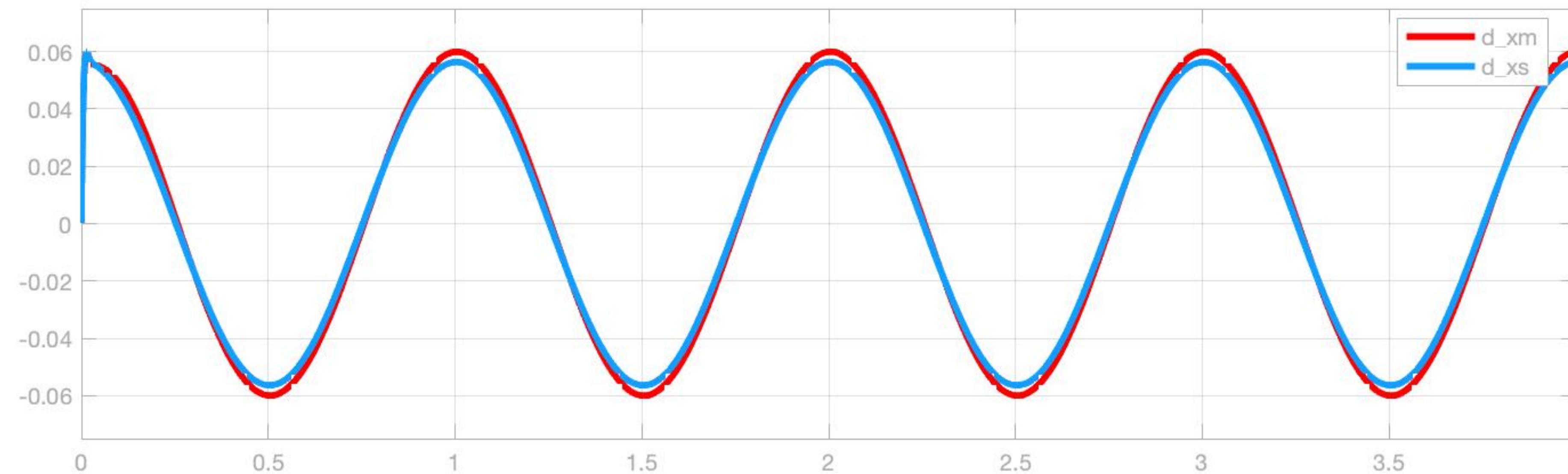
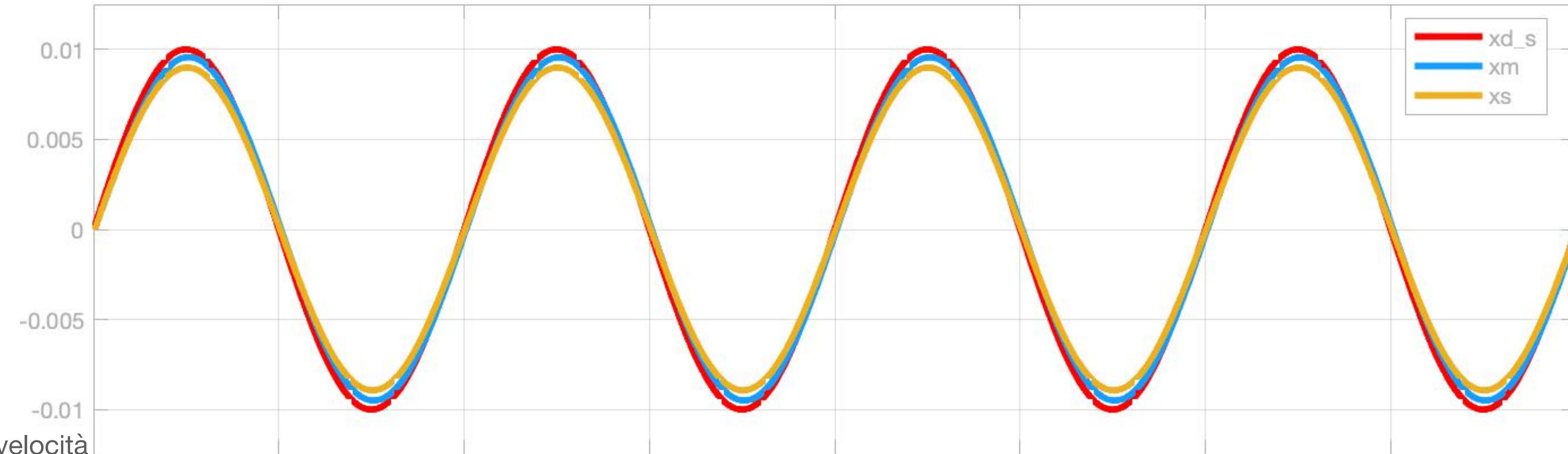


command_master
command_slave



Four channel teleoperation

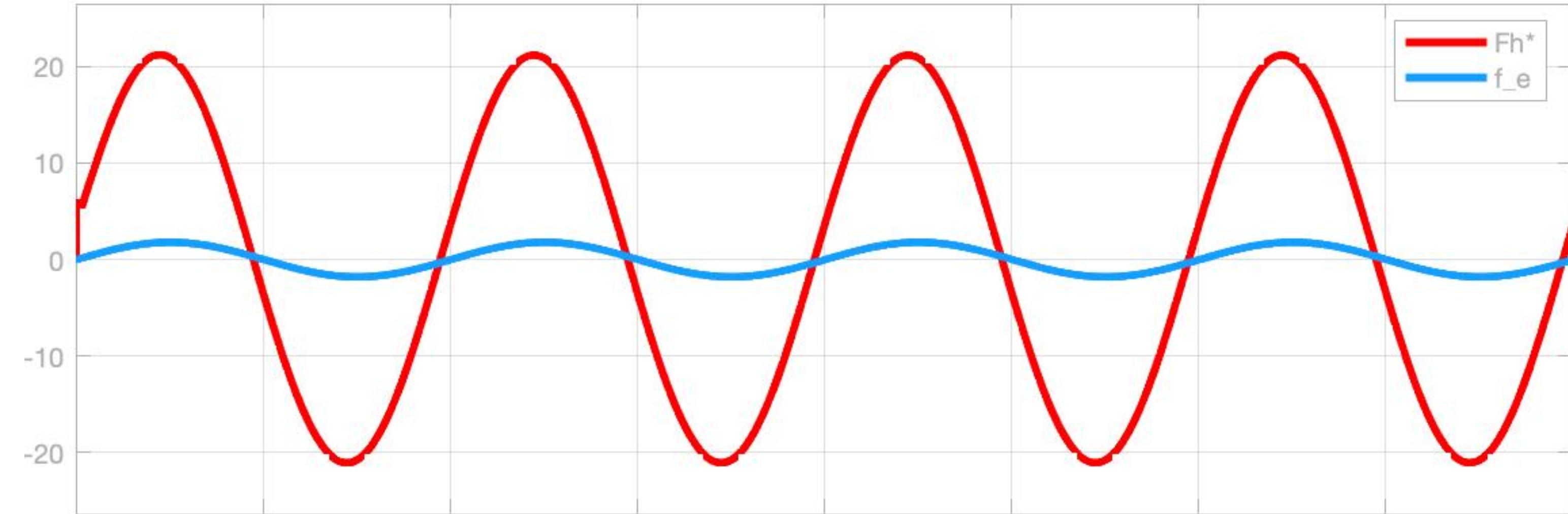
Versione continua



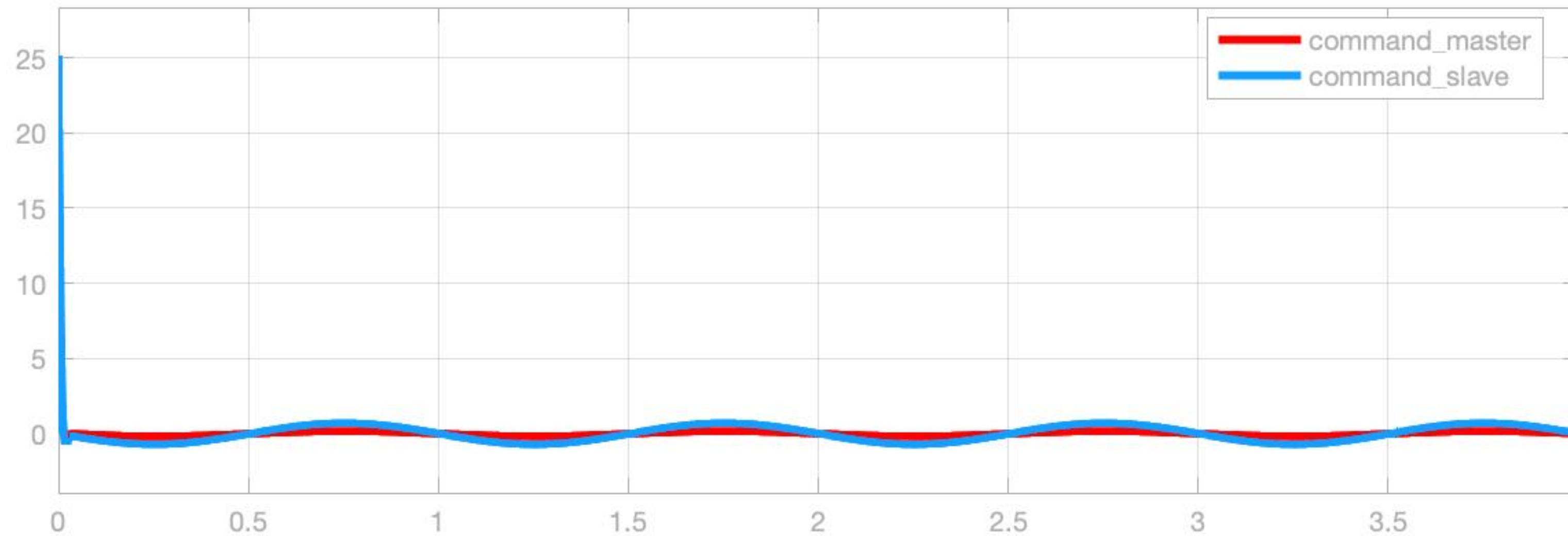
Four channel teleoperation

Versione continua

Contact - Forze e Comandi

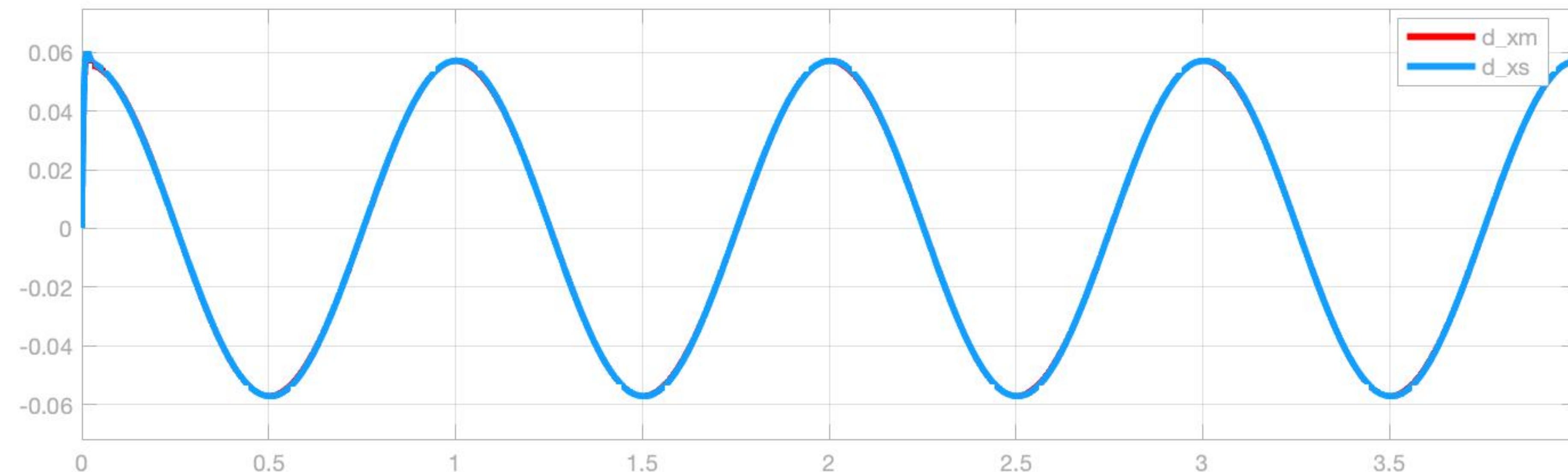
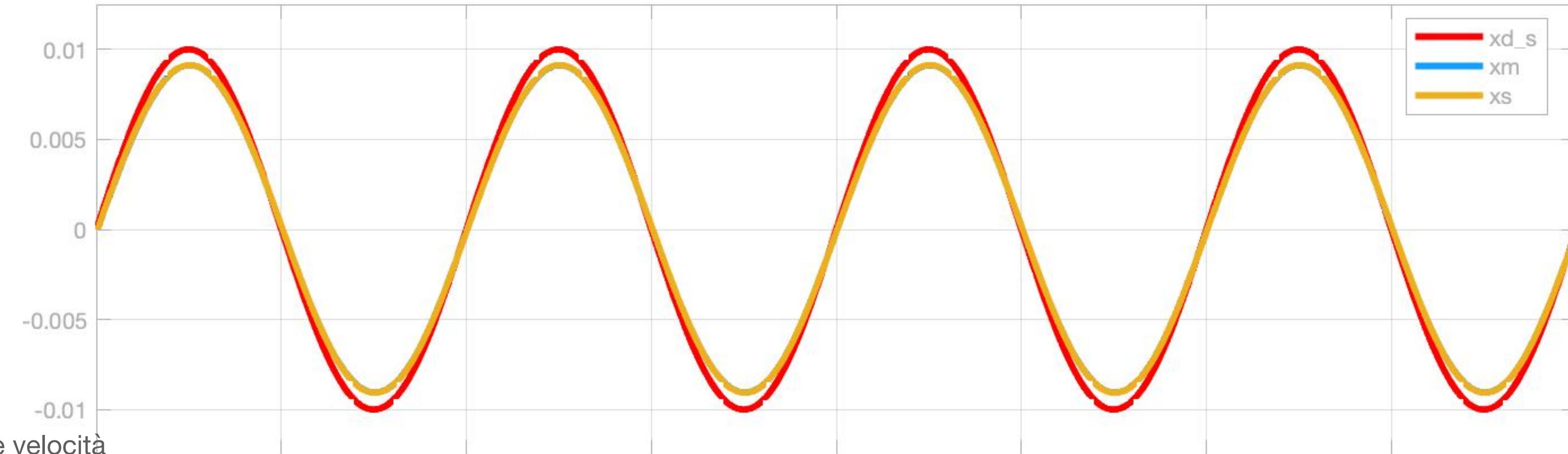


command_master
command_slave



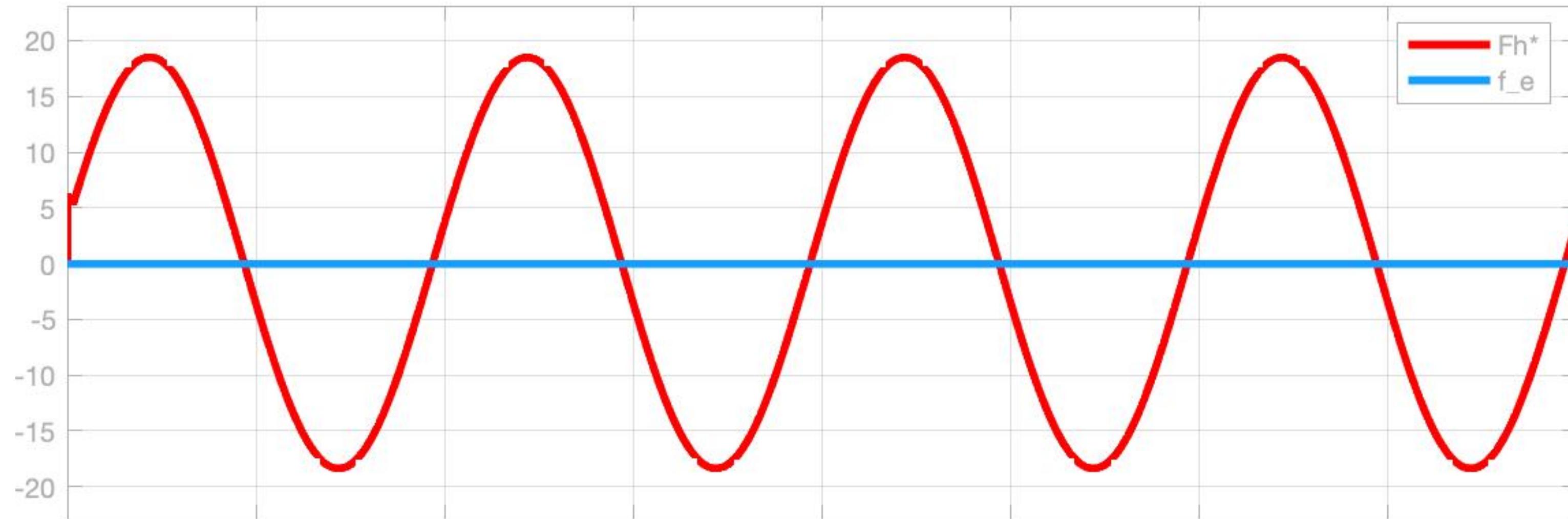
Four channel teleoperation

Versione continua

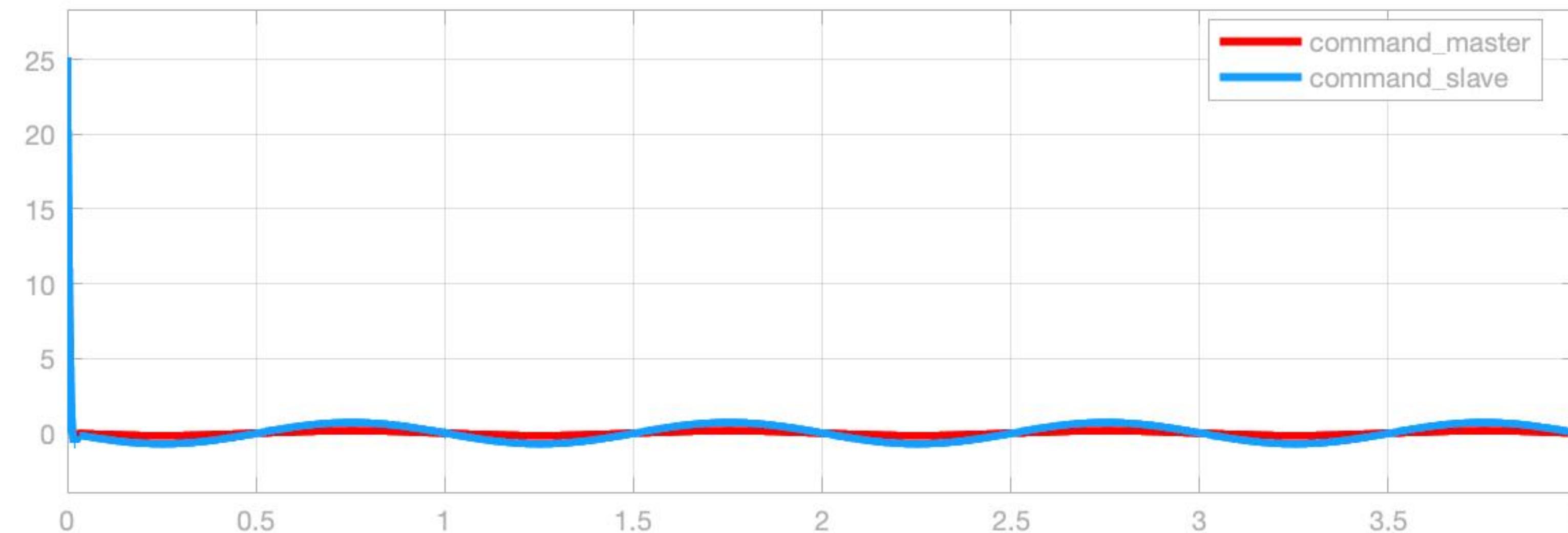


Four channel teleoperation

Versione continua



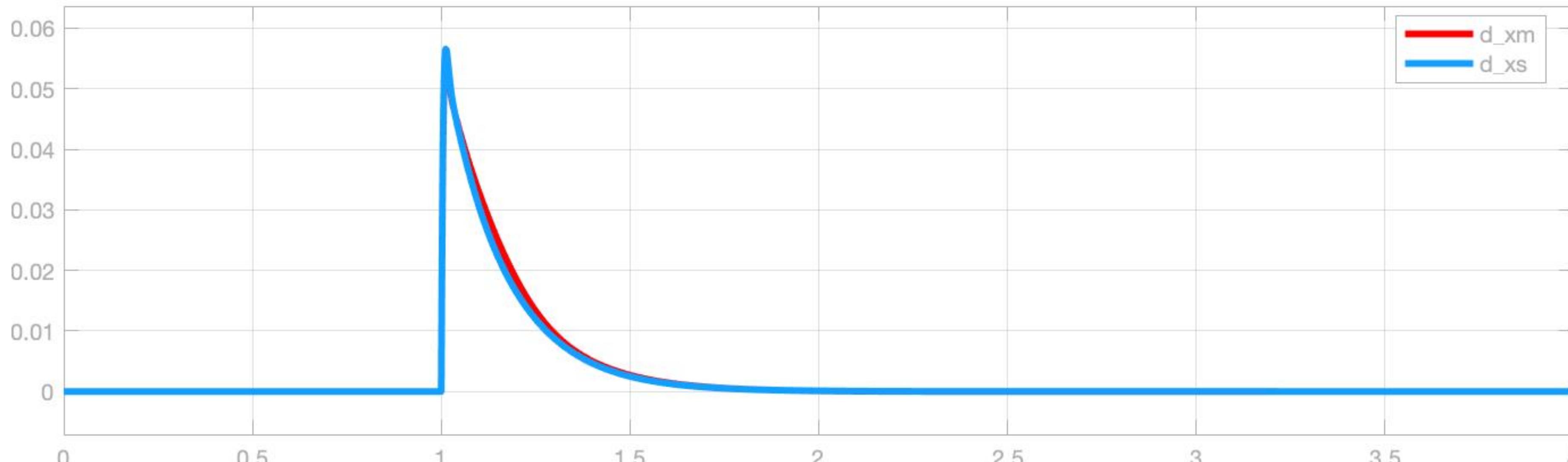
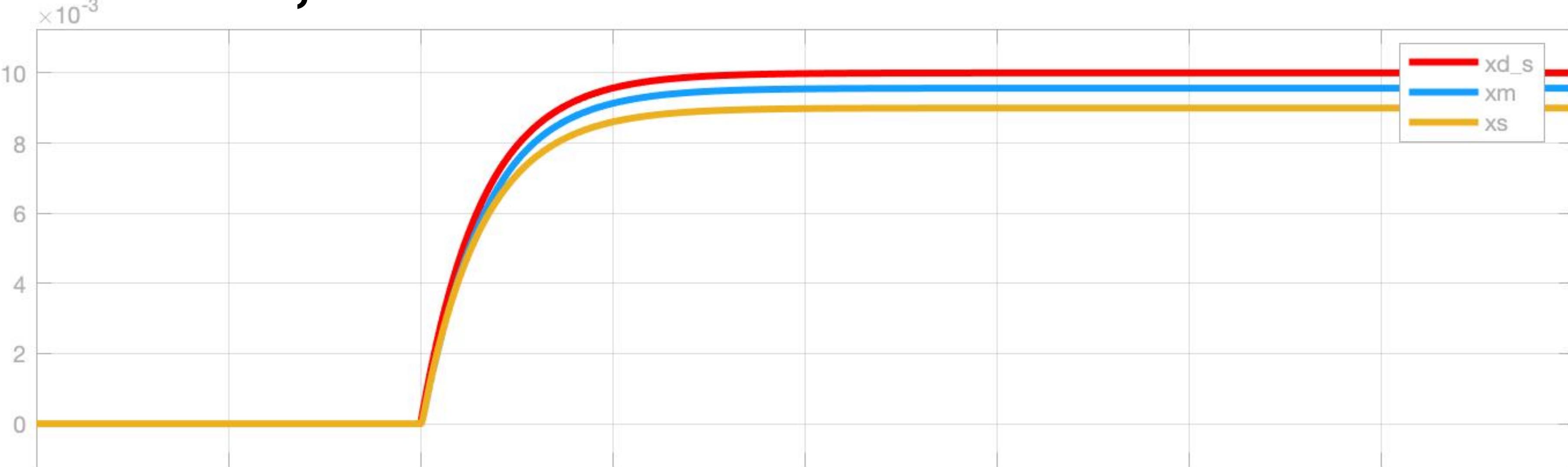
Free motion - Forze e Comandi



Four channel teleoperation

Versione Discreta - DM = 5, DS = 10

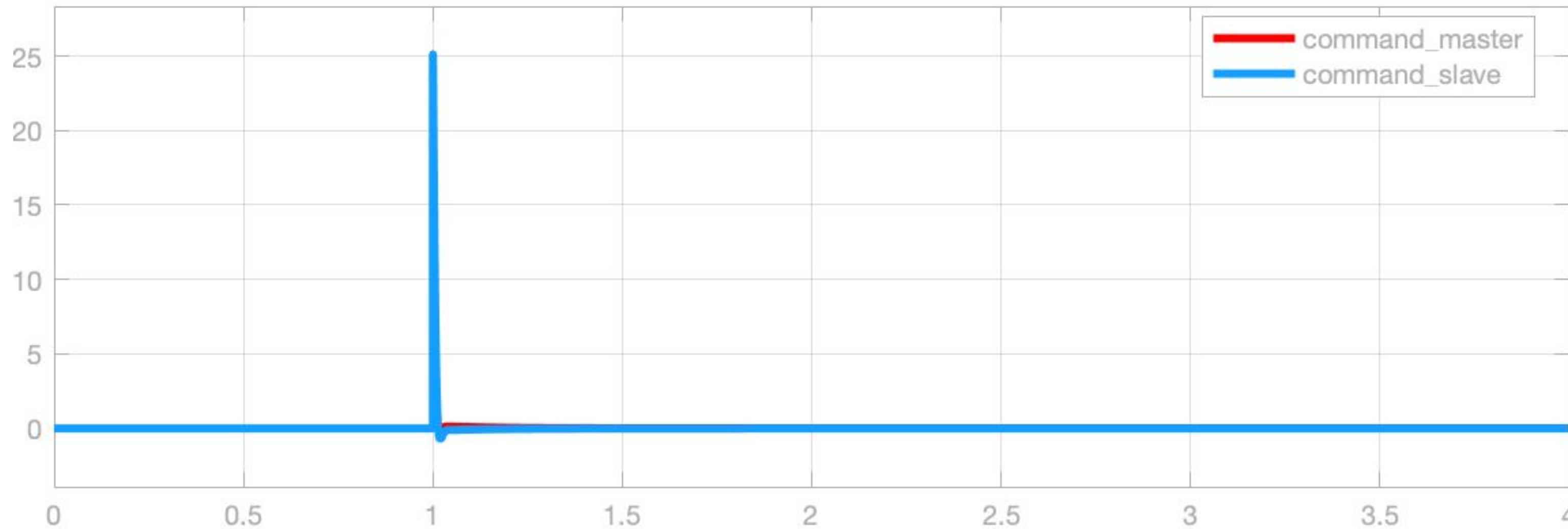
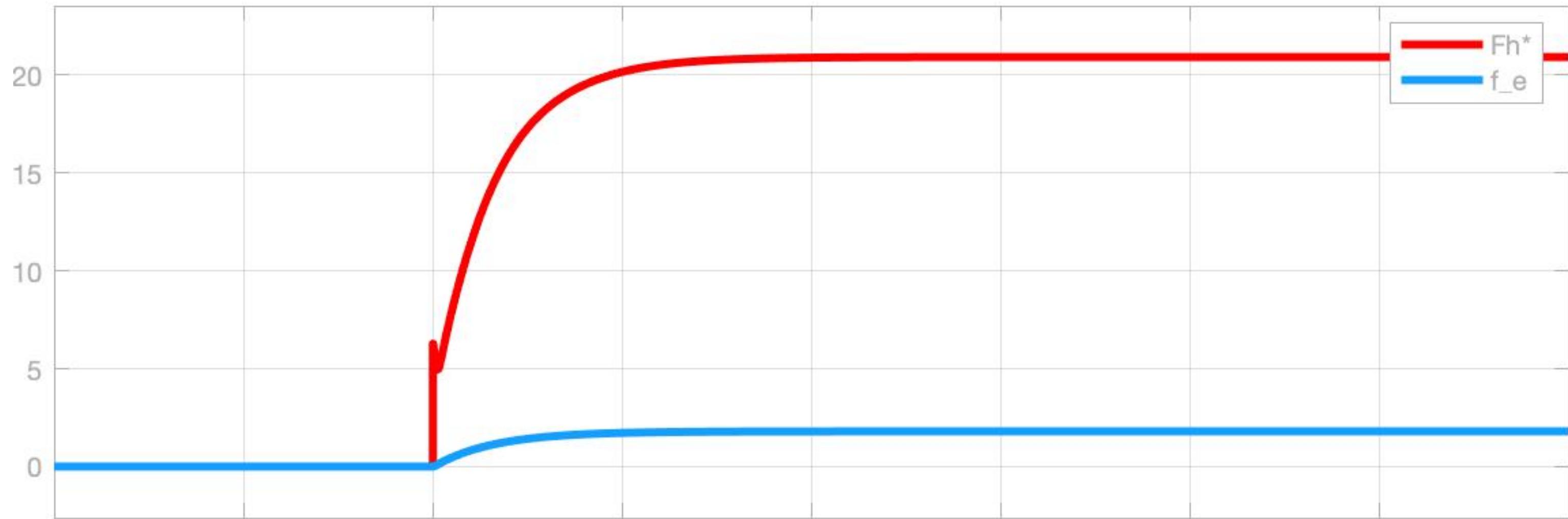
Contatto con l'ambiente - Posizioni e velocità



Four channel teleoperation

Versione Discreta - DM = 5, DS = 10

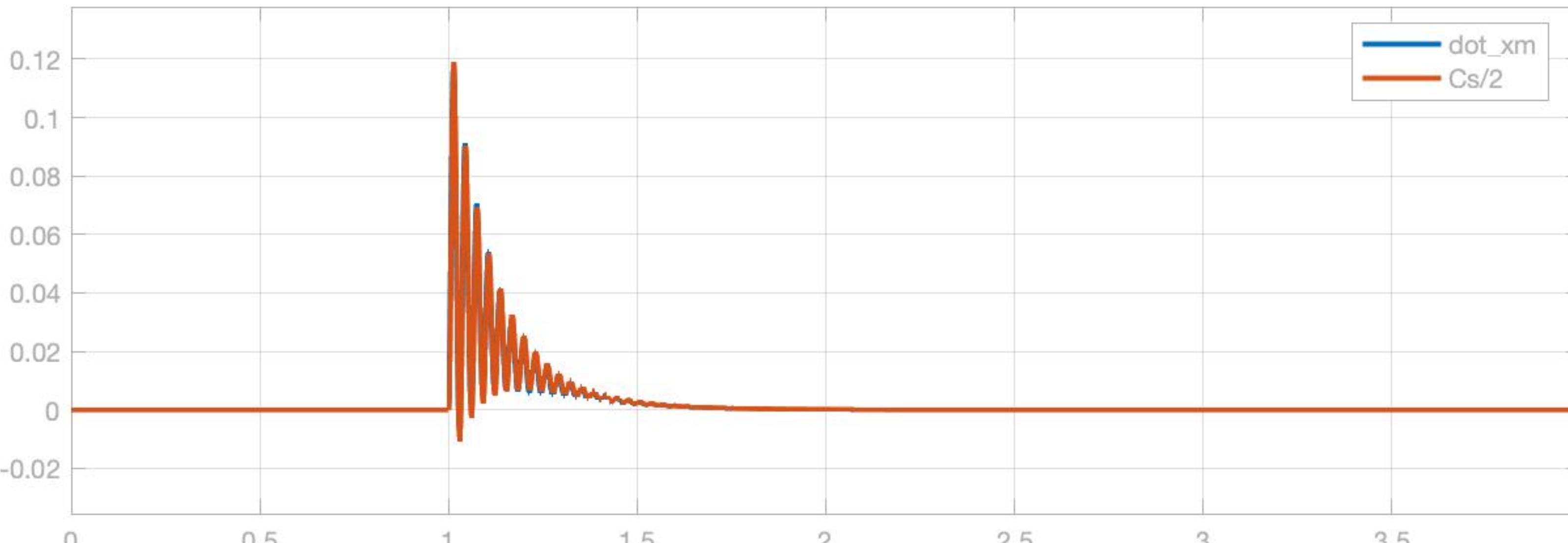
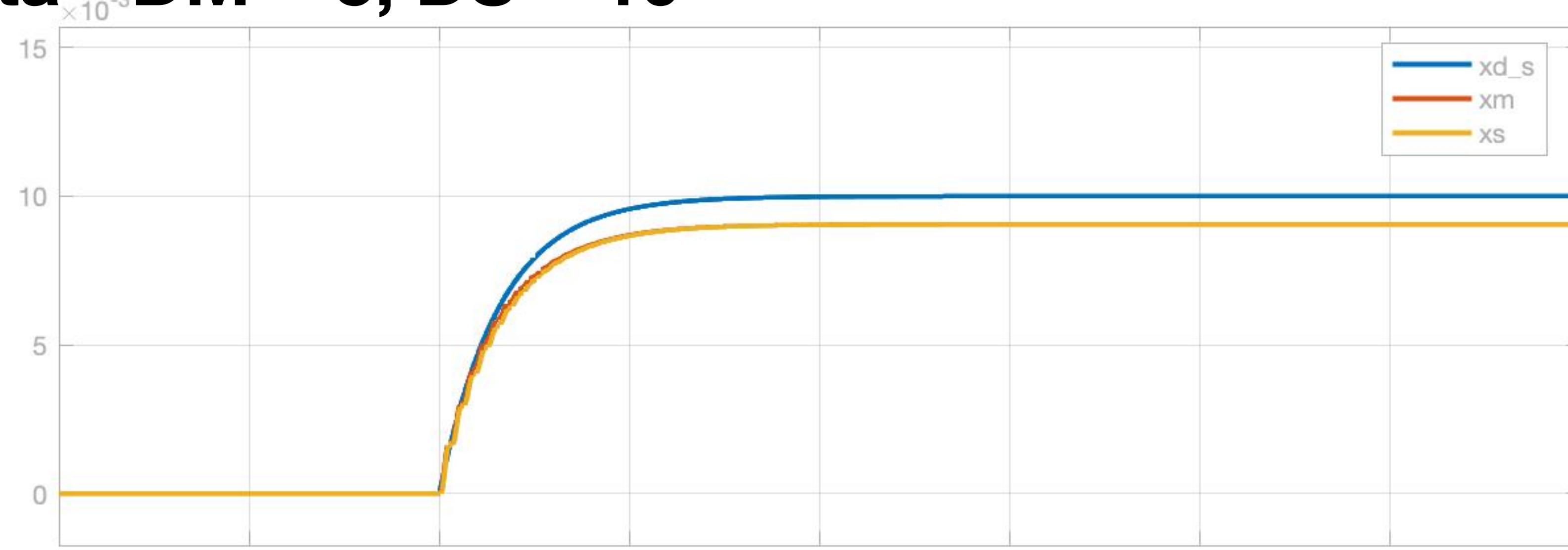
Contatto con l'ambiente - Forze e Comandi



Four channel teleoperation

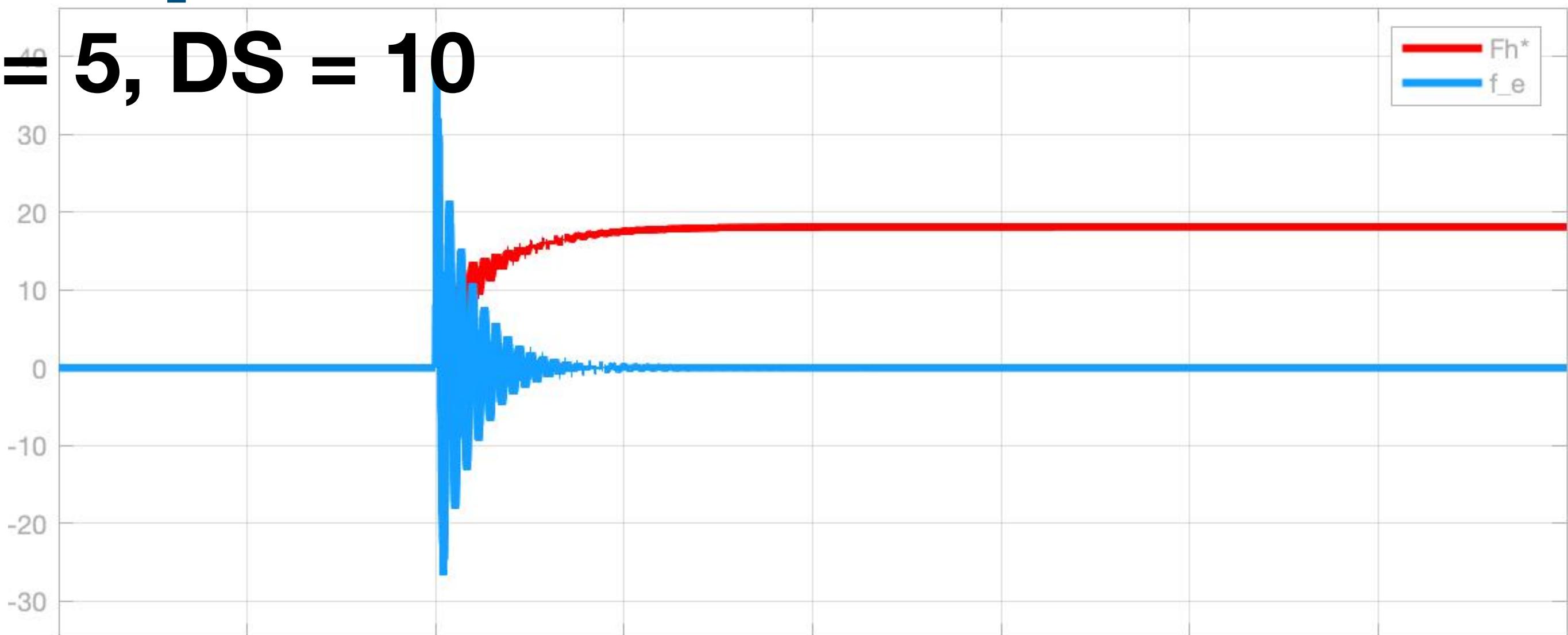
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Free - Posizioni e velocità

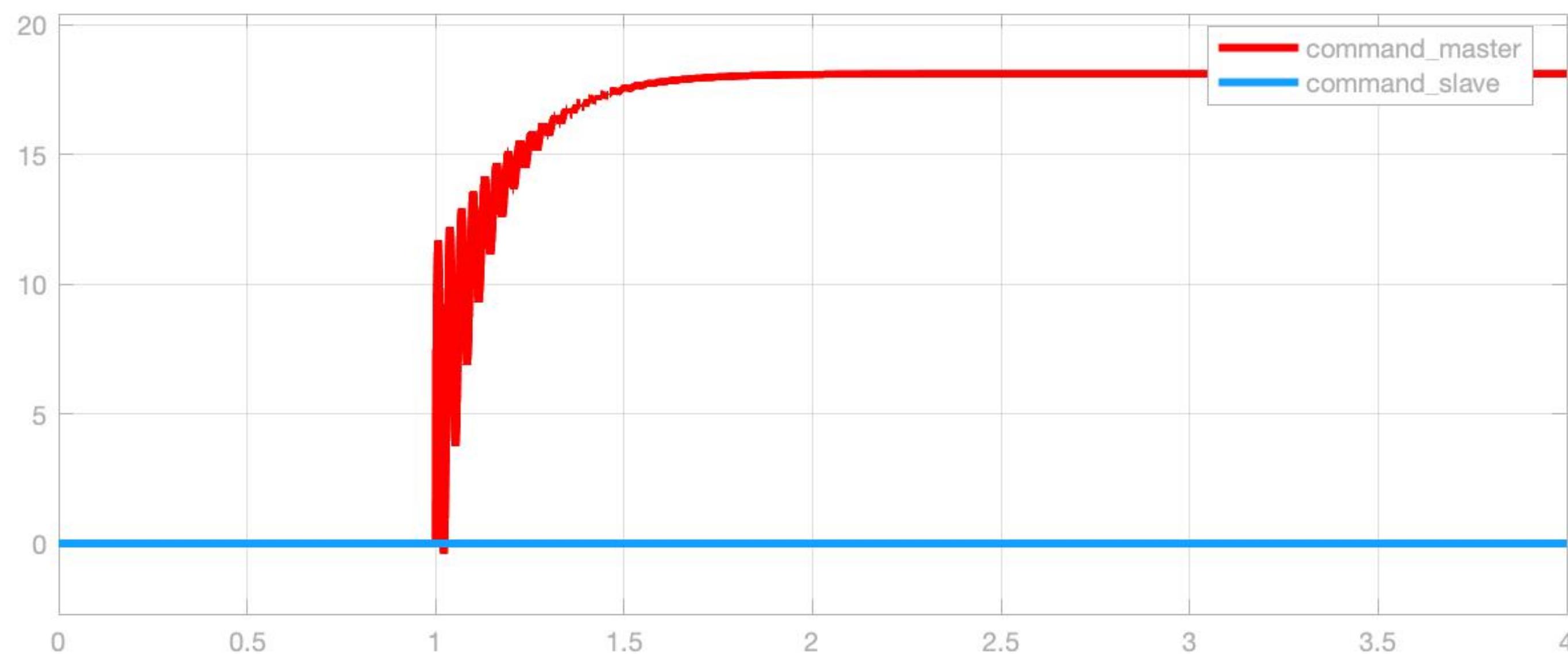


Four channel teleoperation

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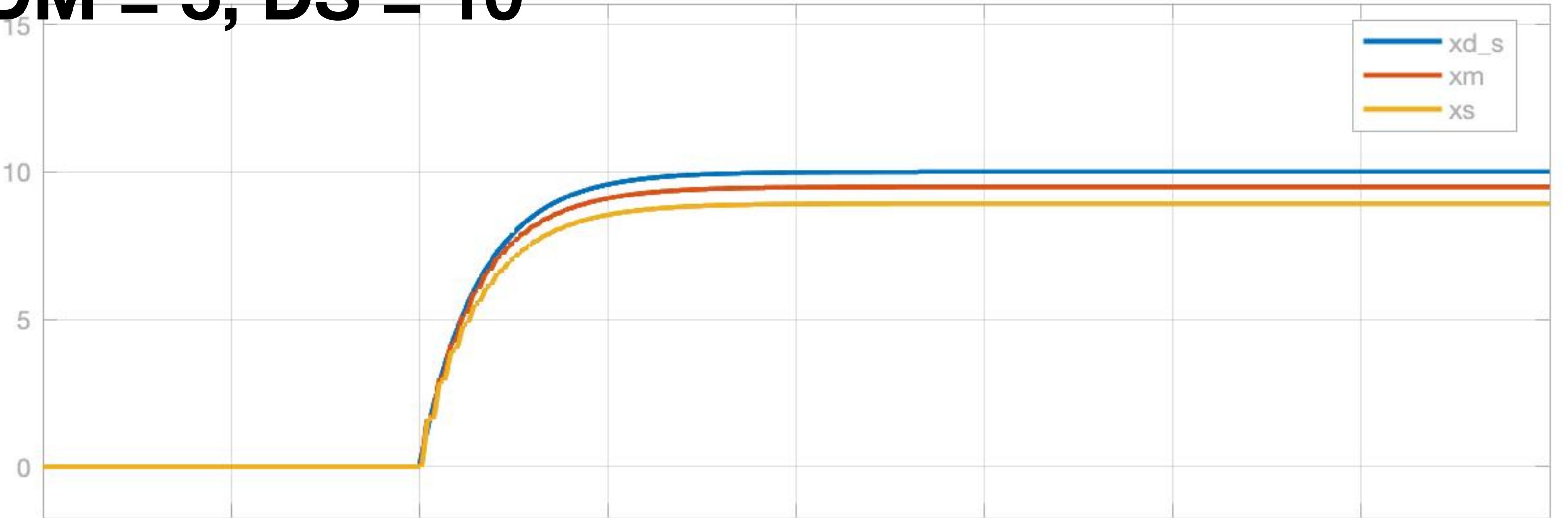


Free motion - Forze e Comandi

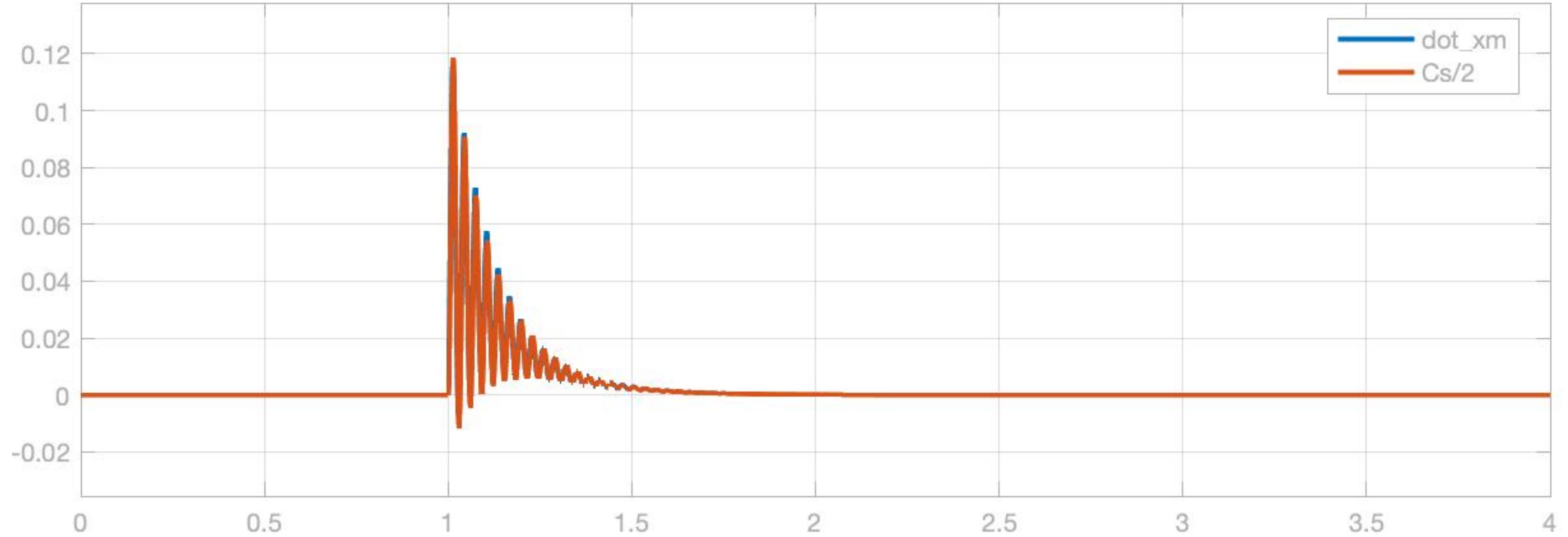


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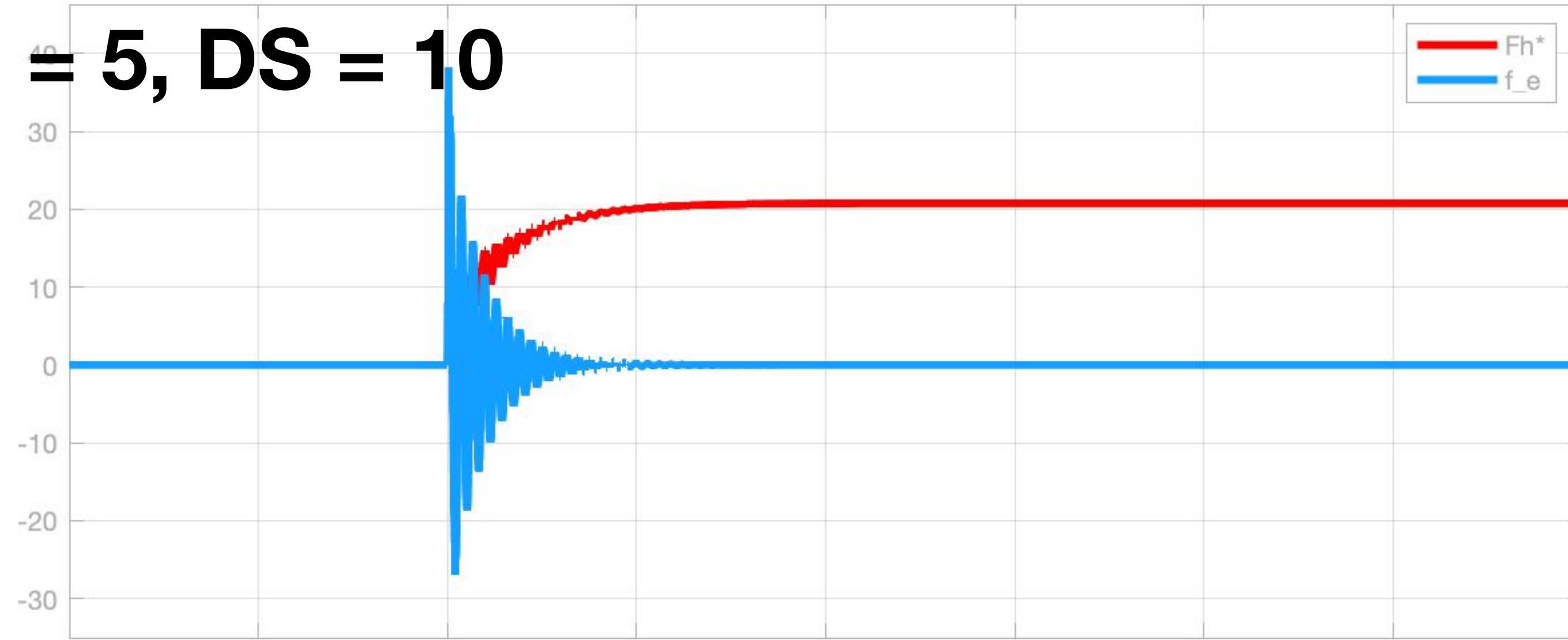


Contact - Posizioni e velocità

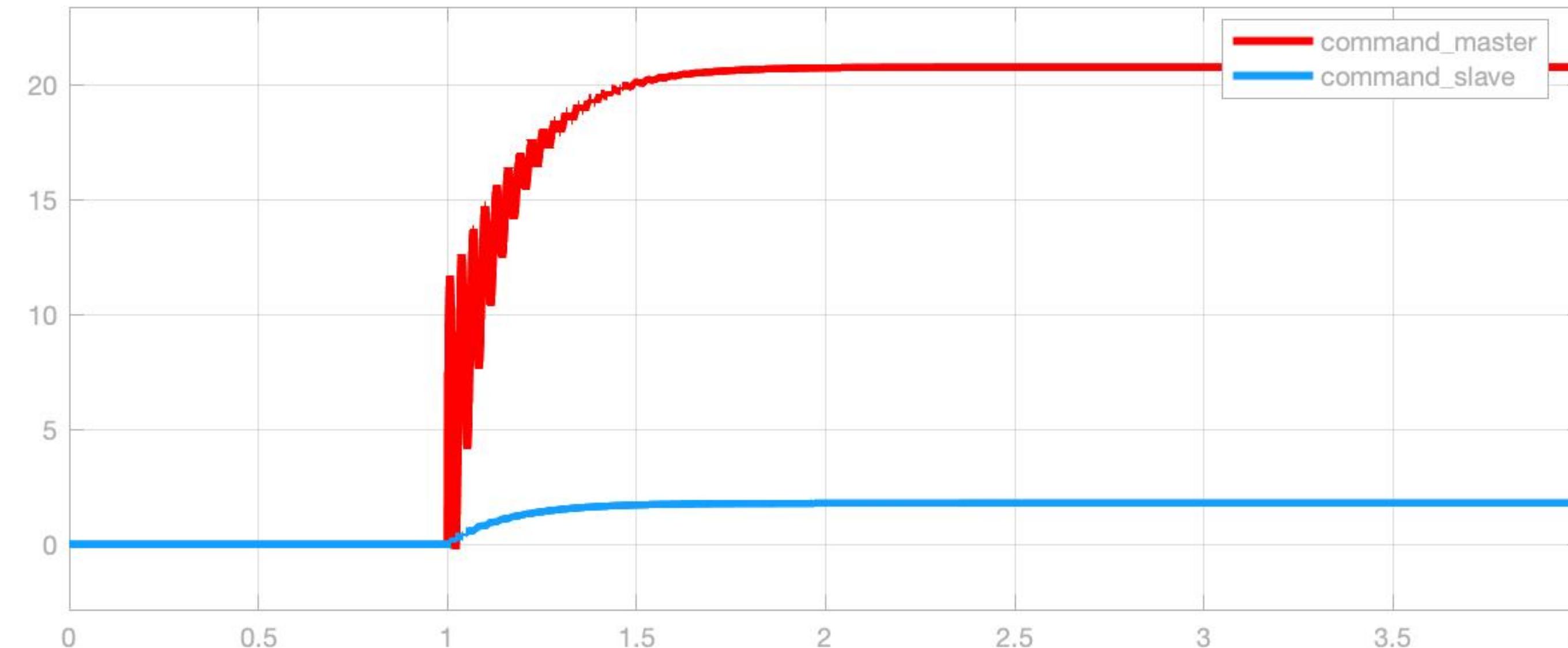


Four channel teleoperation

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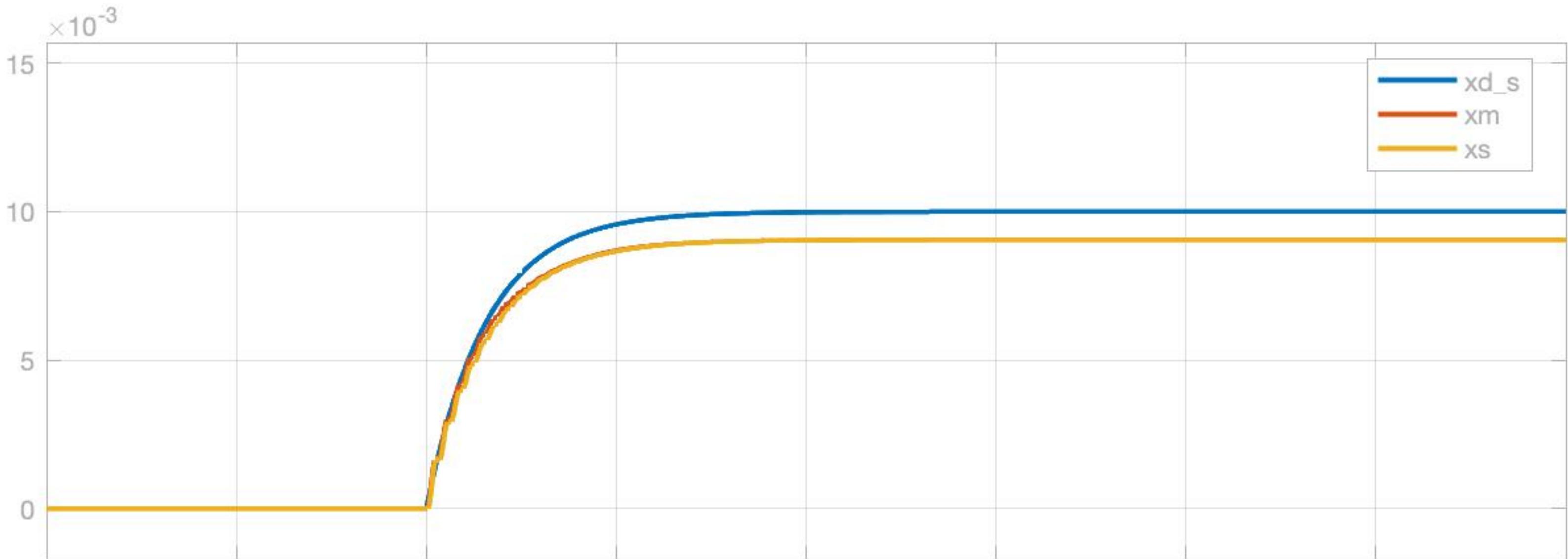


Contact - Forze e Comandi

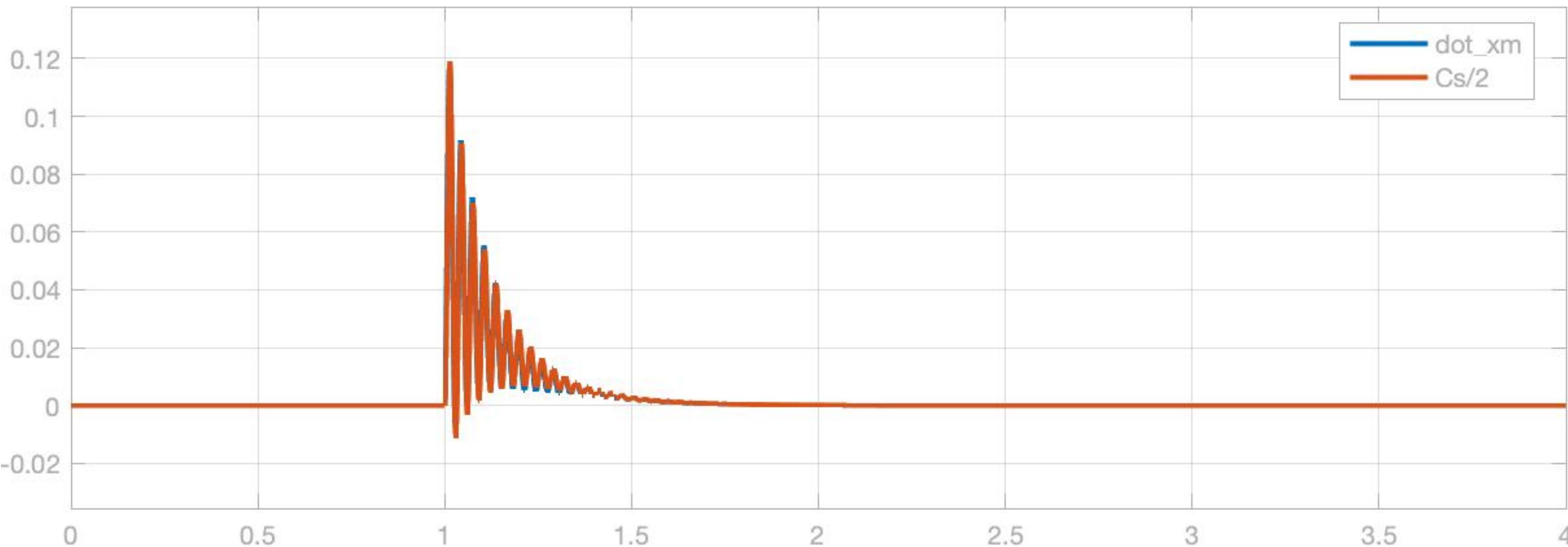


Four channel teleoperation

Versione Discreta



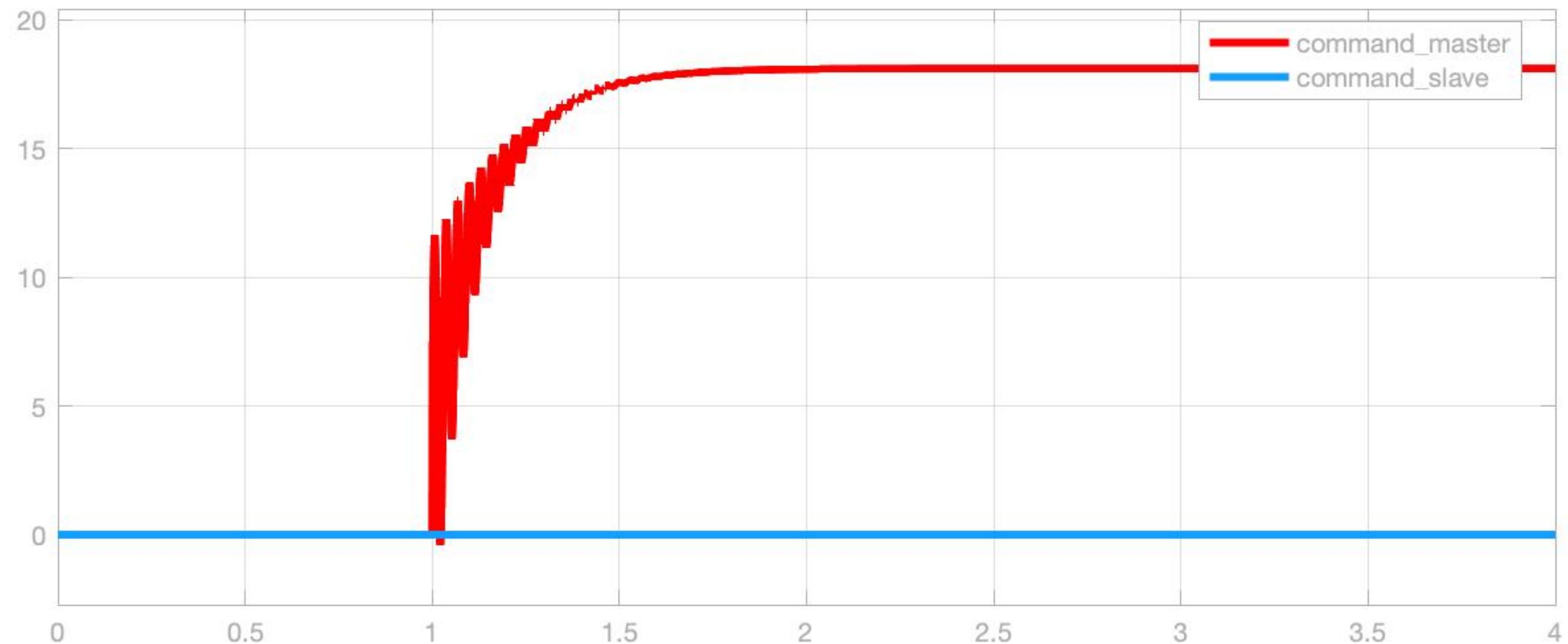
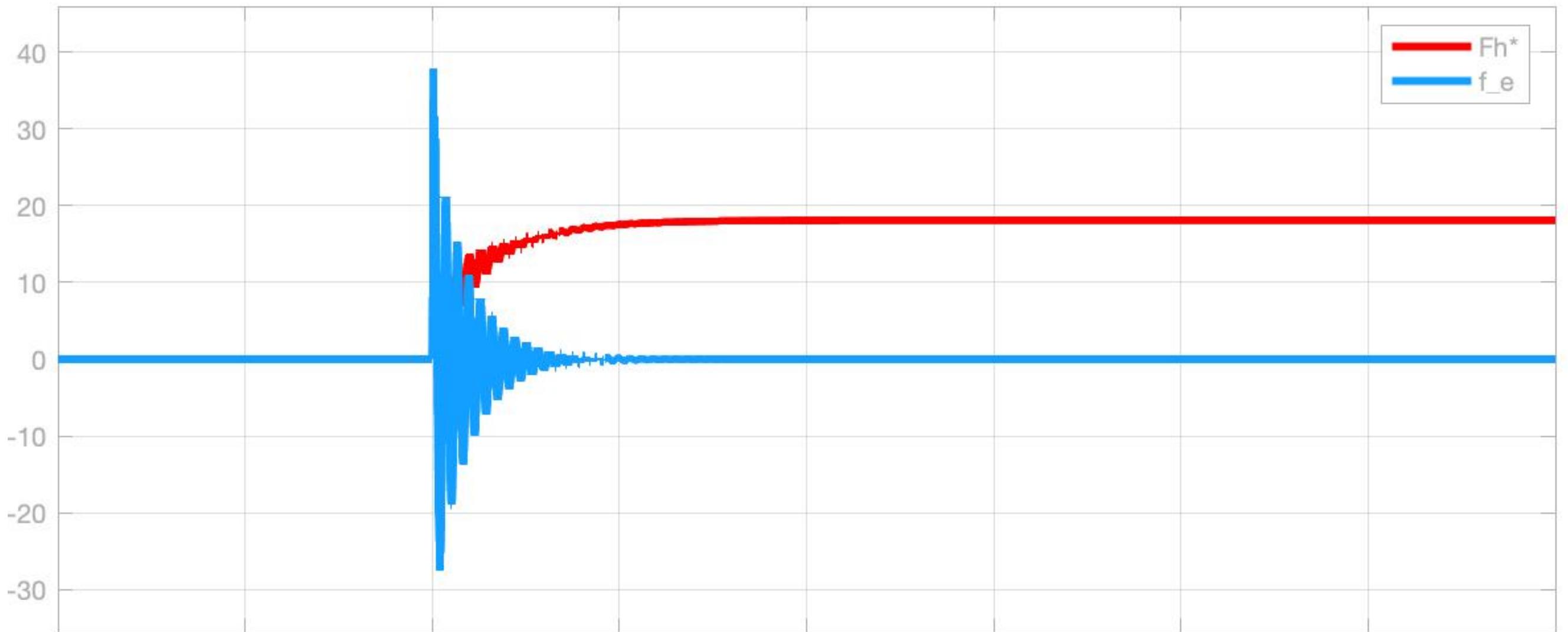
Free motion - Posizioni e velocità



Four channel teleoperation

Versione Discreta

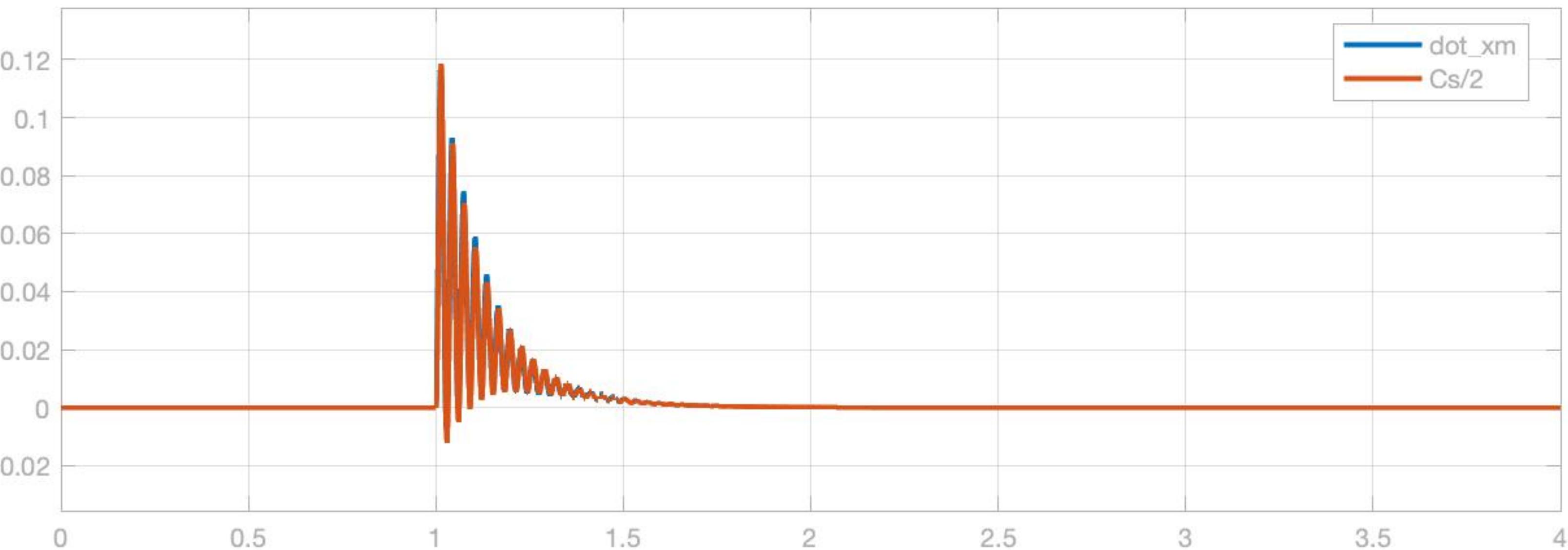
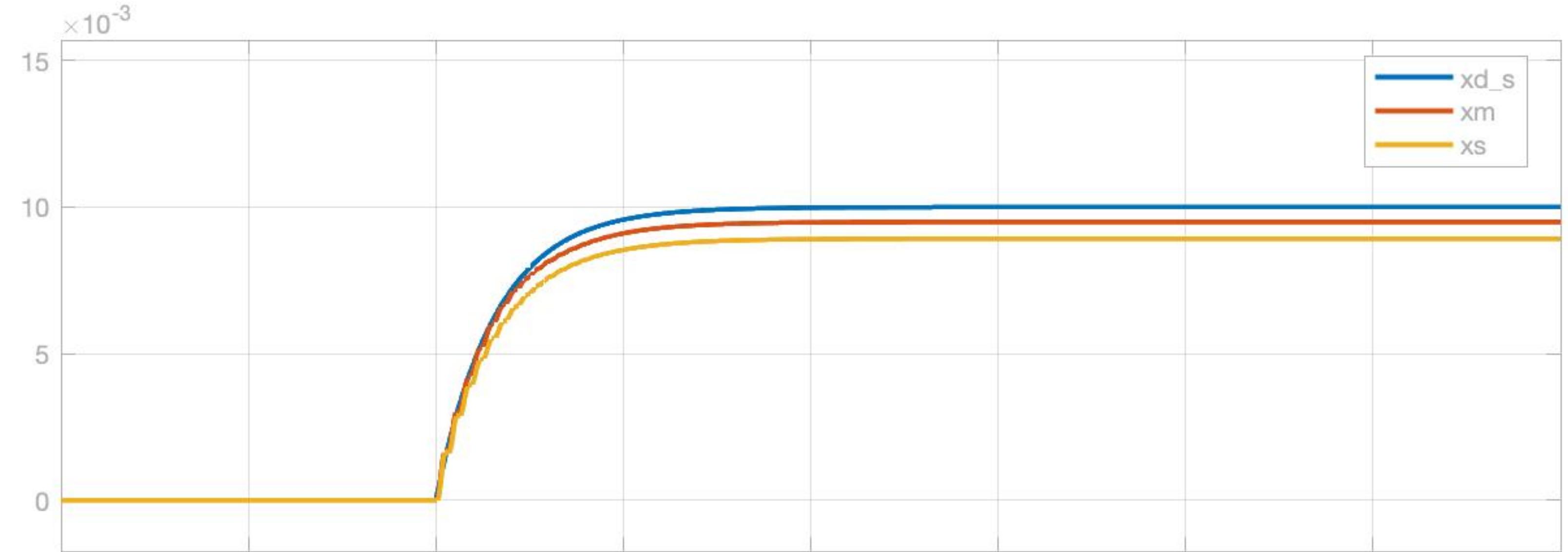
Free motion - Forze e Comandi



Four channel teleoperation

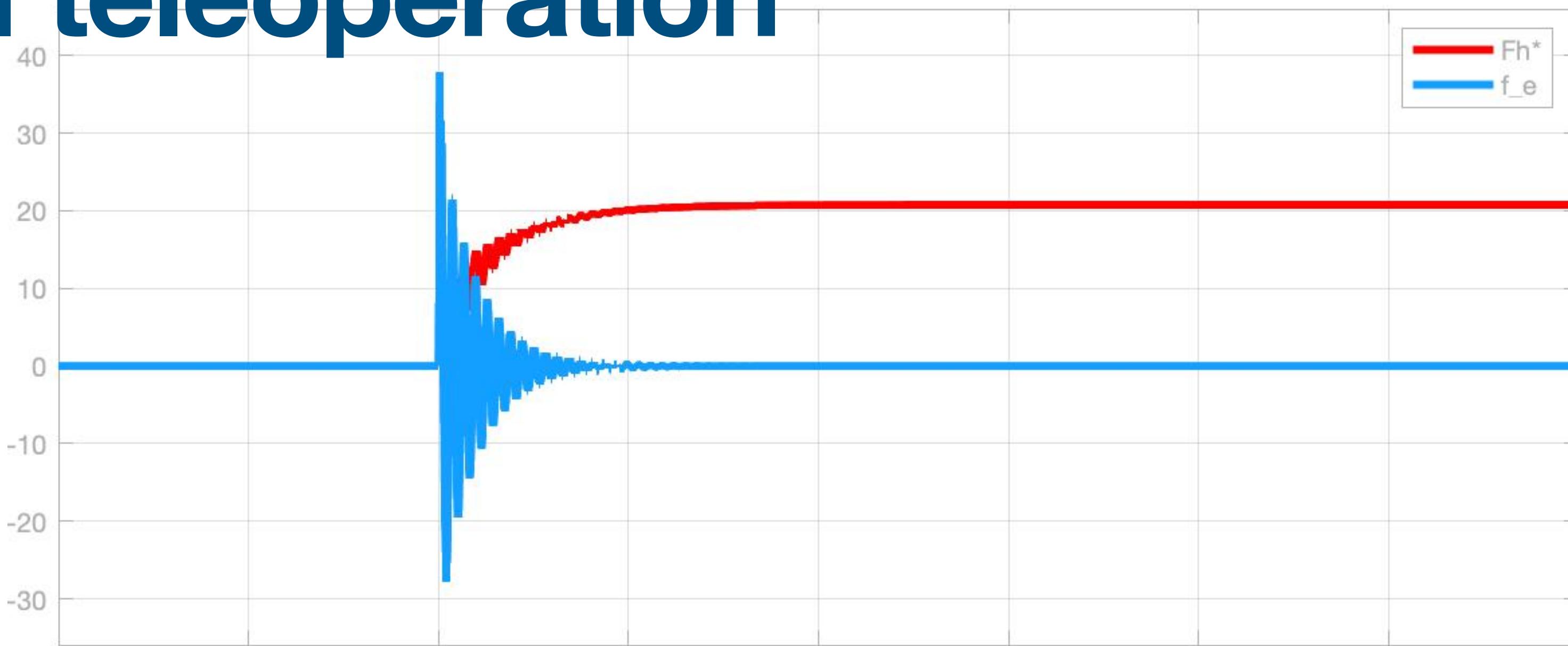
Versione Discreta

Contact - Posizioni e velocità

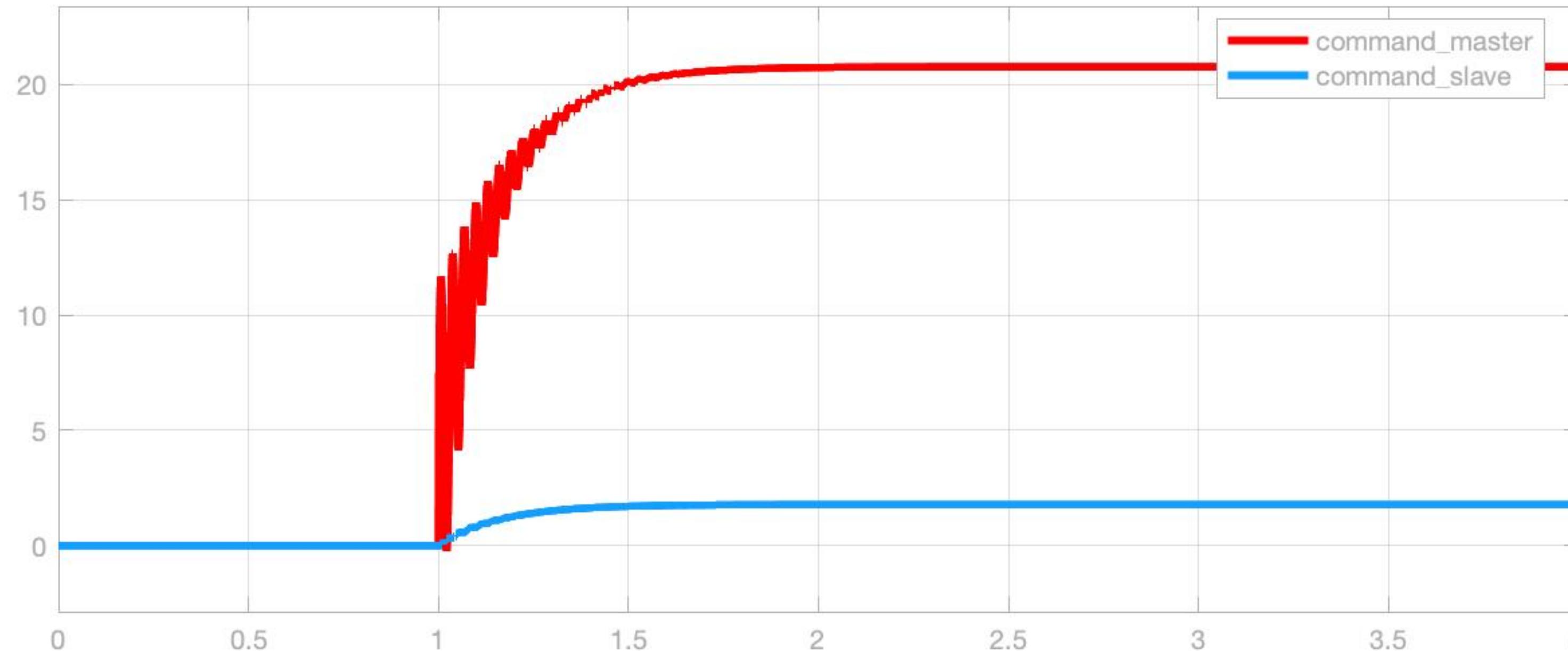


Four channel teleoperation

Versione Discreta



Contact - Forze e Comandi



Four channel teleoperation

Hybrid matrix - H11

$$H_{11} = \frac{f_m}{\dot{x}_s}, F_s = 0 \quad (1)$$

$$\dot{x}_m = C_1^{-1}(\dot{x}_s Z_{cs} - F_m C_3) \quad (2)$$

$$C_4 C_1 \dot{x}_s = C_1 F_m (1 + C_{mf}) + \dot{x}_s Z_{cs} Z_{cm} - F_m C_3 Z_{cm} \quad (3)$$

$$F_m = \frac{C_4 C_1 + Z_{cs} Z_{cm}}{C_1 (1 + C_{mf}) + C_3 Z_{cm}} \quad (4)$$

Four channel teleoperation

Hybrid matrix - H12

$$H_{12} = -\frac{f_m}{f_s}, \dot{x}_s = 0 \quad (5)$$

$$F_m(1 + C_{mf}) - C_2 F_s - Z_{cm} \dot{x}_m = 0 \quad (6)$$

$$\dot{x}_m = Z_{cm}^{-1}(-C_2 F_s + F_m(1 + C_{mf})) \quad (7)$$

$$C_3 F_m + C_1 \dot{x}_m - F_s(1 + C_{sf}) = 0 \quad (8)$$

$$F_s(-Z_{cm}(1 + C_{sf}) - C_1 C_2) + F_m(Z_{cm} C_3 + C_1(1 + C_{mf})) = 0 \quad (9)$$

$$H_{12} = \frac{-Z_{cm}(1 + C_{sf}) - C_1 C_2}{Z_{cm} C_3 + C_1(1 + C_{mf})} \quad (10)$$

Four channel teleoperation

Hybrid matrix - H21

$$H_{21} = \frac{\dot{x}_m}{\dot{x}_s}, F_s = 0 \quad (11)$$

$$F_m(1 + C_{mf}) - C_4 \dot{x}_s - Z_{cm} \dot{x}_m = 0 \quad (12)$$

$$F_m = \frac{\dot{x}_s C_4 + \dot{x}_m Z_{cm}}{1 + C_{mf}} \quad (13)$$

$$C_3 F_m + C_1 \dot{x}_m - Z_{cs} \dot{x}_s = 0 \quad (14)$$

$$\dot{x}_s(C_3 C_4 + (1 - C_{mf})Z_{cs}) + \dot{x}_m(C_3 Z_{cm} + C_1(1 + C_{mf})) \quad (15)$$

$$H_{21} = -\frac{C_3 C_4 + Z_{cs}(1 - C_{mf})}{Z_{cm} C_3 + C_1(1 + C_{mf})} \quad (16)$$

Four channel teleoperation

Hybrid matrix - H22

$$H_{22} = -\frac{\dot{x}_m}{F_s}, \dot{x}_s = 0 \quad (17)$$

$$F_m(1 + C_{mf}) - C_2 F_s - Z_{cm} \dot{x}_m = 0 \quad (18)$$

$$F_m = \frac{F_s C_2 + \dot{x}_m Z_{cm}}{1 + C_{mf}} \quad (19)$$

$$C_1 \dot{x}_m + C_3 F_m - F_s(1 + C_{sf}) = 0 \quad (20)$$

$$F_s(C_3 C_2 - (1 + C_{mf})(1 + C_{sf})) + \dot{x}_m(C_3 Z_{cm} + C_1(1 + C_{mf})) \quad (21)$$

$$H_{22} = -\frac{C_3 C_2 - (1 + C_{mf})(1 + C_{sf})}{Z_{cm} C_3 + C_1(1 + C_{mf})} \quad (22)$$

Kalman Filtering

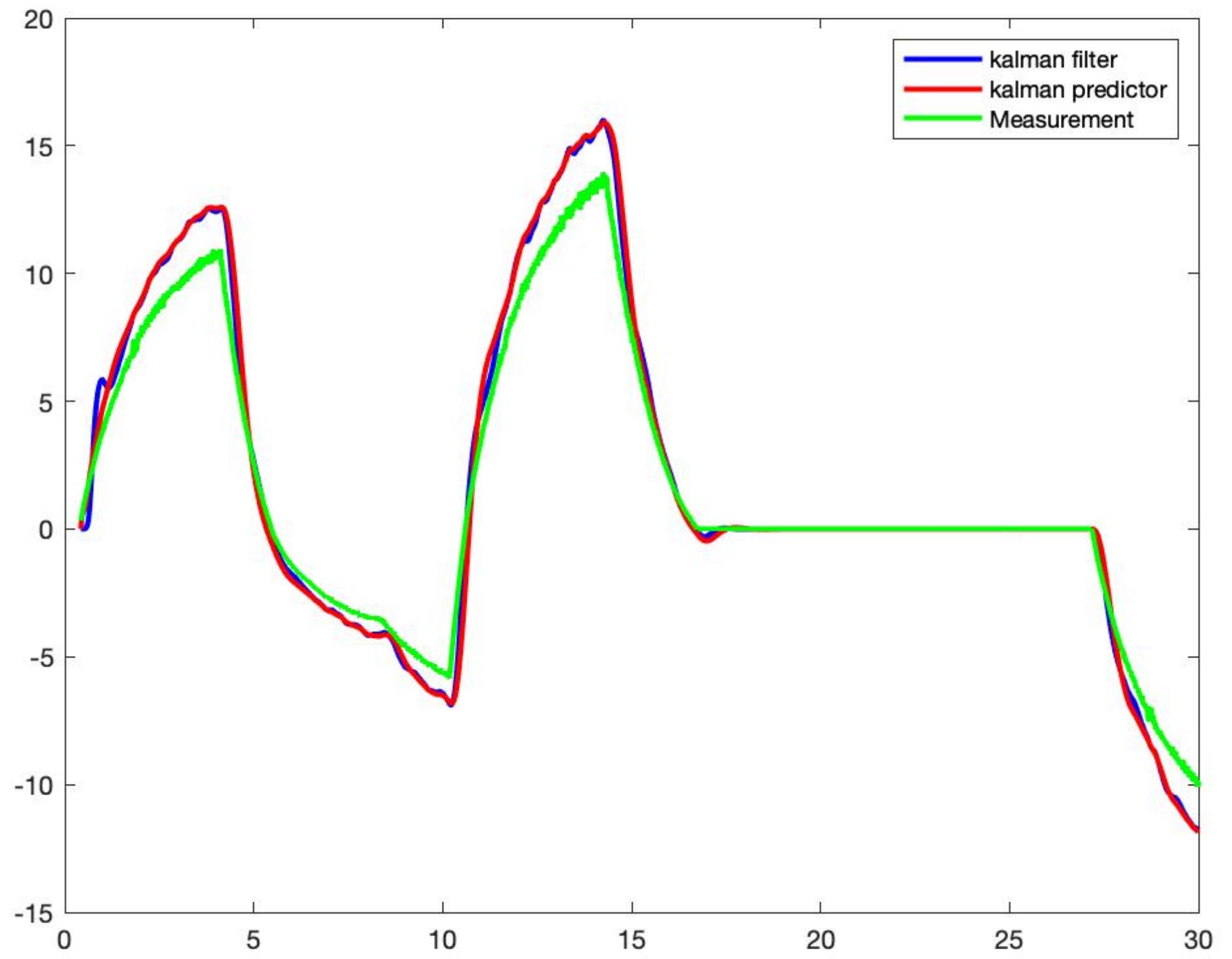
Kalman Filtering

Descrizione

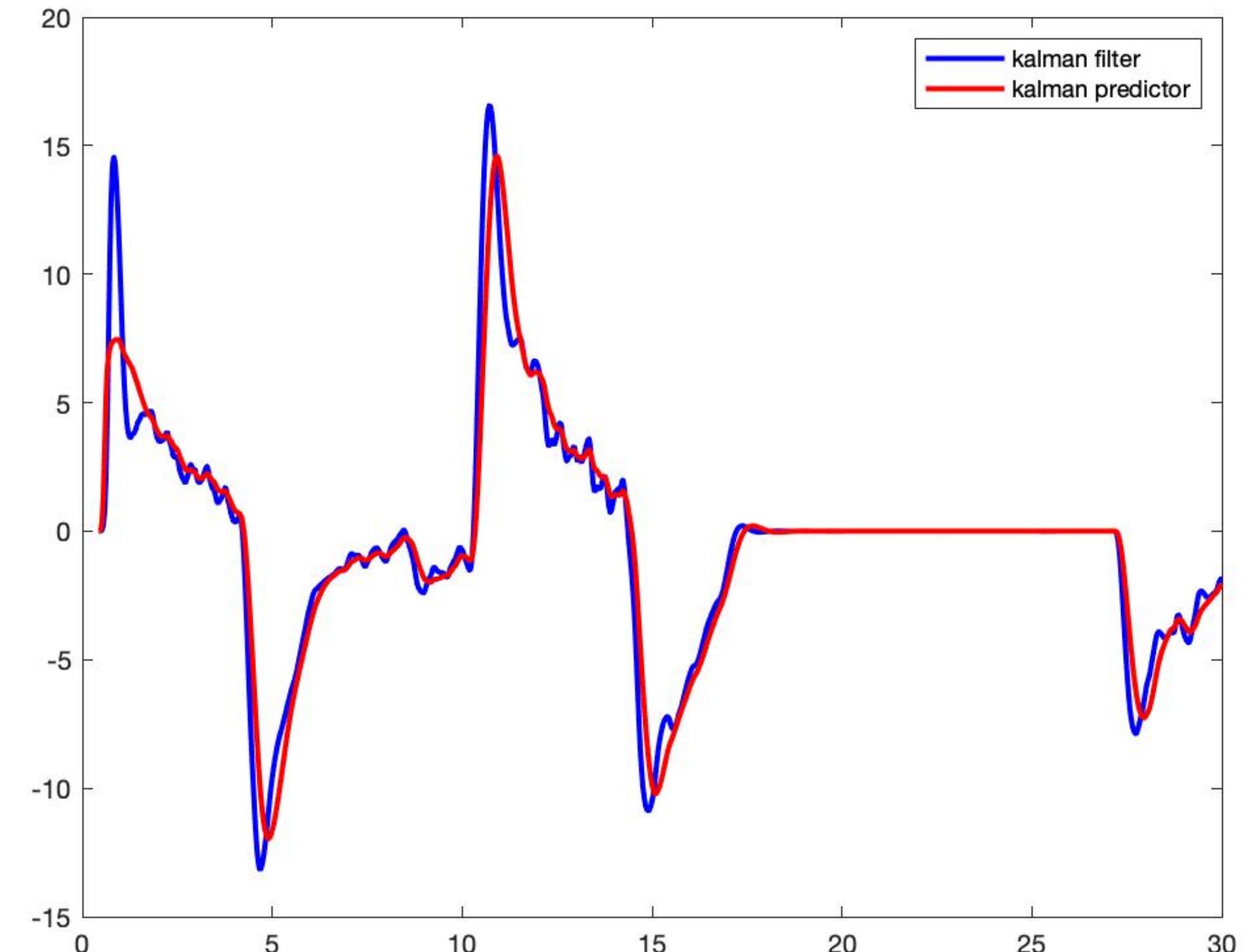
- È il filtro ideale, o filtro a minima varianza
- È possibile stimare velocità e accelerazione grazie al modello di stato
- Oltre al filtro, esiste il predittore e lo smoother
- Il filtro calcola il valore $X_{k+1|k+1}$
- Il predittore calcola il valore $X_{k+1|k}$
- Lo smoother invece è uno strumento esclusivamente da utilizzare offline perché è presente una fase di backward (forward -> 1:N, backward -> N:1).

Kalman Filtering

Dataset : 1kHz motor



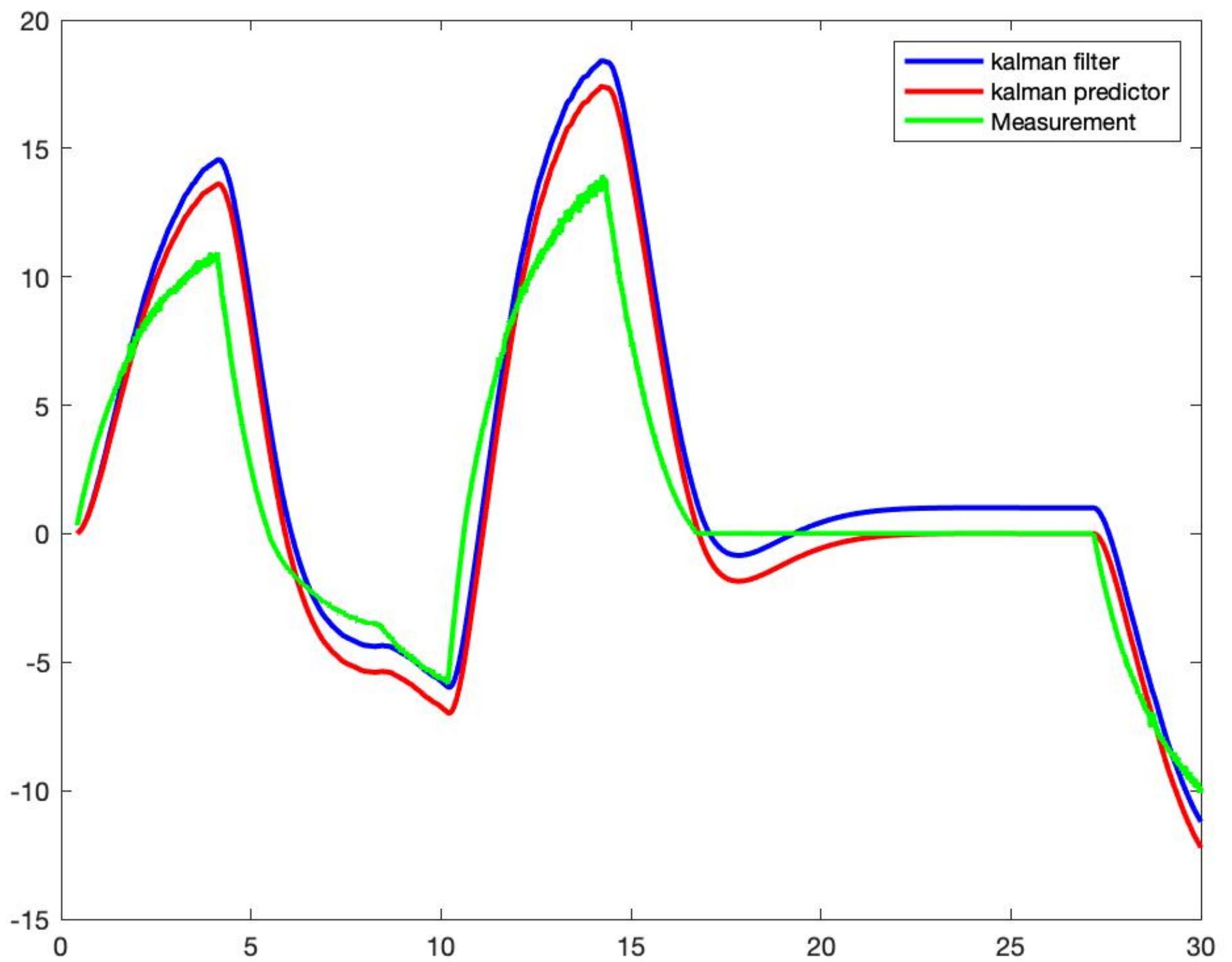
Velocità



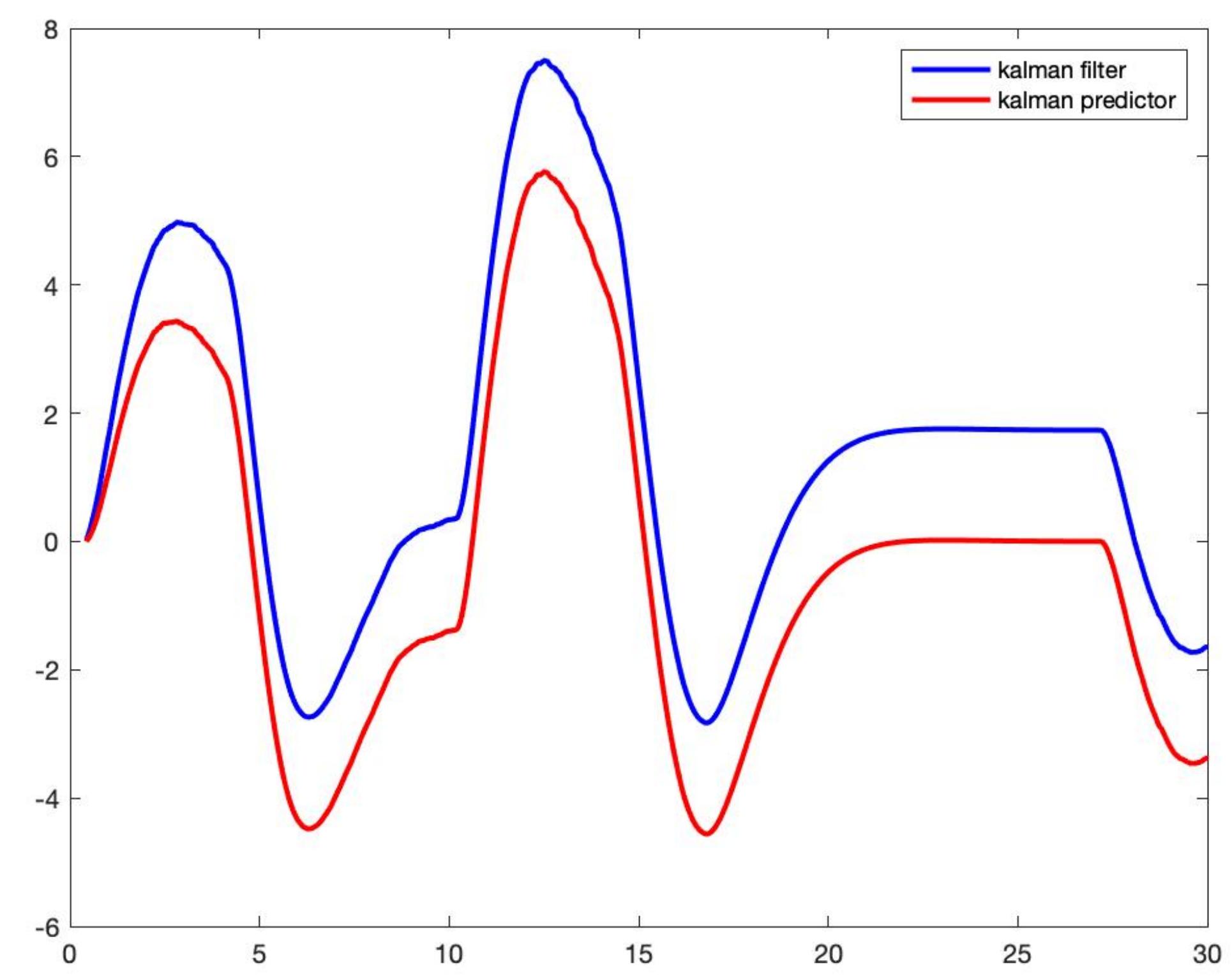
Accelerazioni

Kalman Filtering

Dataset : 1kHz motor



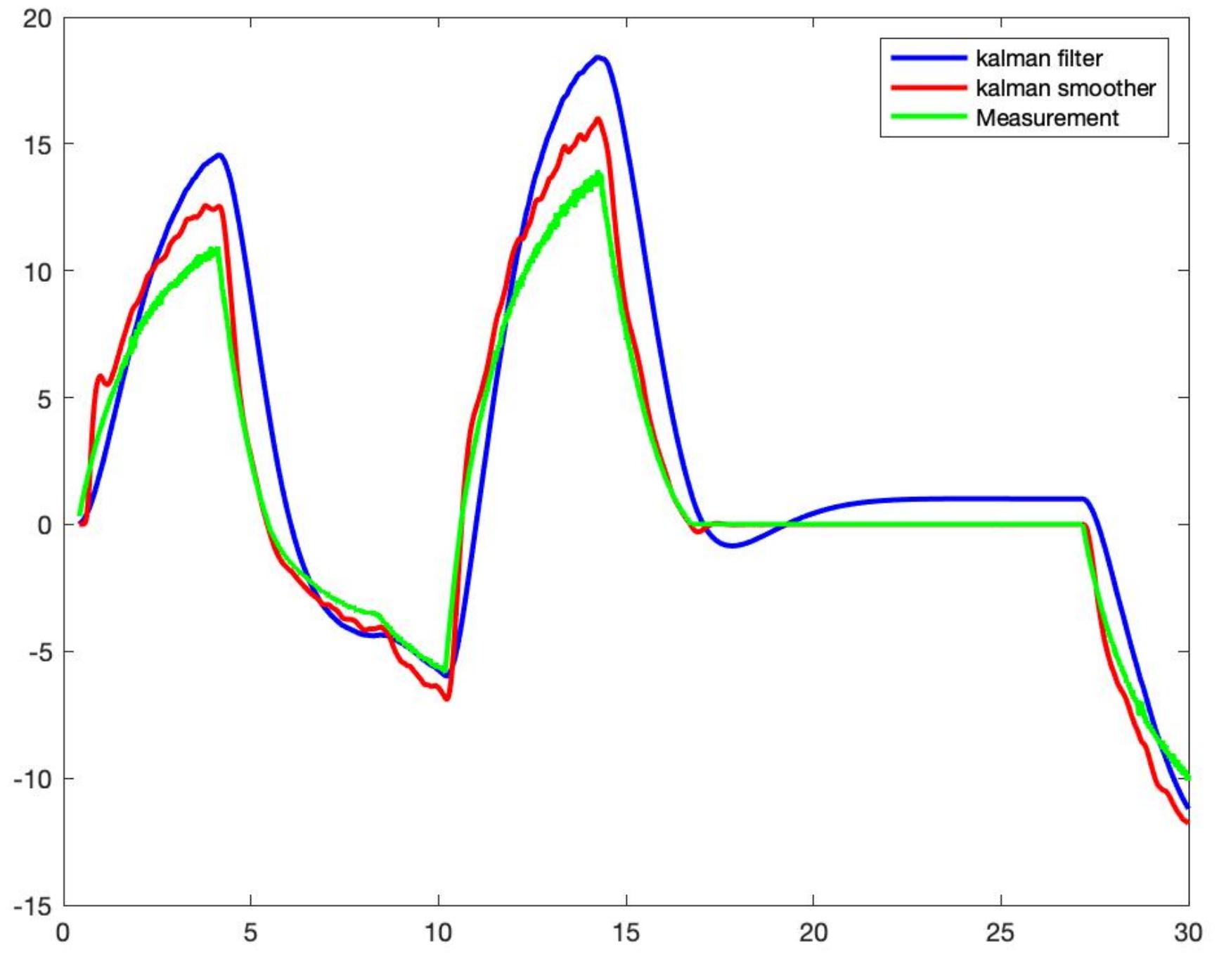
Velocità - Steady state



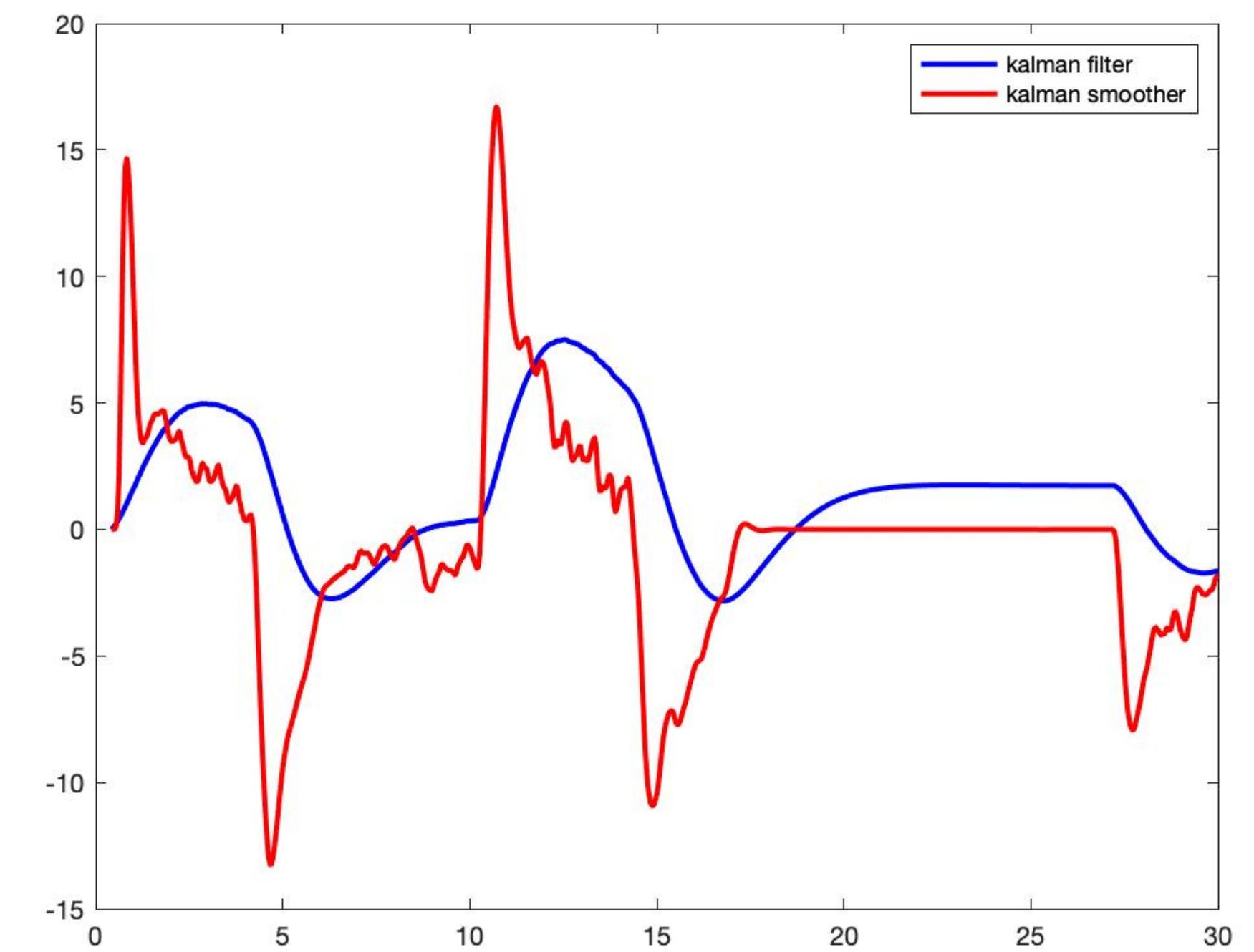
Accelerazioni - Steady state

Kalman Filtering

Dataset : 1kHz motor



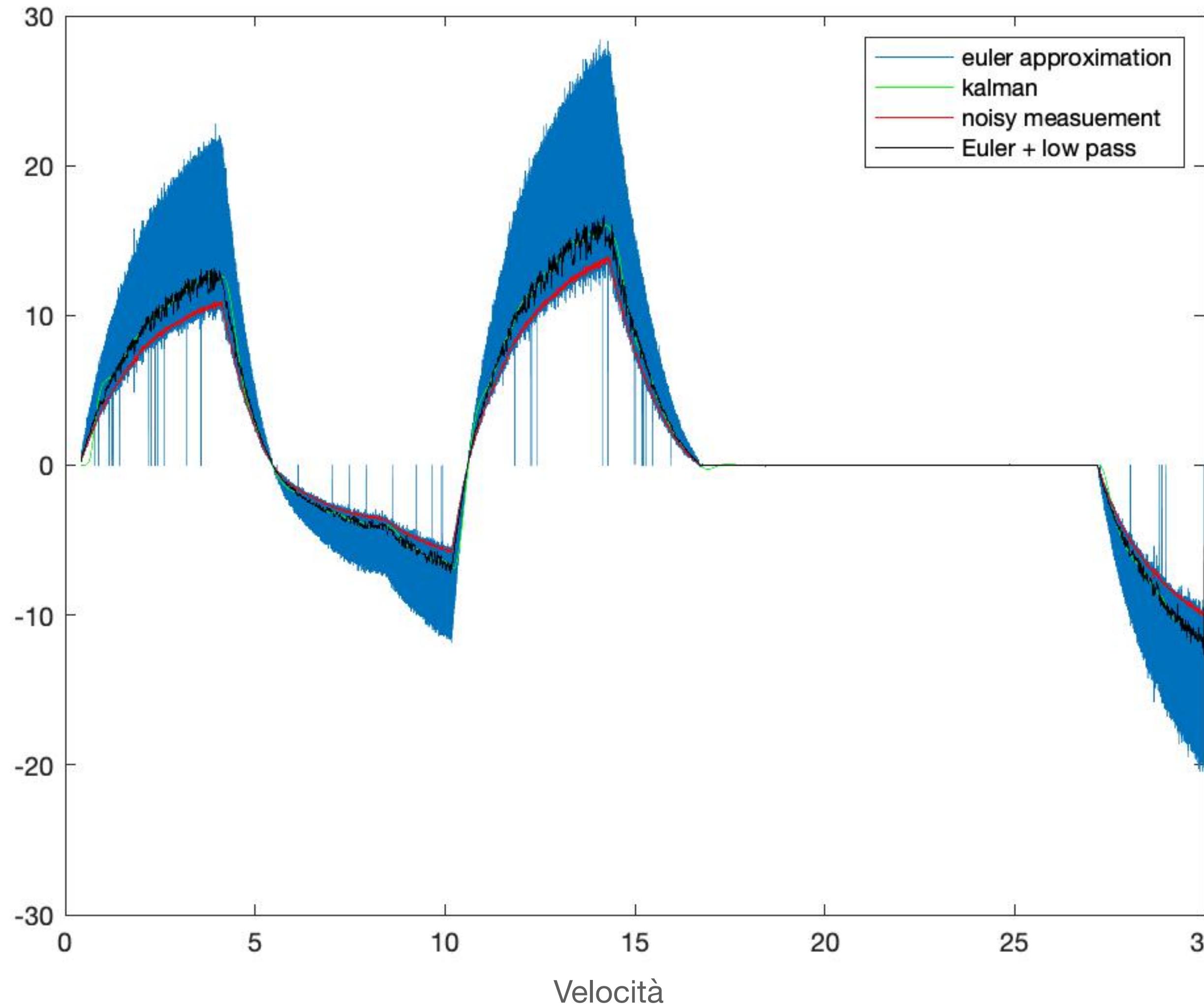
Velocità



Accelerazioni

Kalman Filtering

Confronto con altri metodi



- Approssimazione di Eulero è decisamente imprecisa
- Se applicato un filtro passa basso, alla stima di Eulero, la stima migliora
- Il filtro di Kalman rappresenta la migliore alternativa ai precedenti punti

RLS

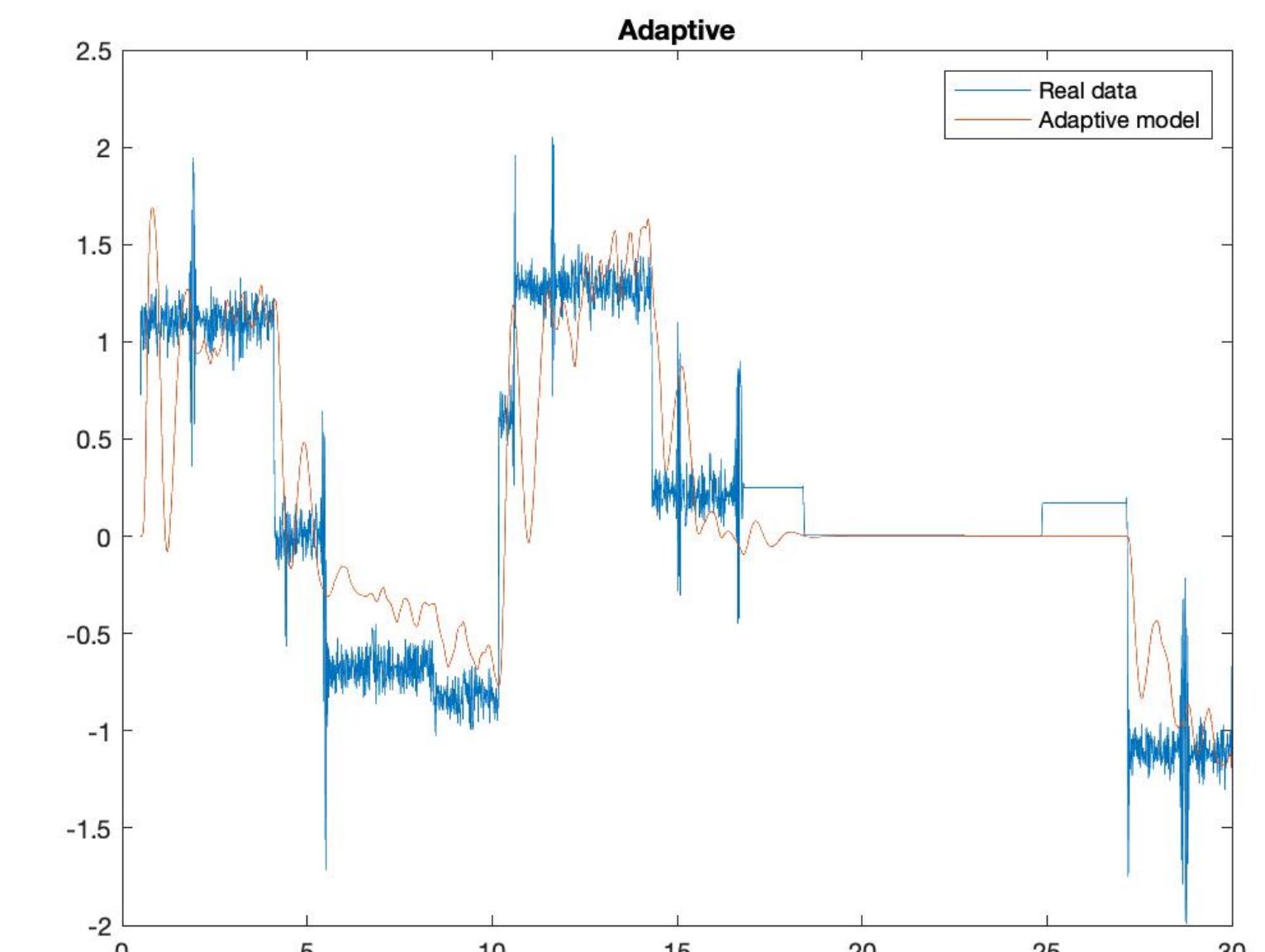
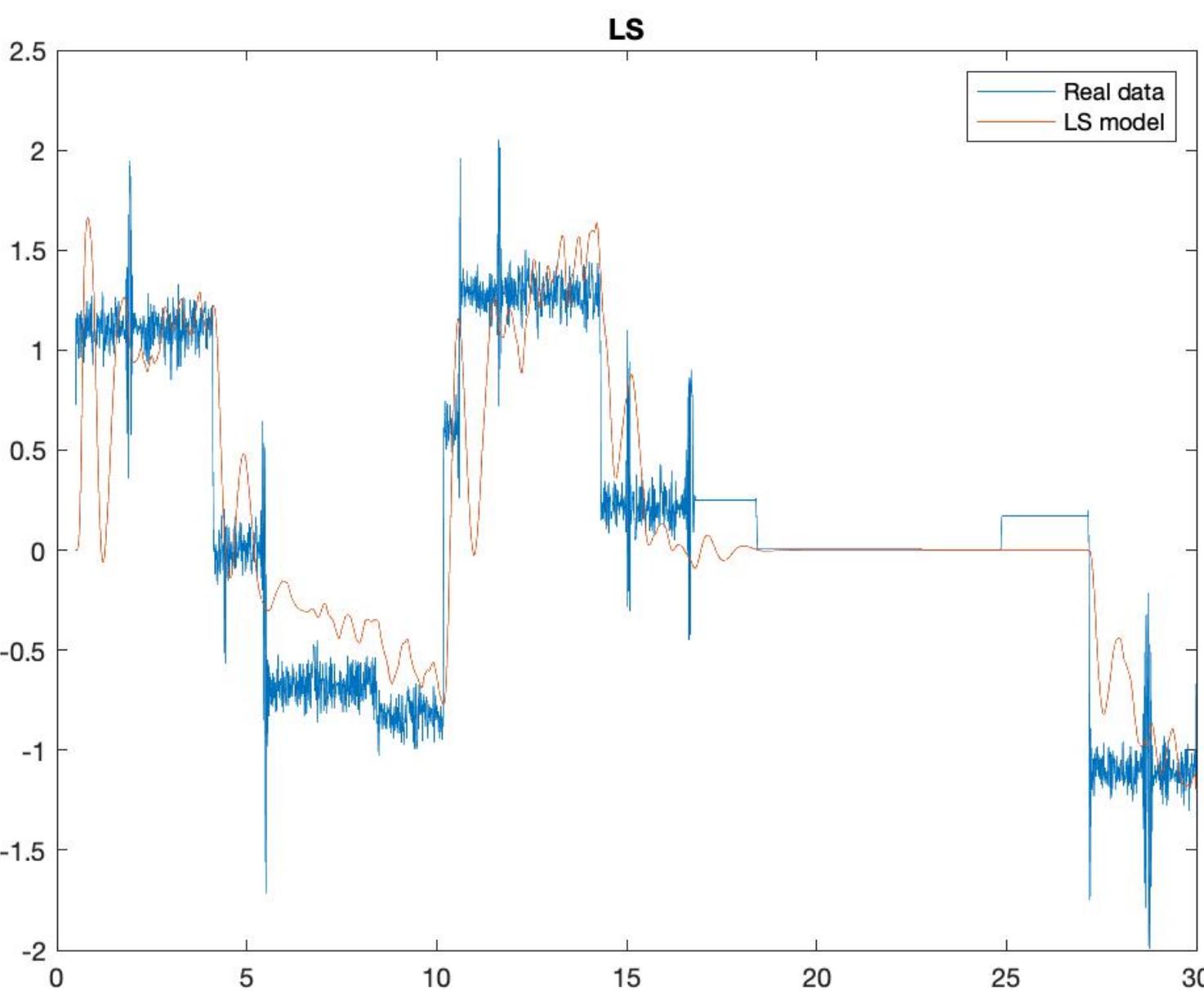
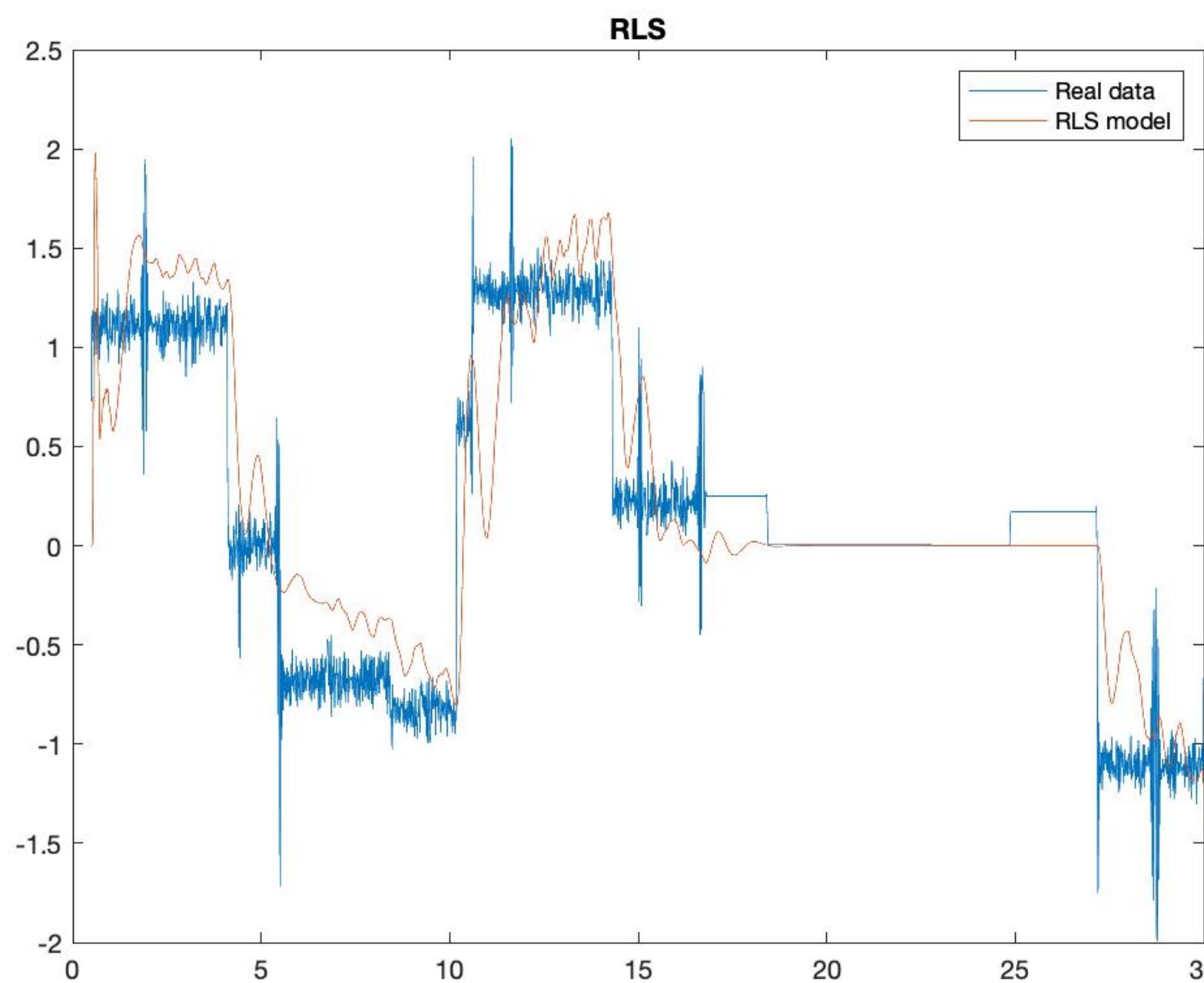
RLS

Descrizione

- Versione LTI del least square algorithm
- La versione LTI produce lo stesso risultato della versione analitica che è ottenuta tramite moltiplicazione delle matrici X, Y
- RLS calcola il valore di B in base agli N campioni attuali misurati
- L'algoritmo “adaptive” invece cerca di minimizzare una funzione di costo trovando i valori corretti per B , è soggetta a un valore di “apprendimento”, e i risultati dipendono da questo valore
- La funzione di costo è basata sull’errore quadratico

RLS

Comparazione con LS e Adaptive



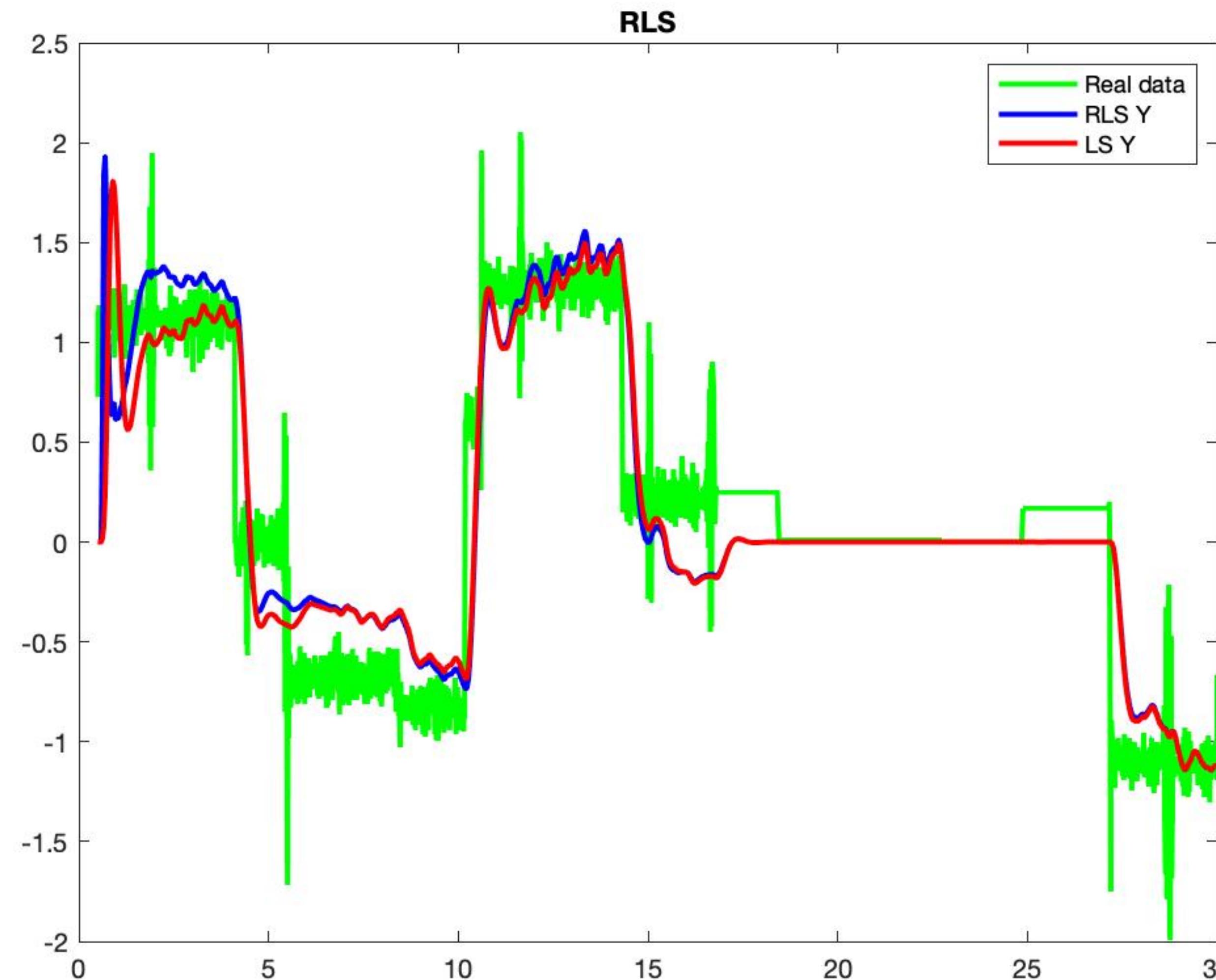
LS :
0.0630
0.0854

RLS :
0.0630
0.0854

ADAPTIVE :
0.0630
0.0854

RLS

Stima di Y in RLS vs LS nel tempo



Scattering

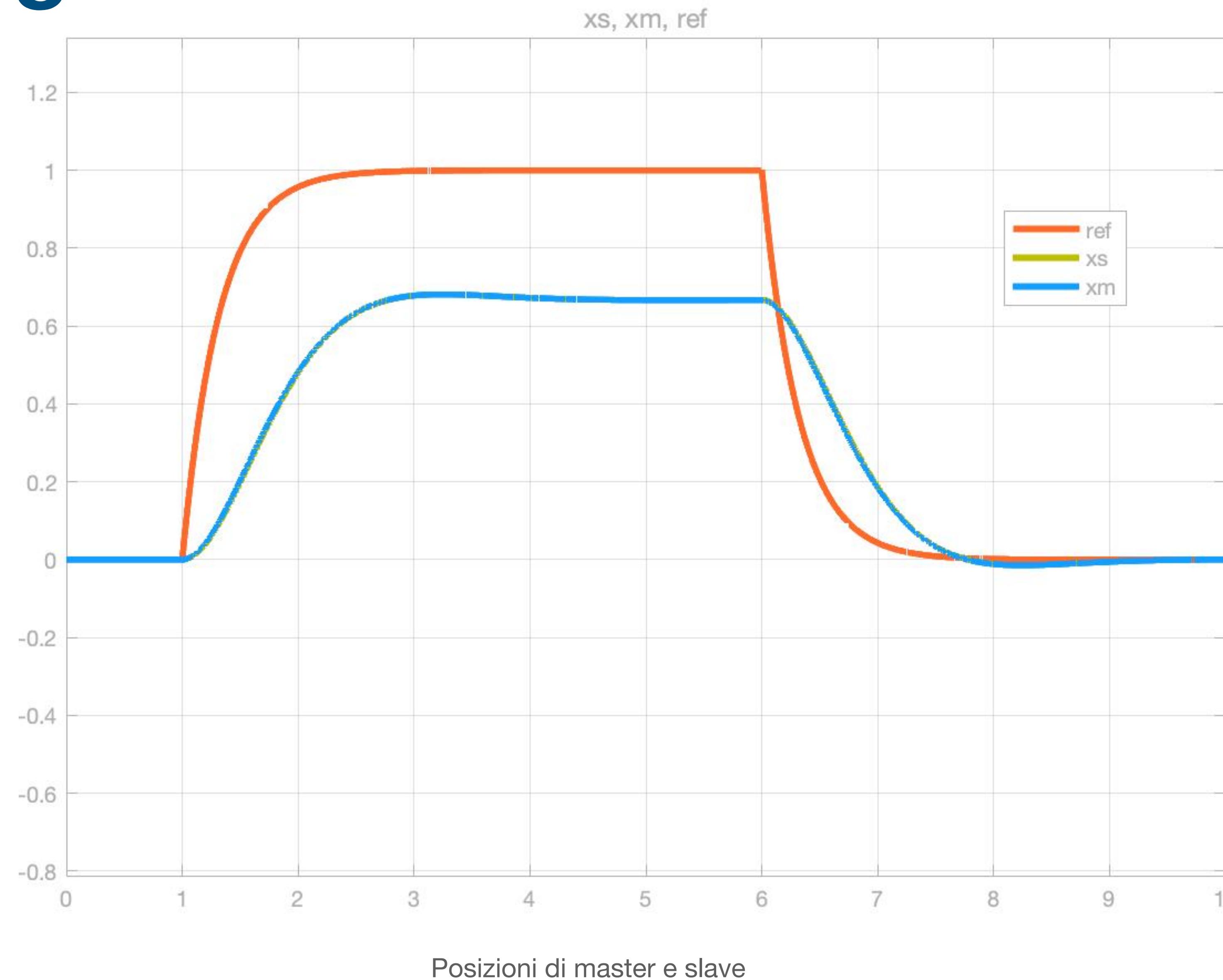
Scattering

Descrizione

- È uno strumento matematico per passare a variabili d'onda(w, z) partendo da variabili di potenza(u, y)
- La conversione da variabile d'onda a variabile di potenza è univoco
- È possibile garantire la passività di un sistema anche tramite variabili d'onda
- La passività per un sistema $G(s)$ SISO LTI, con operatore di scattering $S(s)$, è garantita se: $|S(j\omega)| < 1 \quad \forall \omega \in [-\infty, +\infty]$

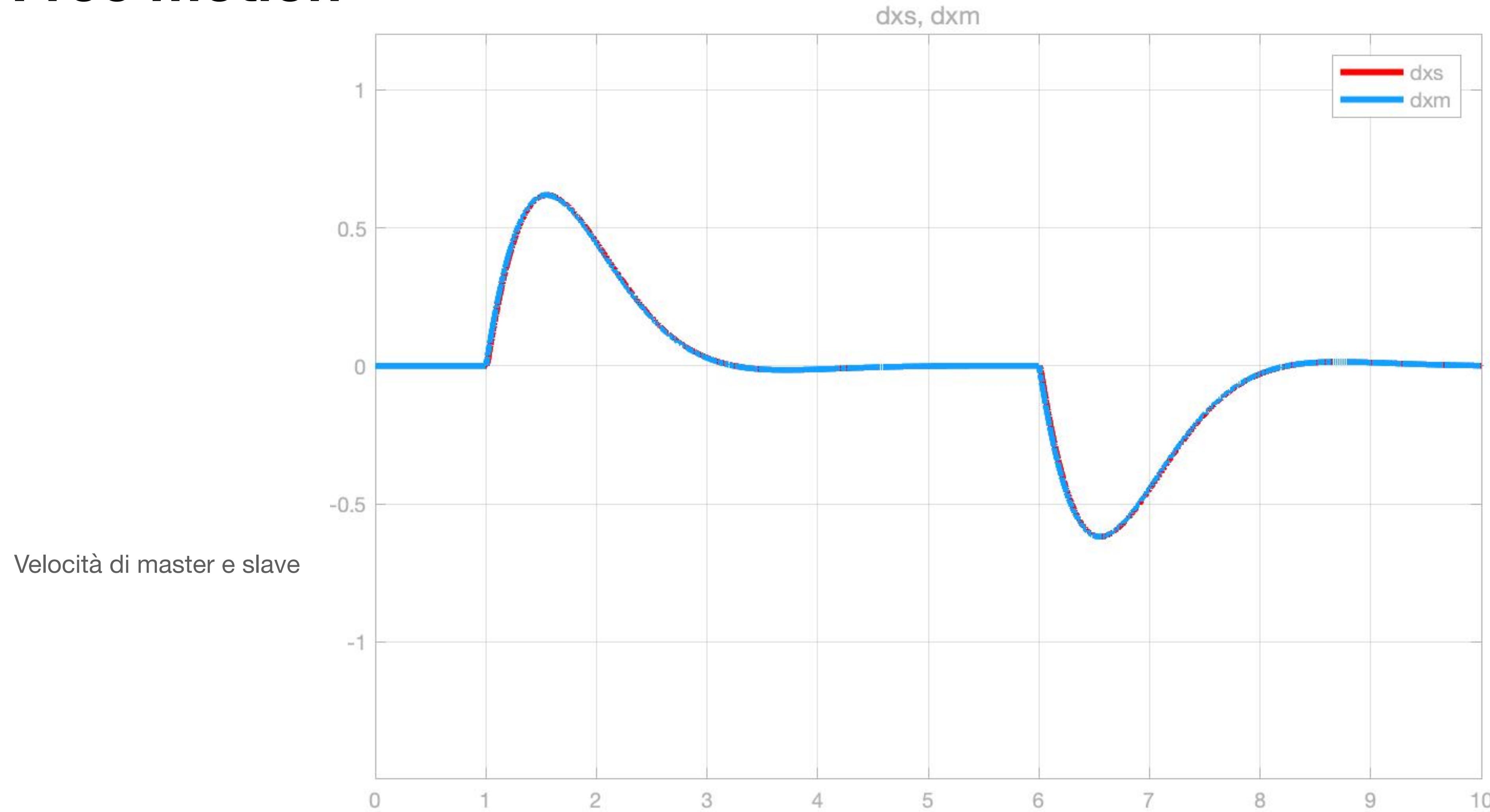
Scattering - FP

Free motion



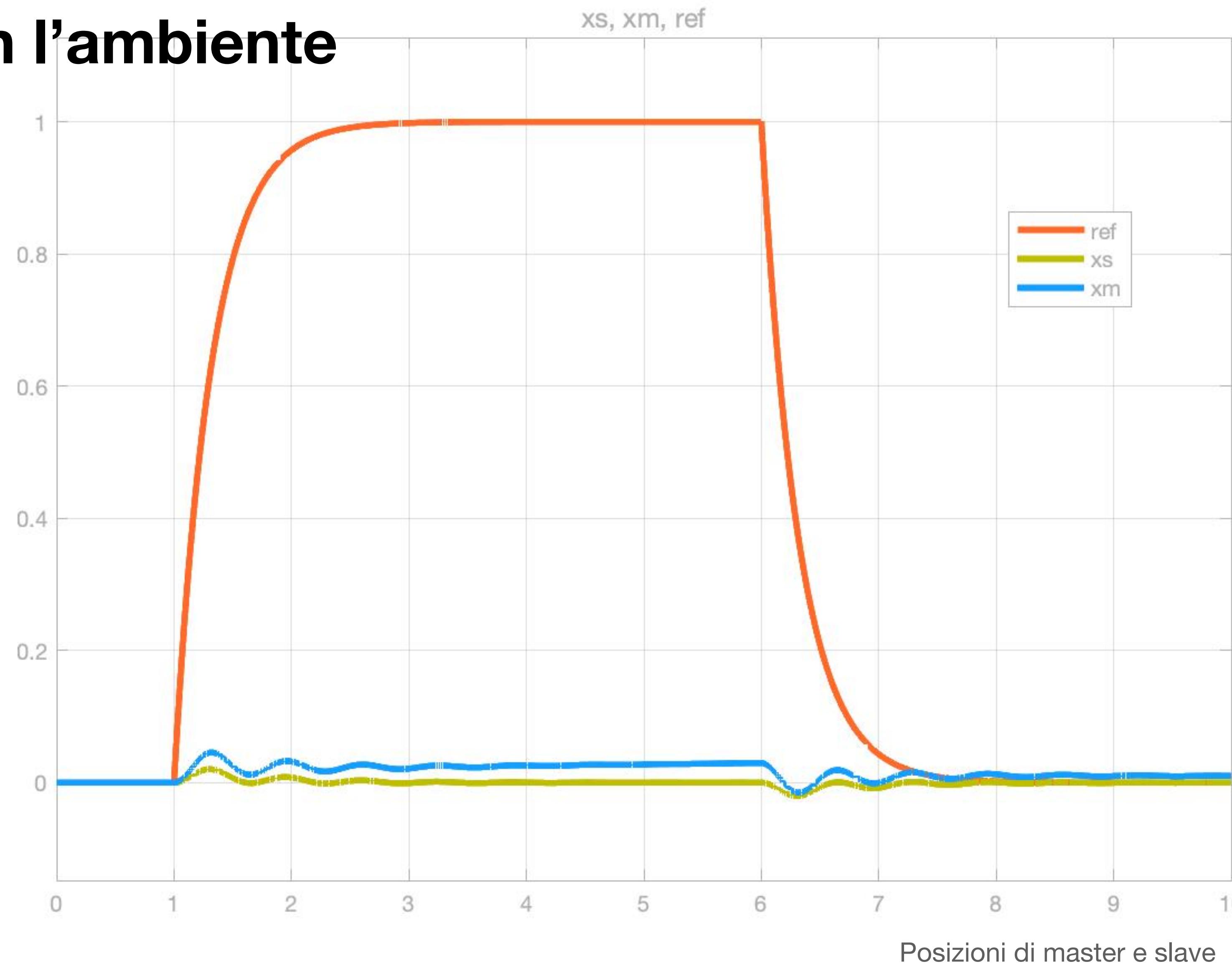
Scattering - FP

Free motion



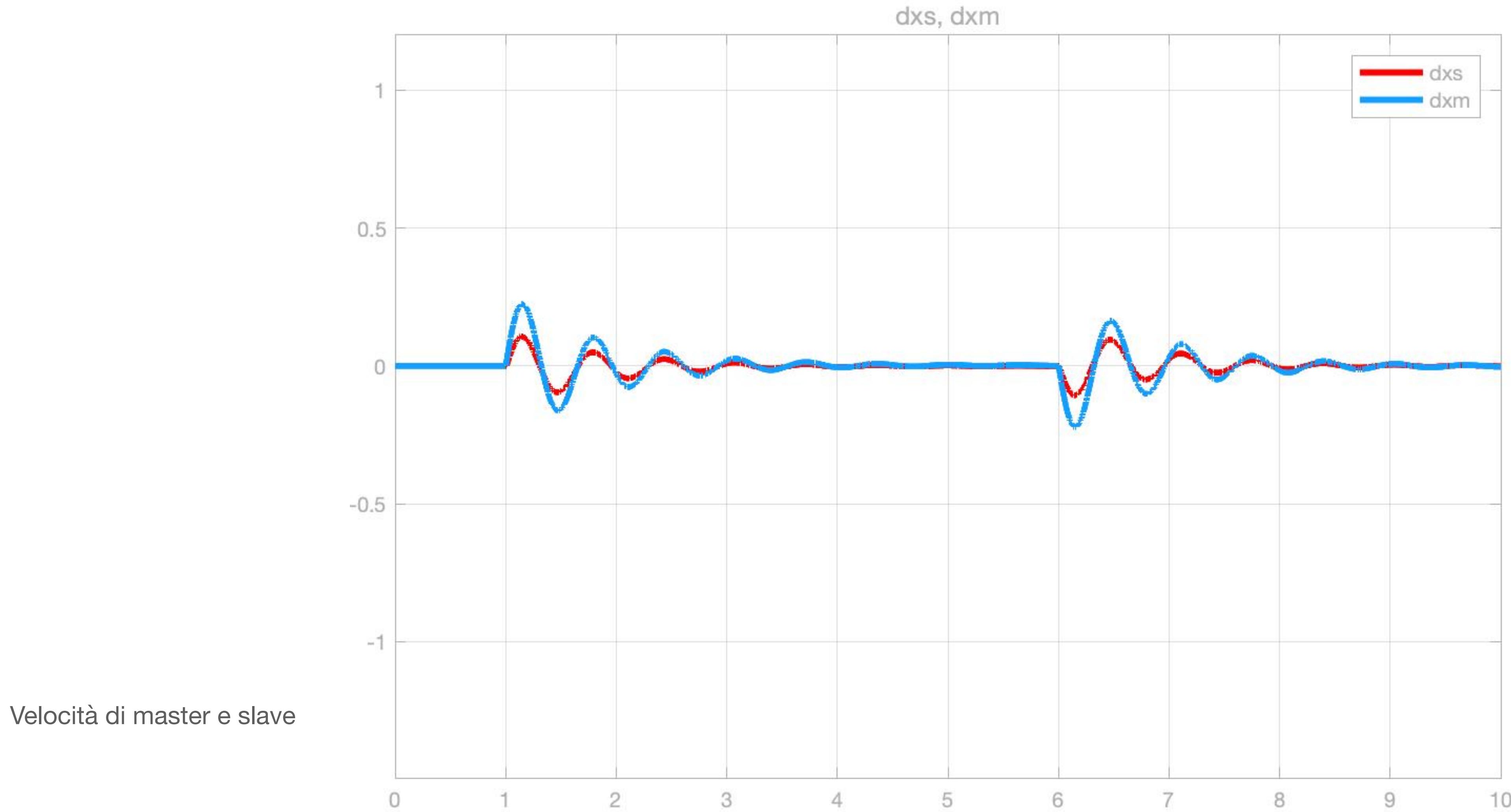
Scattering - FP

Contatto con l'ambiente



Scattering - FP

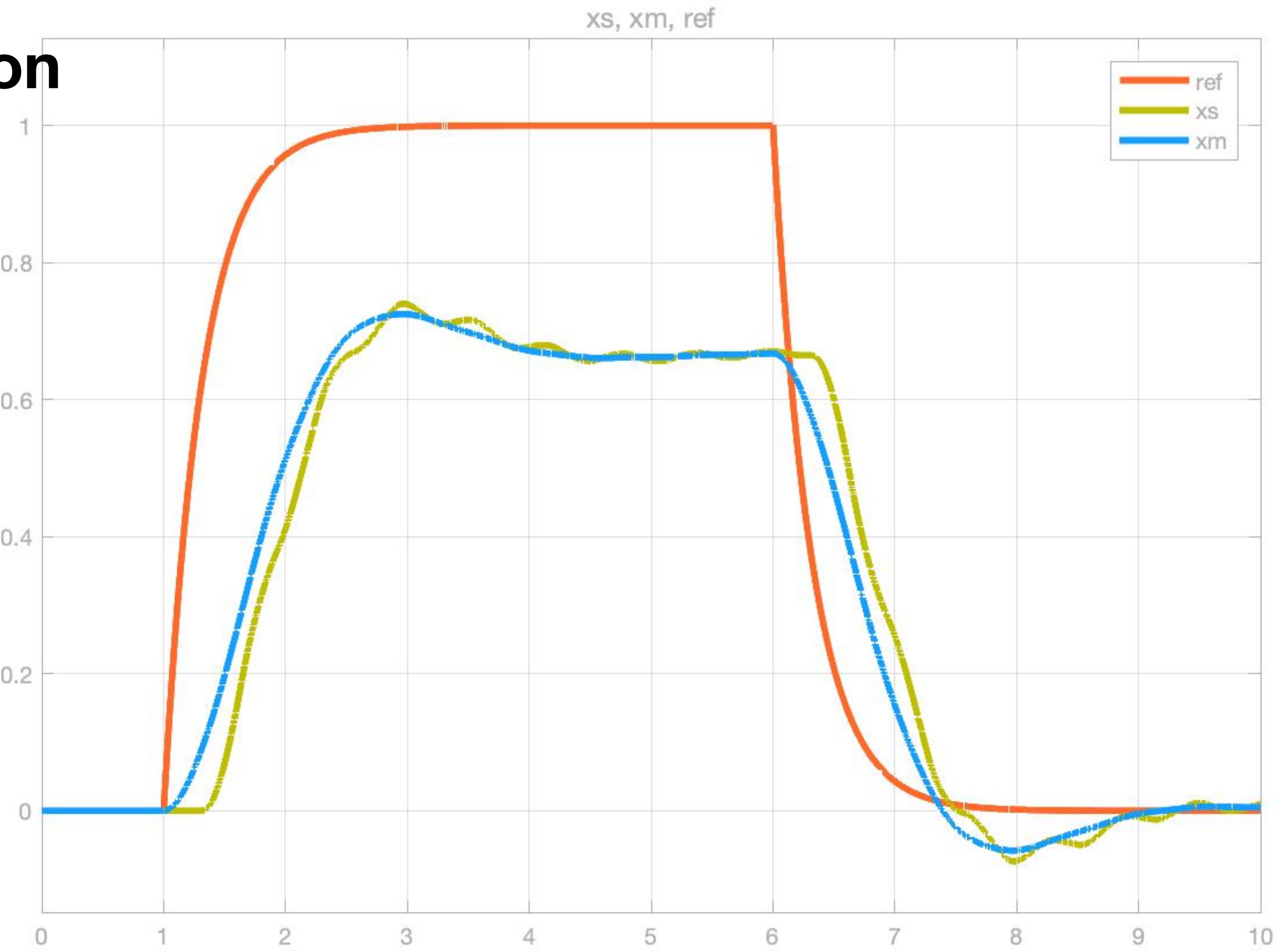
Contatto con l'ambiente



Scattering - FP

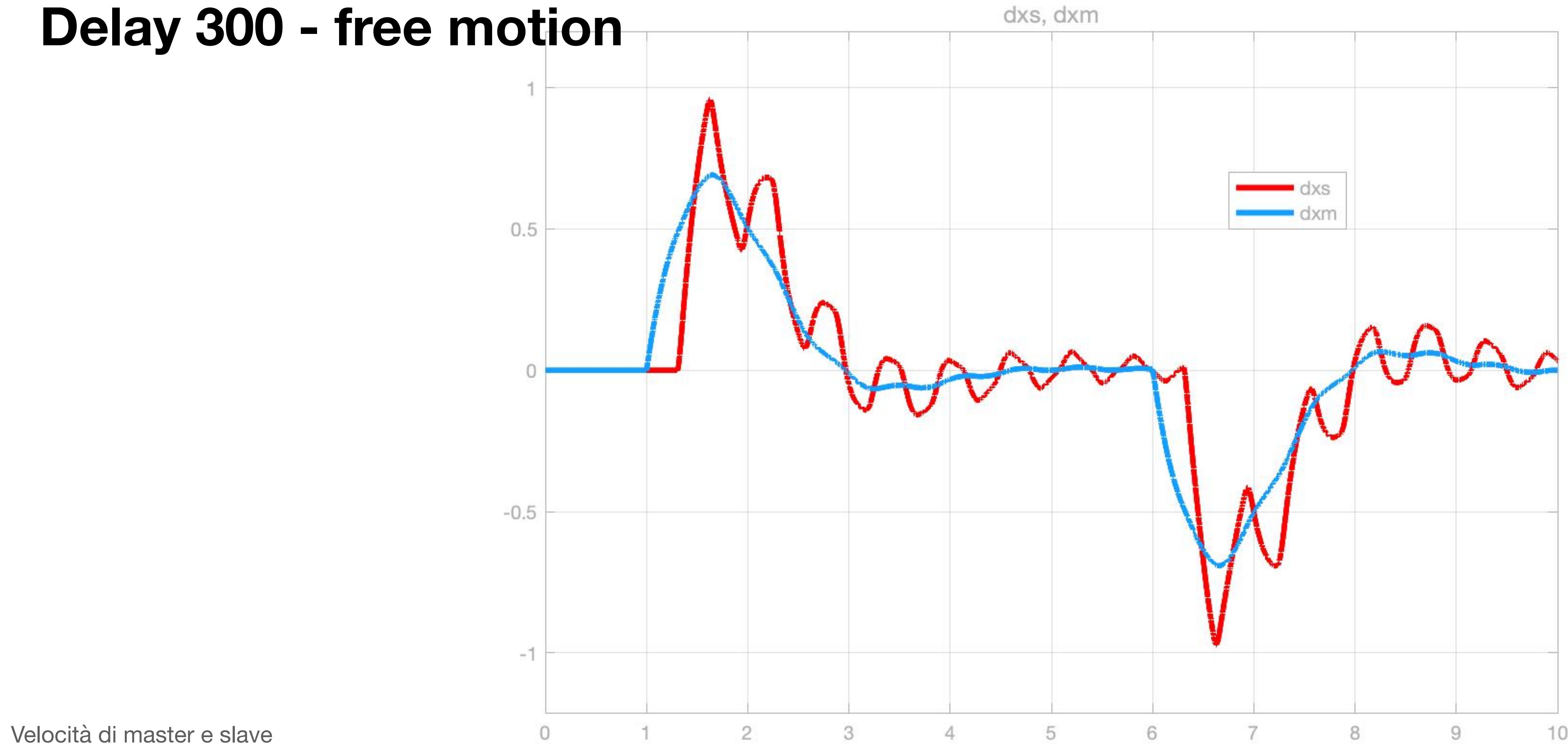
Delay 300 - free motion

Posizioni di master e slave



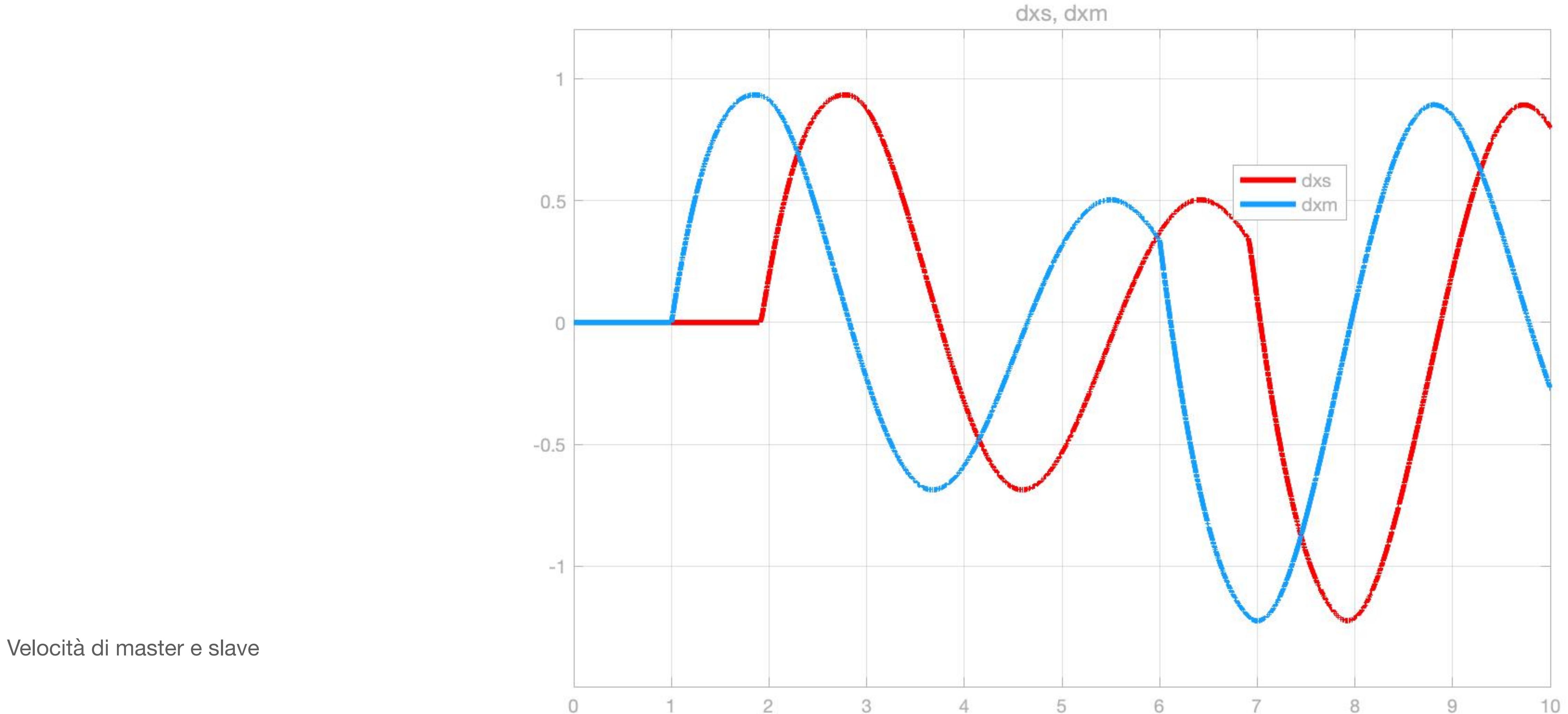
Scattering - FP

Delay 300 - free motion



Scattering - FP

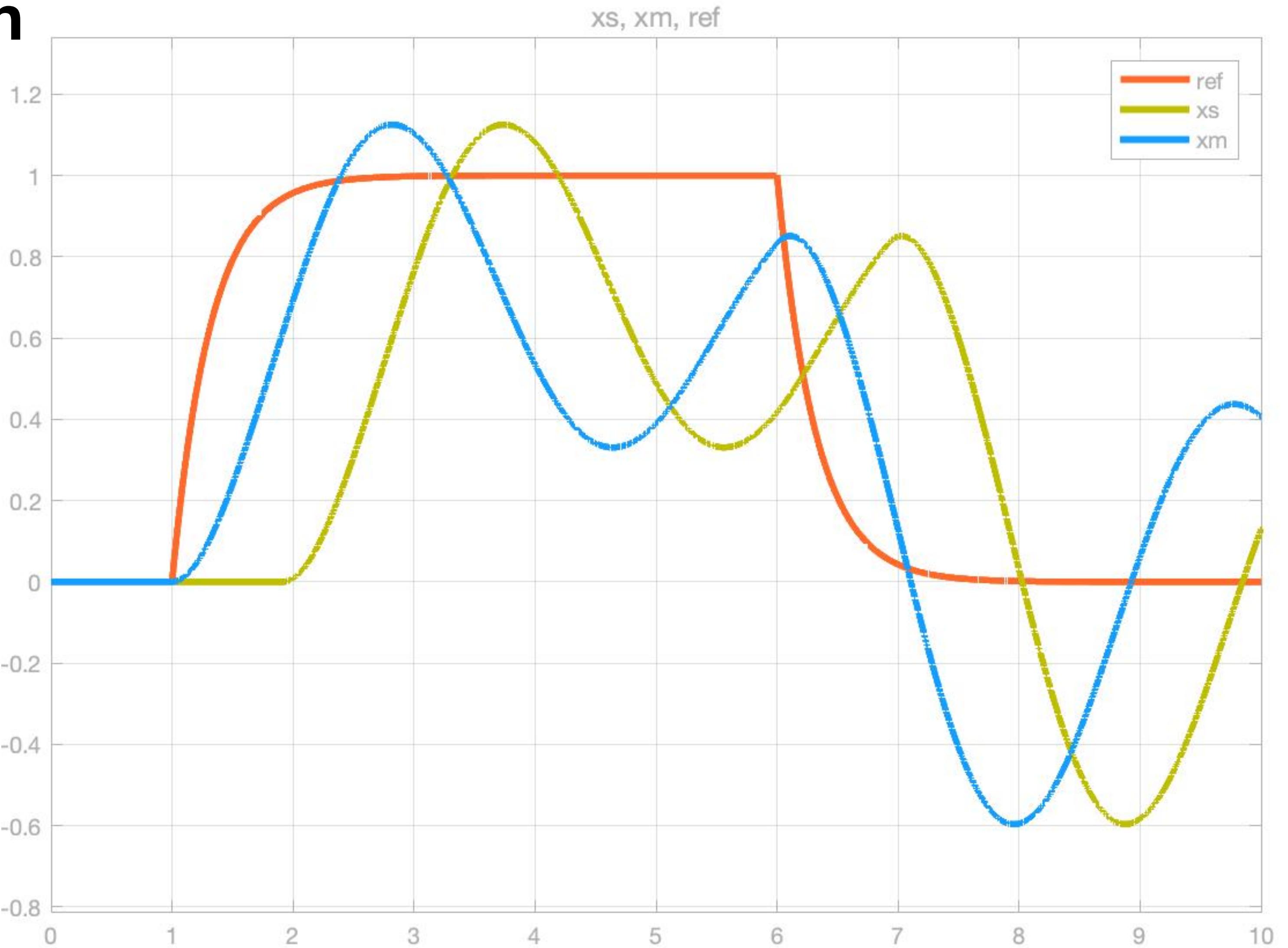
Delay 300 - free motion, no scattering



Scattering - FP

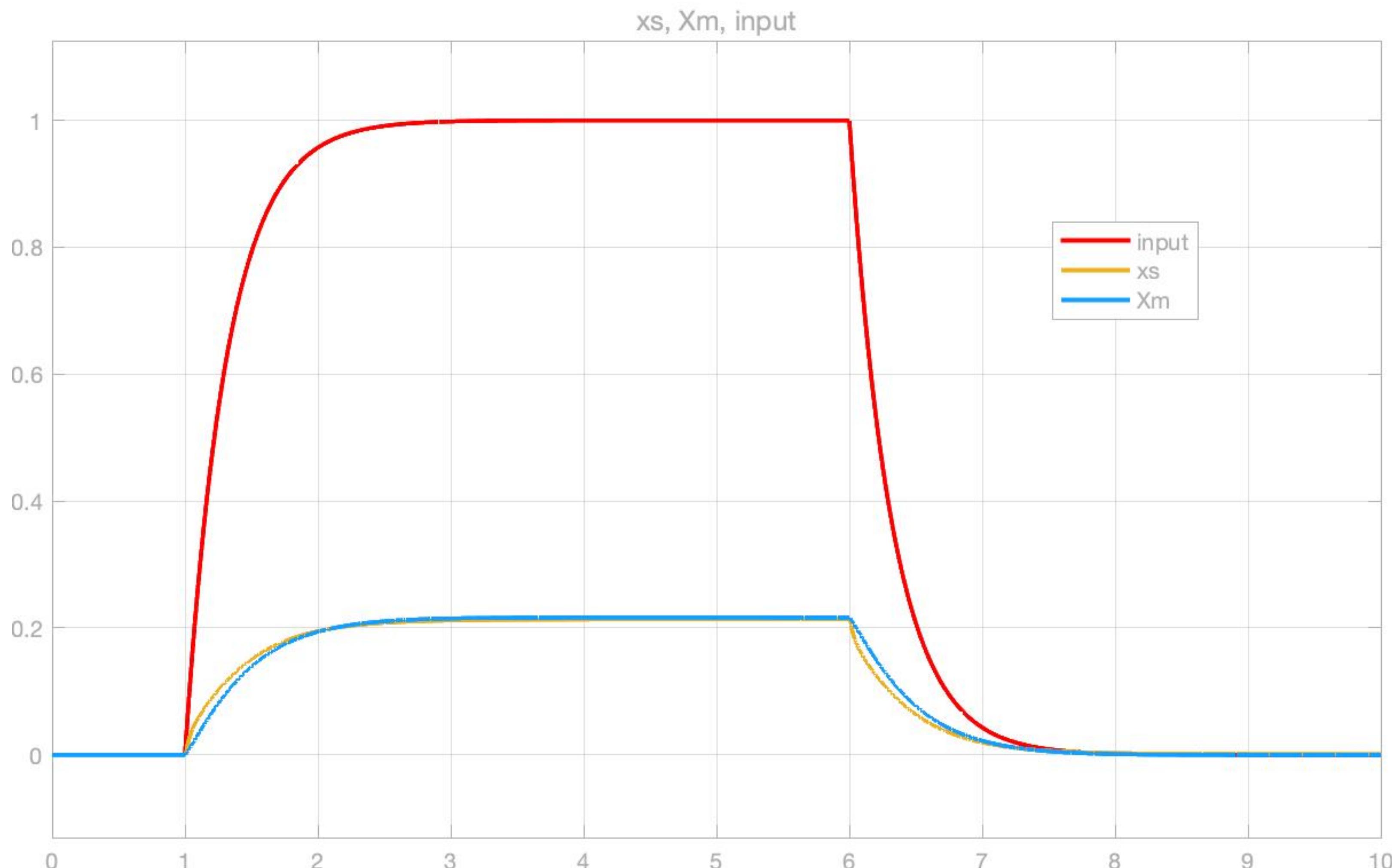
Delay 300 - free motion

Velocità di master e slave



Scattering - PP

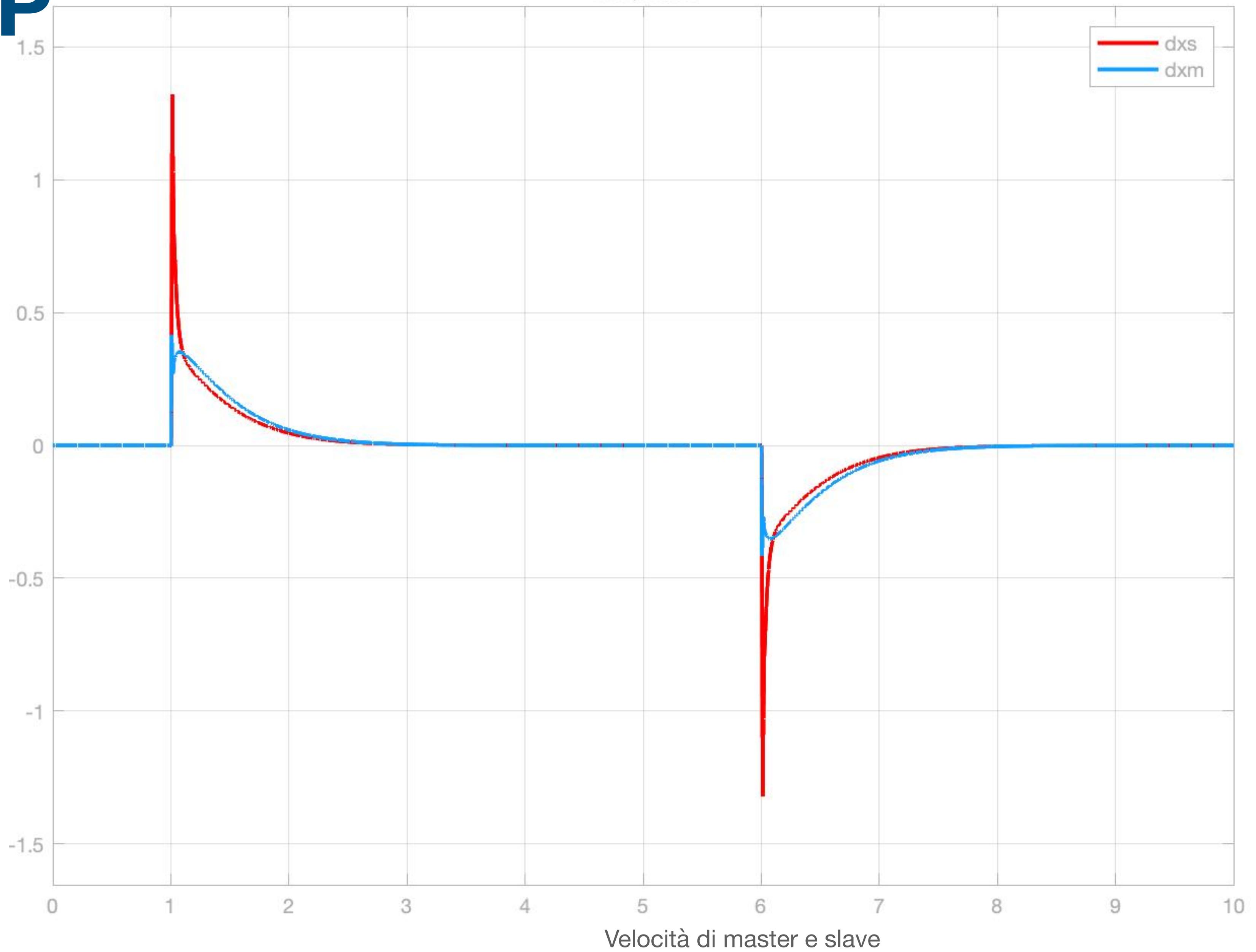
Free motion



Scattering - PP

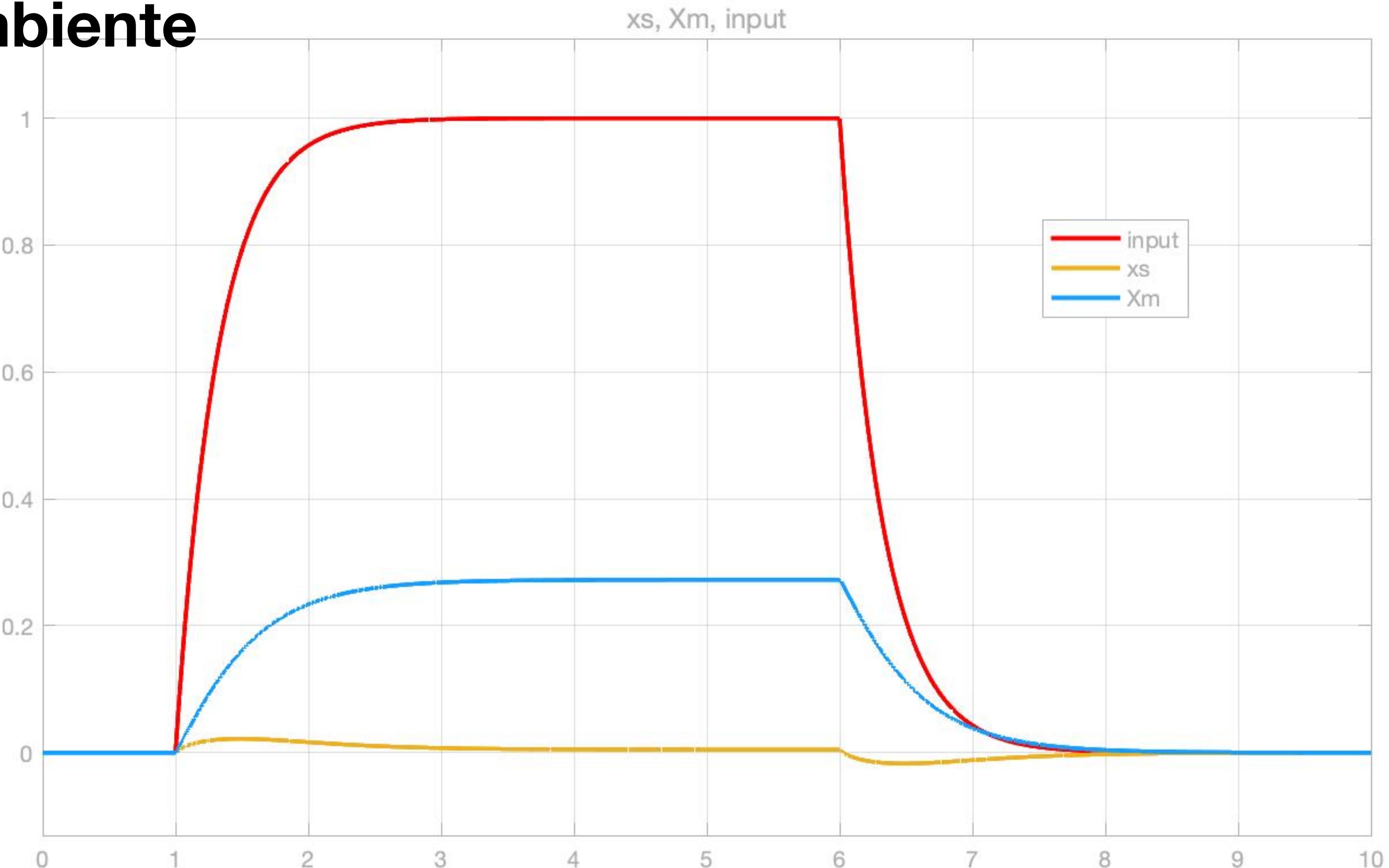
Free motion

d_{xs}, d_{xm}



Scattering - PP

Contatto con l'ambiente

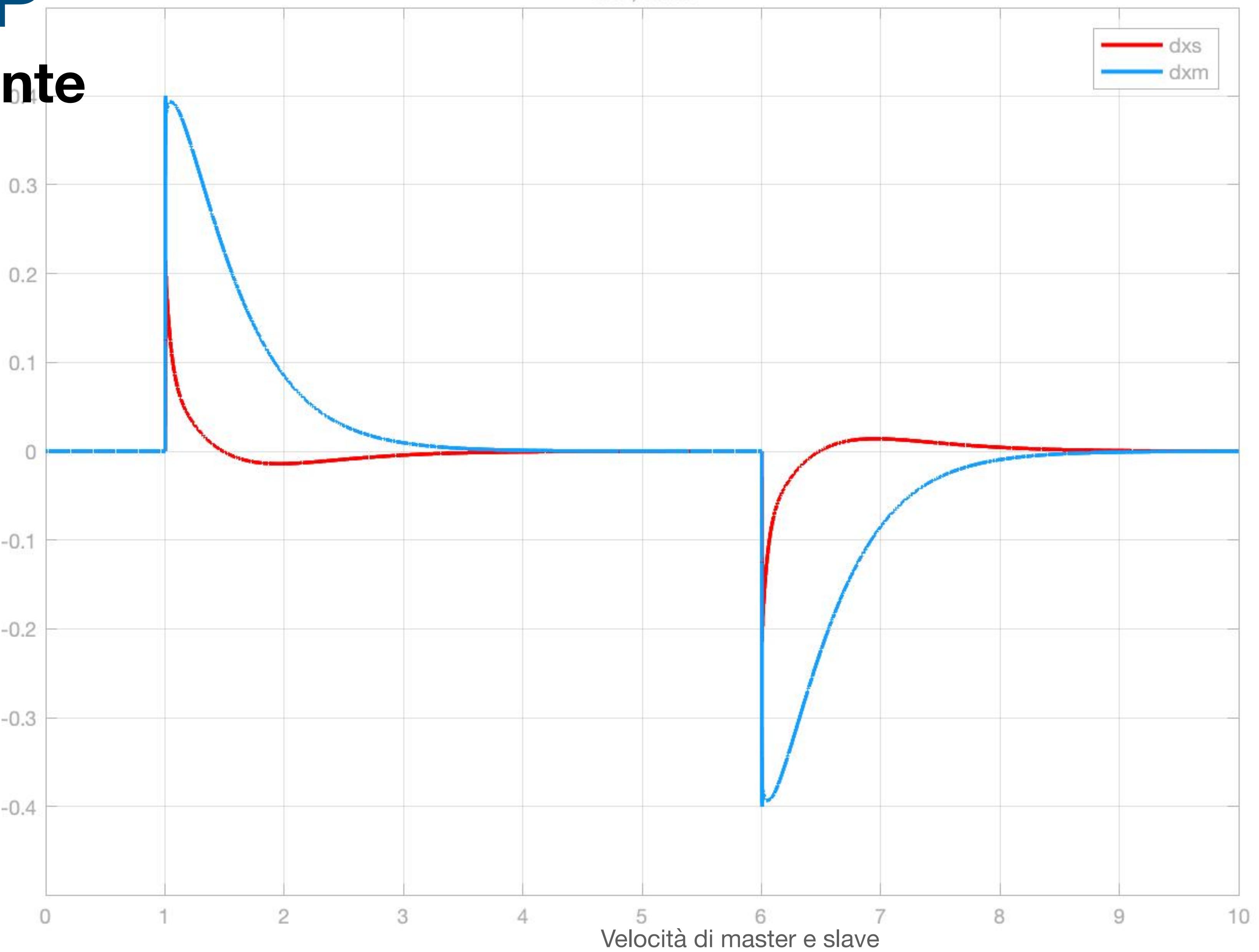


Posizioni di master e slave

Scattering - PP

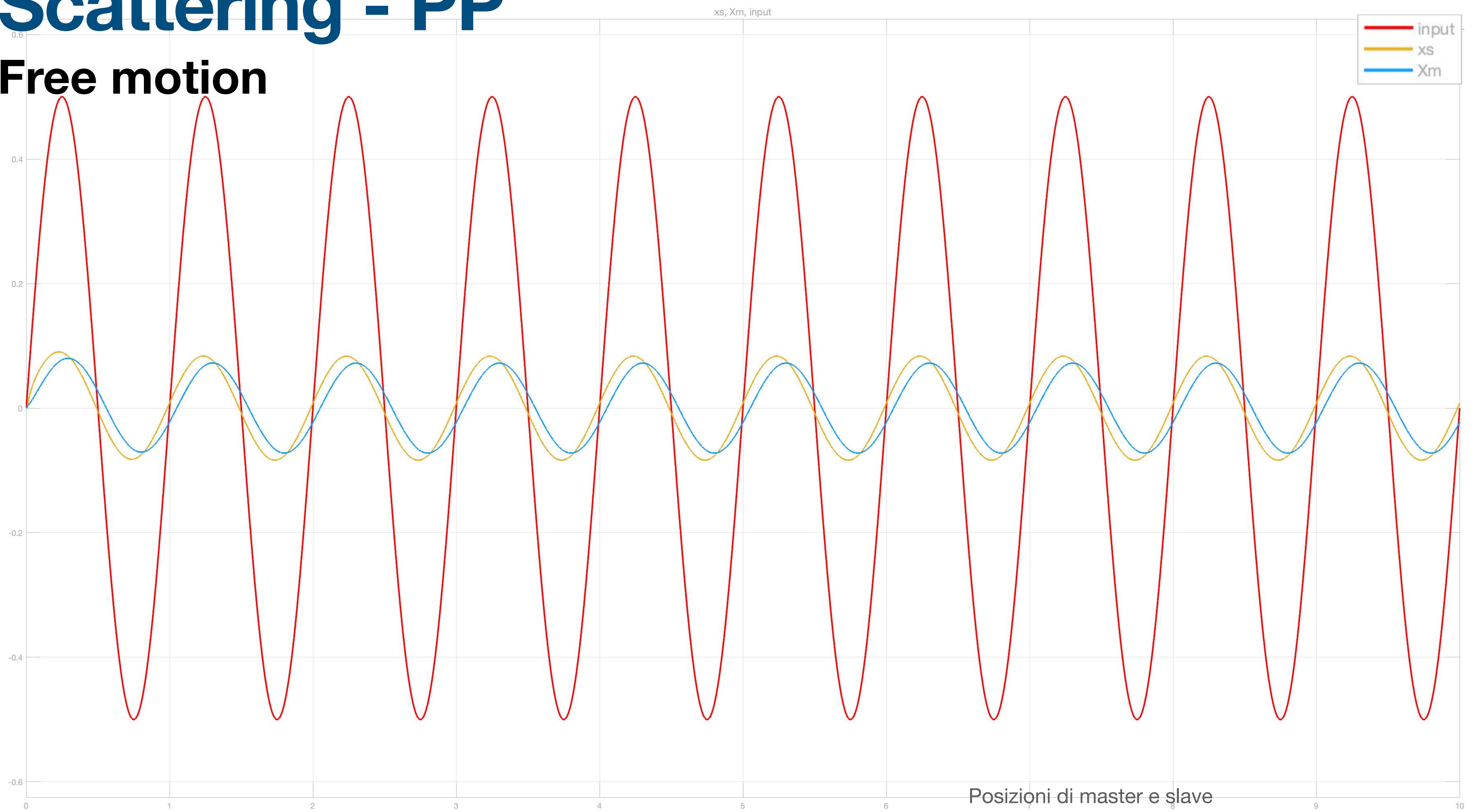
Contatto con l'ambiente

dxs, dxm



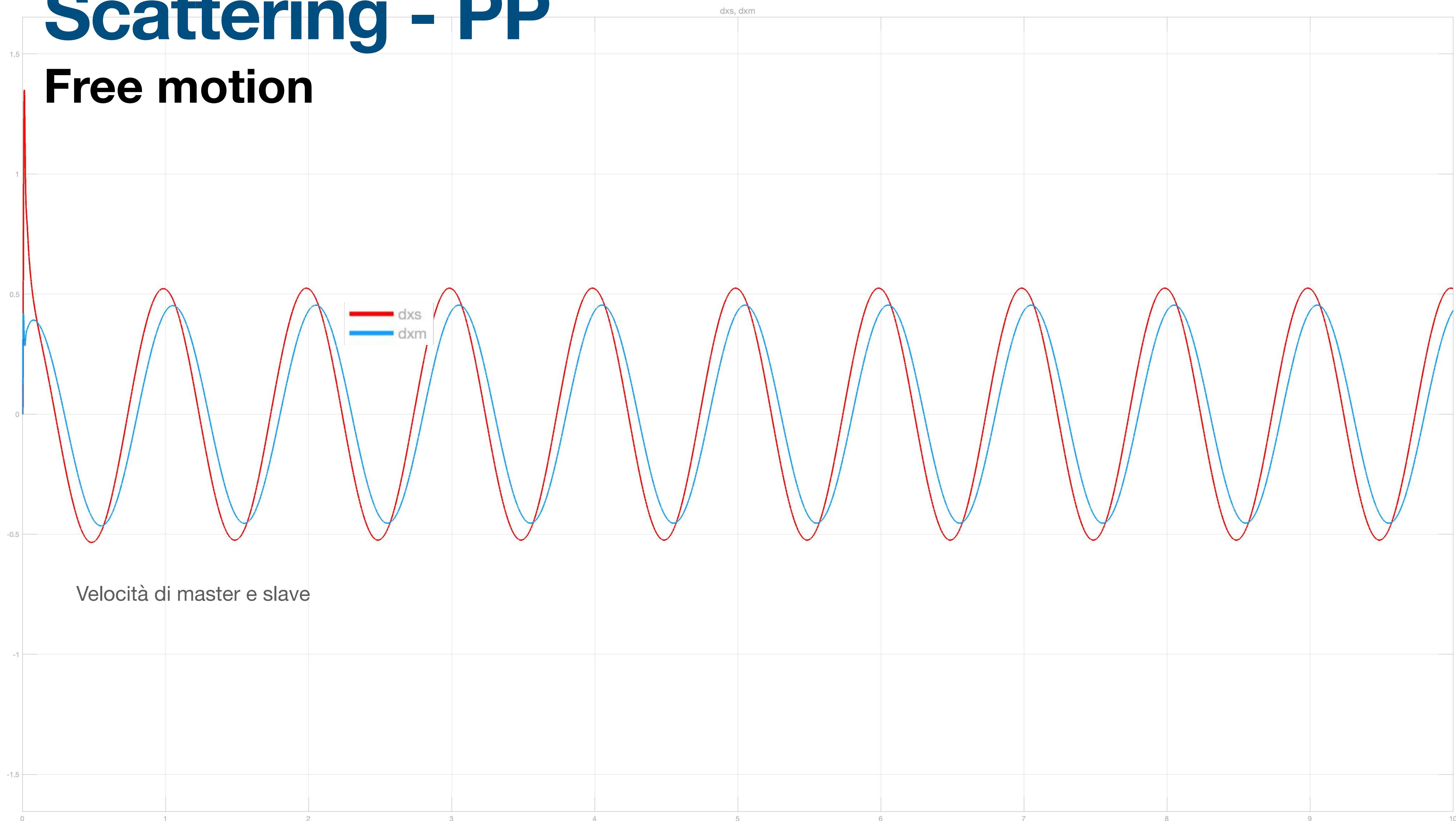
Scattering - PP

Free motion



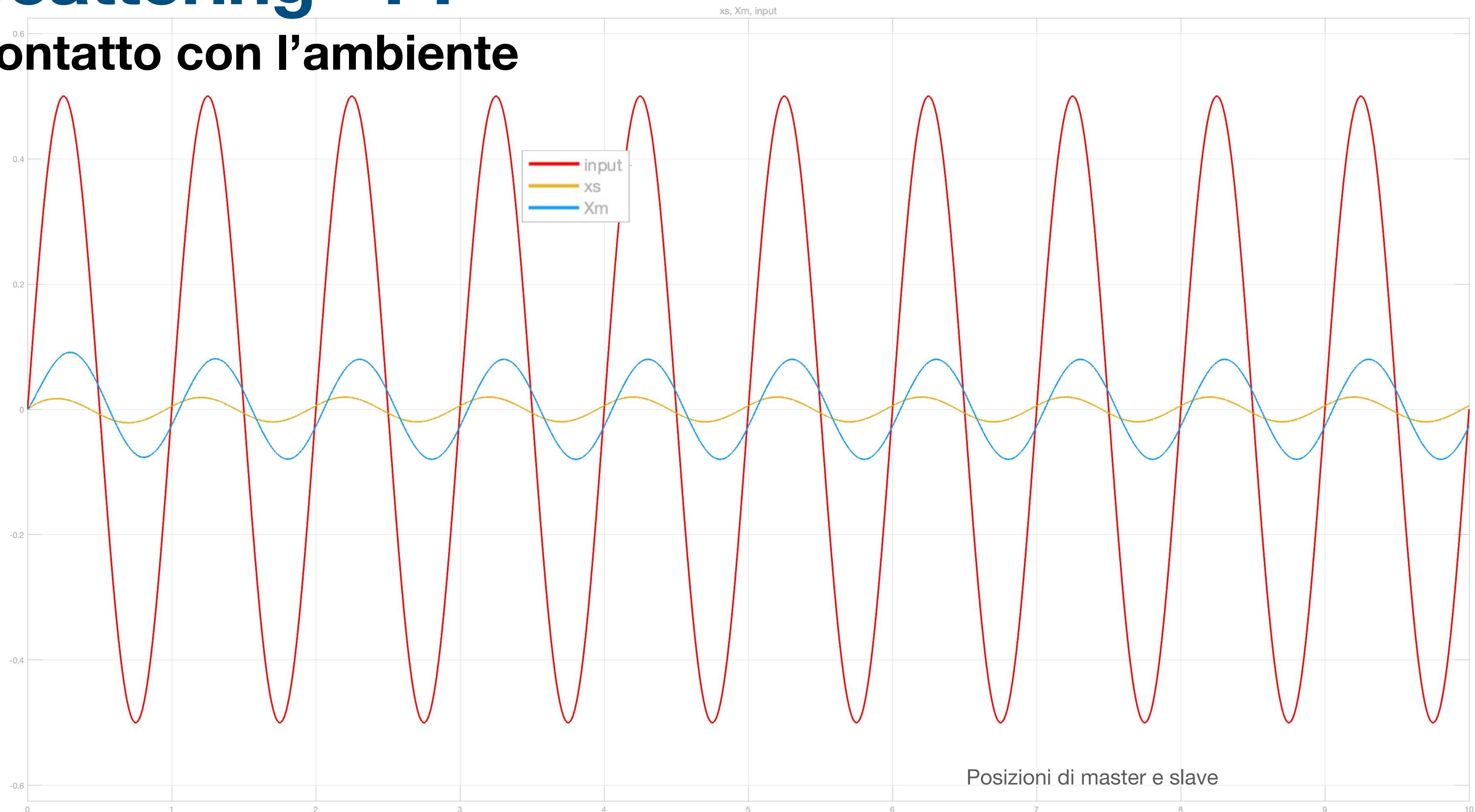
Scattering - PP

Free motion



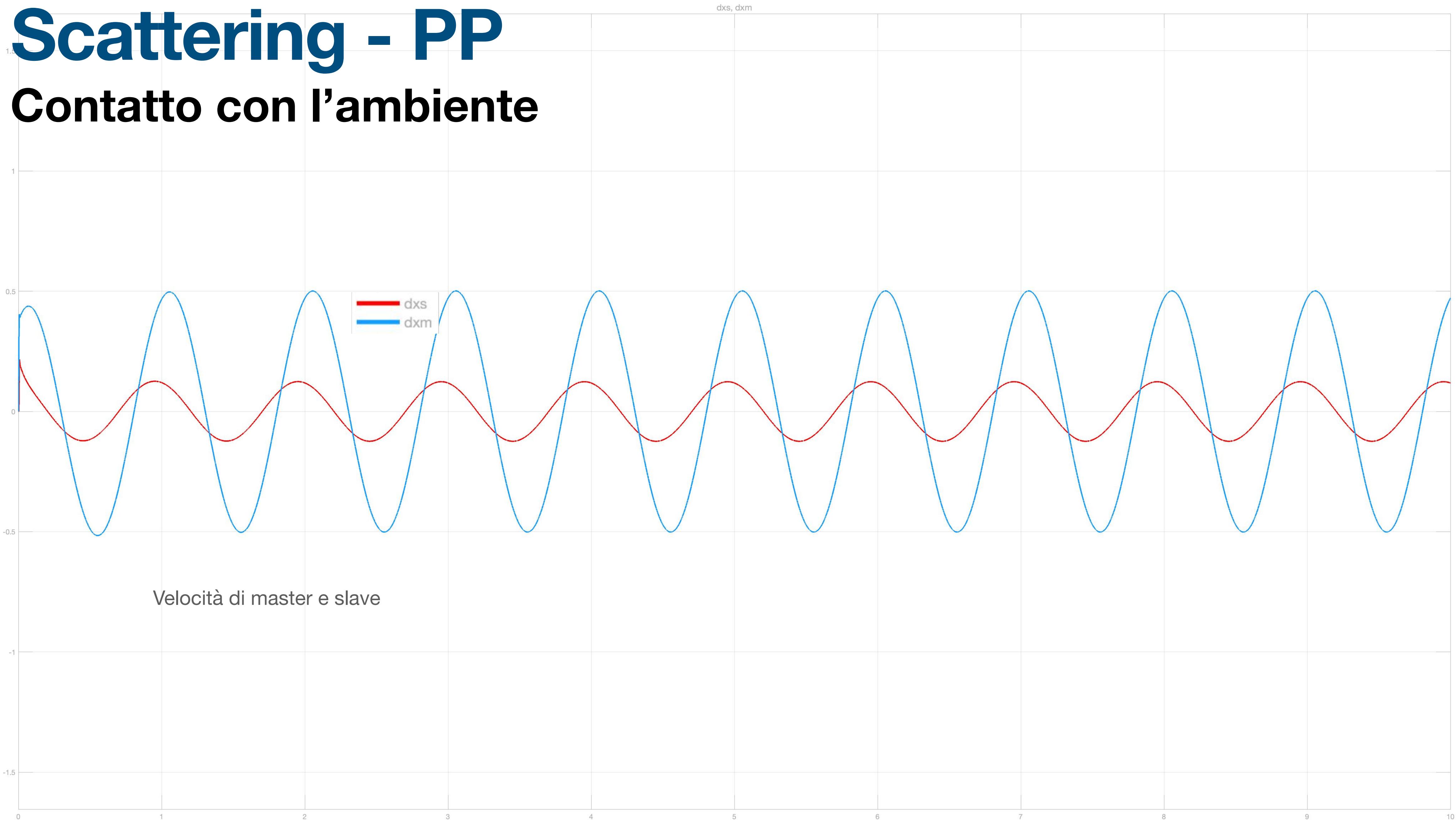
Scattering - PP

Contatto con l'ambiente



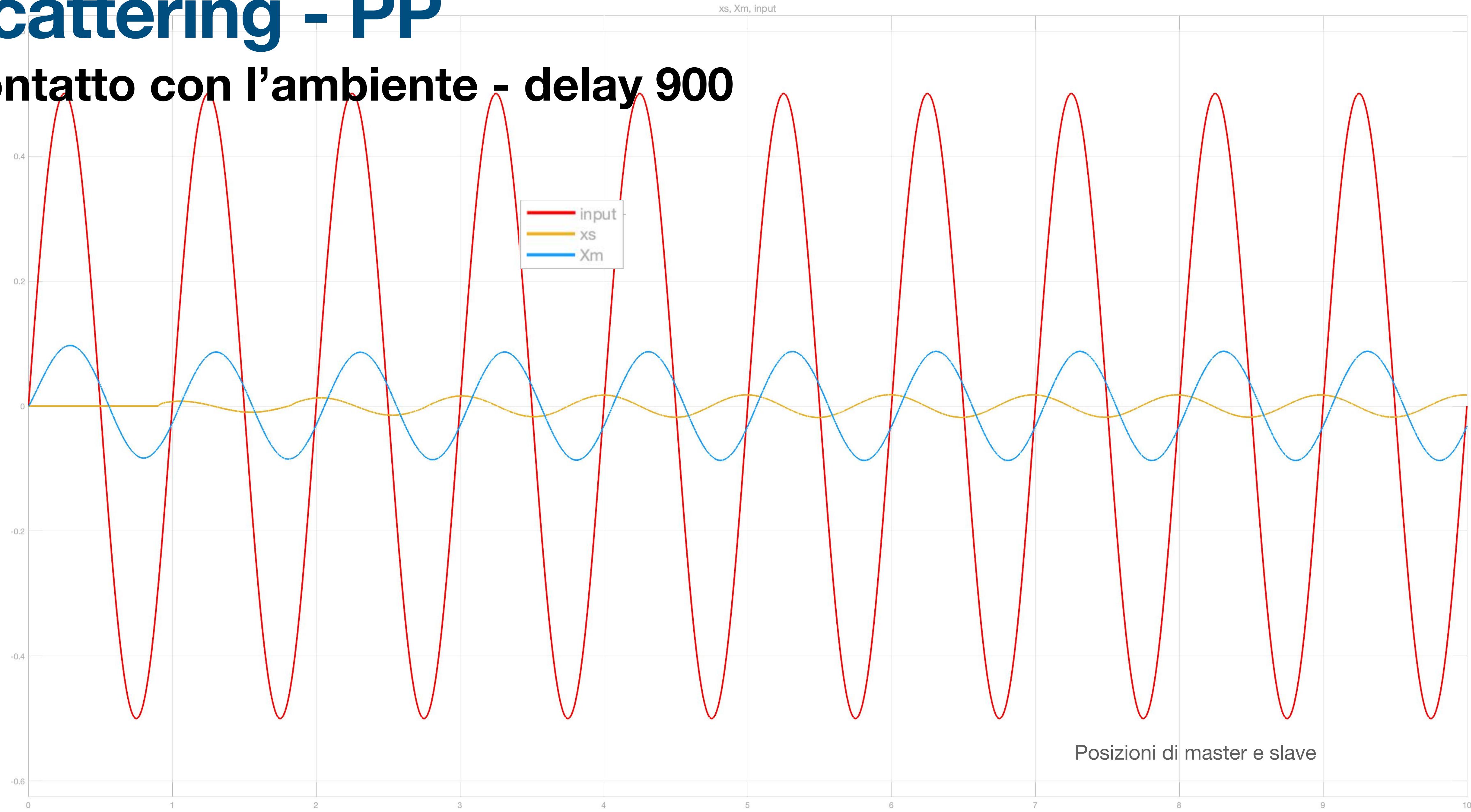
Scattering - PP

Contatto con l'ambiente



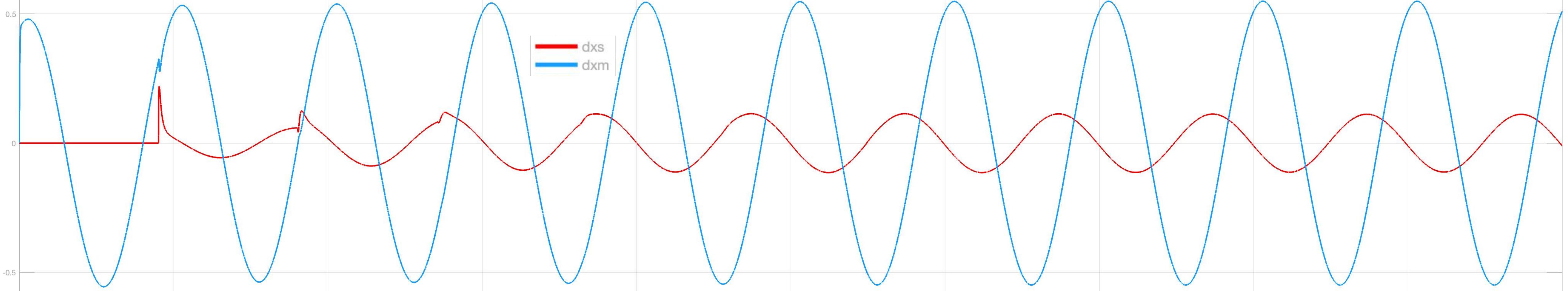
Scattering - PP

Contatto con l'ambiente - delay 900



Scattering - PP

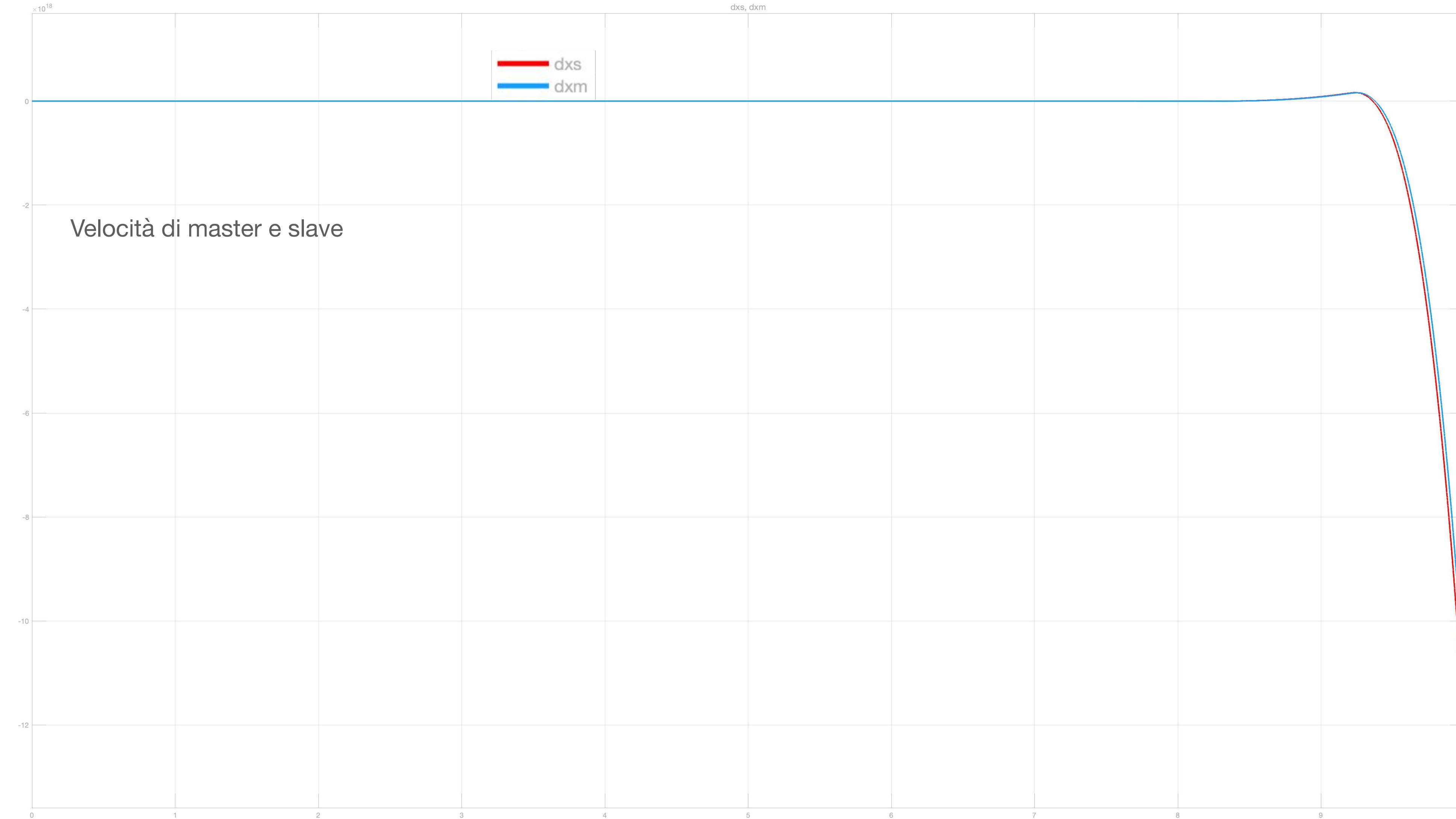
Contatto con l'ambiente - delay 900



Velocità di master e slave

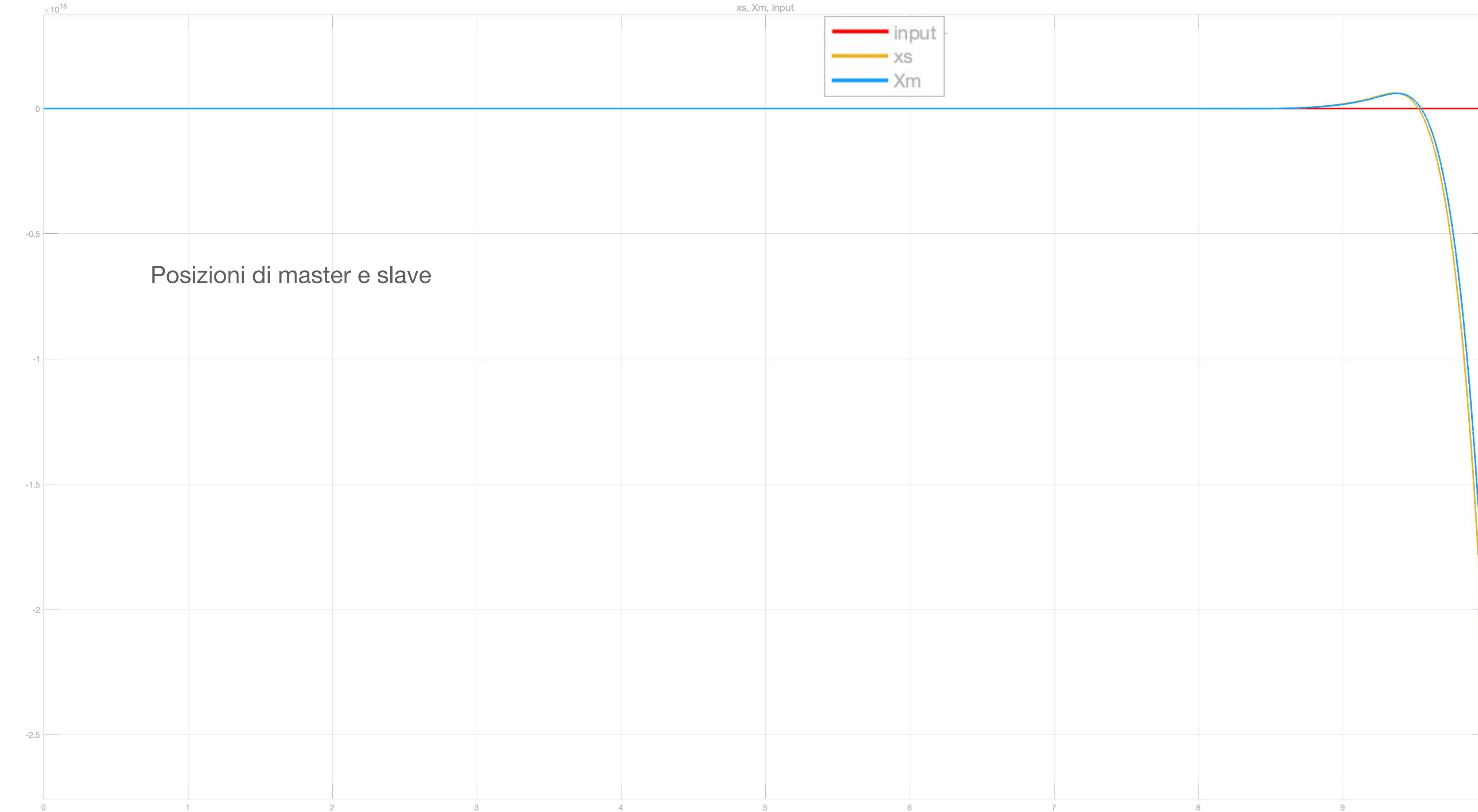
Scattering - PP

Contatto con l'ambiente - delay 900 no scattering



Scattering - PP

Contatto con l'ambiente - delay 900 no scattering



Franken et all architecture

Franken et all architecture

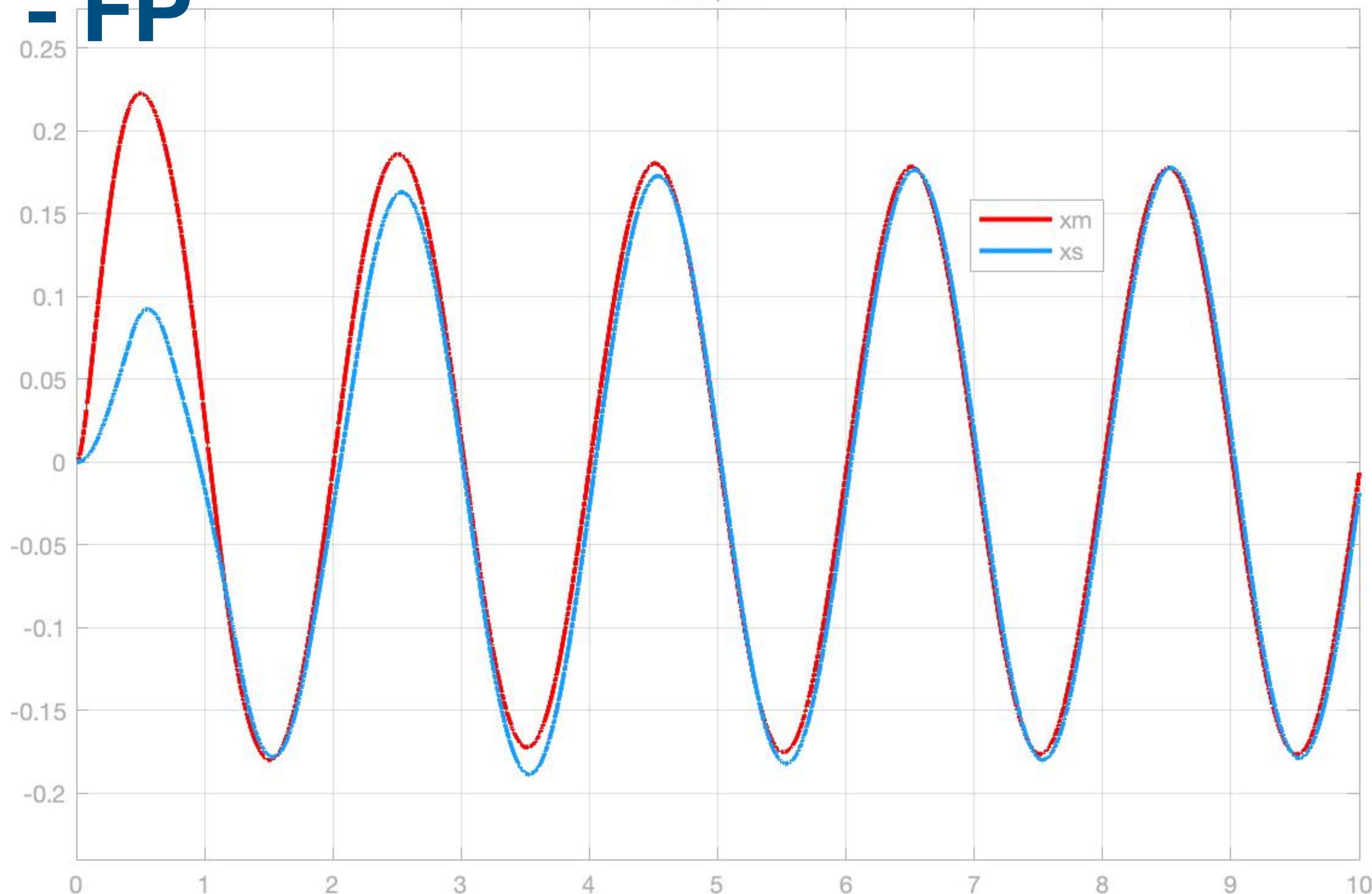
Descrizione

- È un architettura basata sulla passività, implementata attraverso tank di energia
- Sono presenti due layer, passivity layer e transparency layer
- L'azione dei controllori è limitata alla quantità di energia presente nei tank
- Inizialmente i tank sono vuoti, e raggiungono un livello stabile di energia nel tempo
- Per il solo tank master è presente un controller che attinge all'energia che viene generata dal comando dell'utente

Franken - FP

Free motion

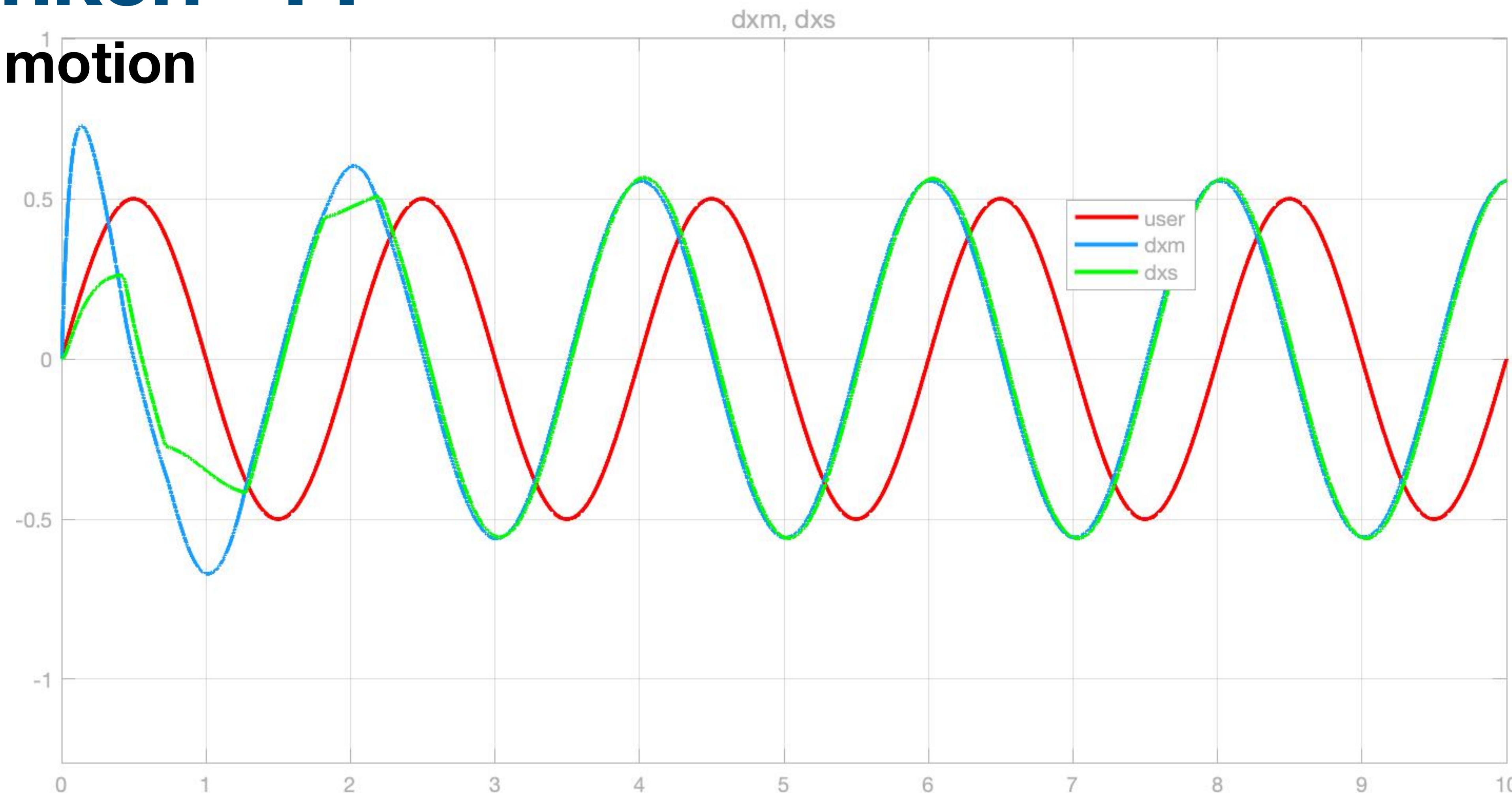
xm, xs



Posizioni di master e slave

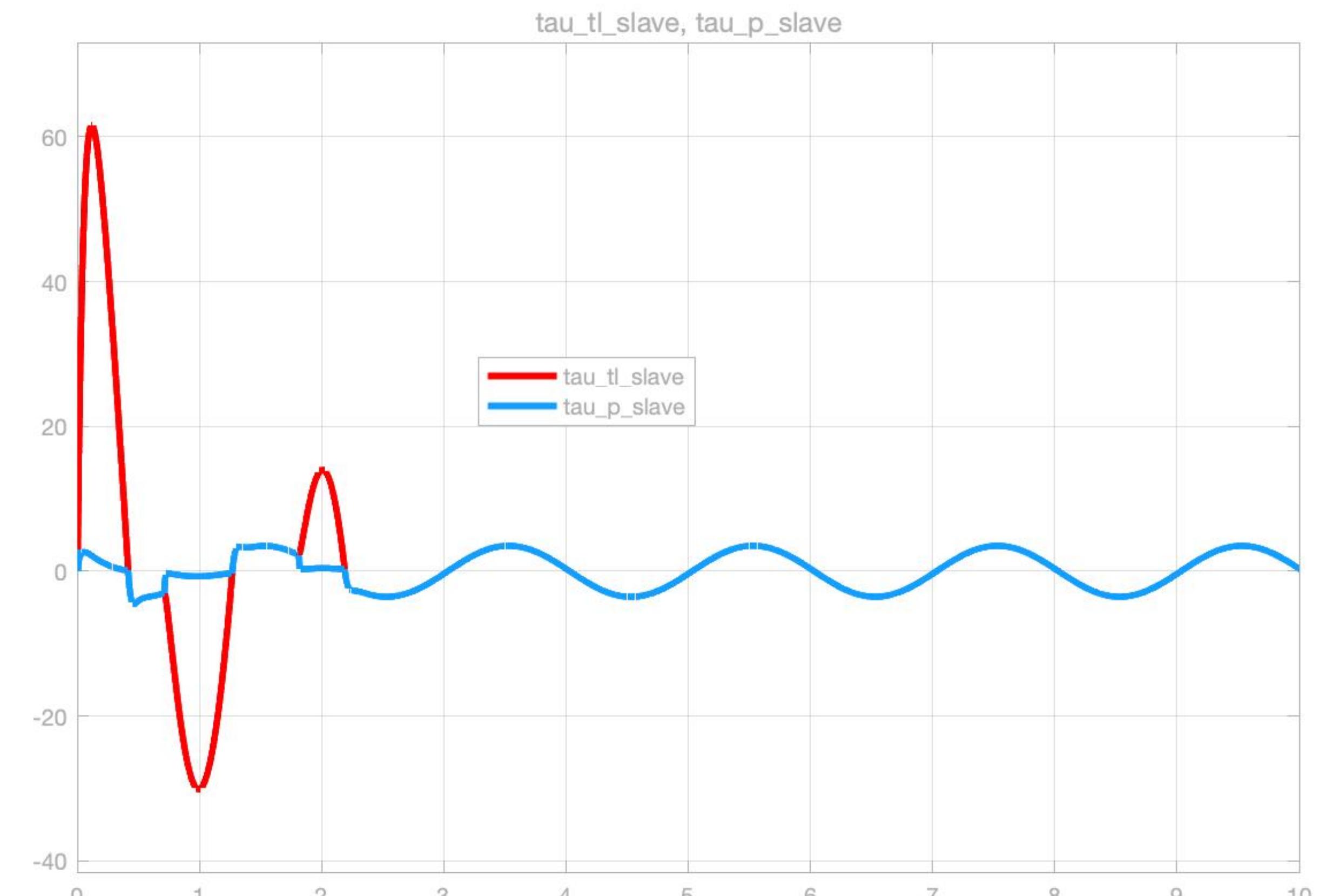
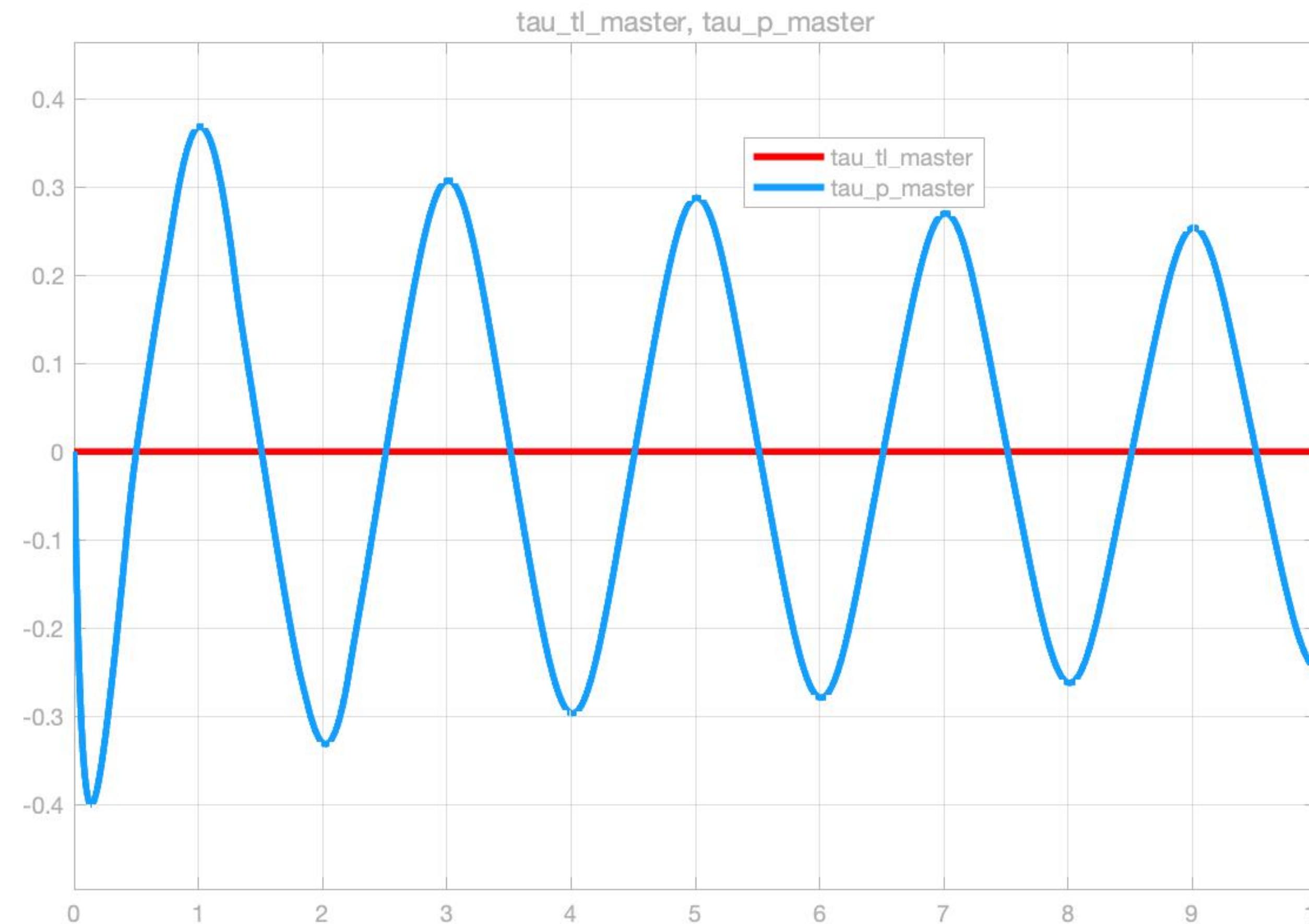
Franken - FP

Free motion



Franken - FP

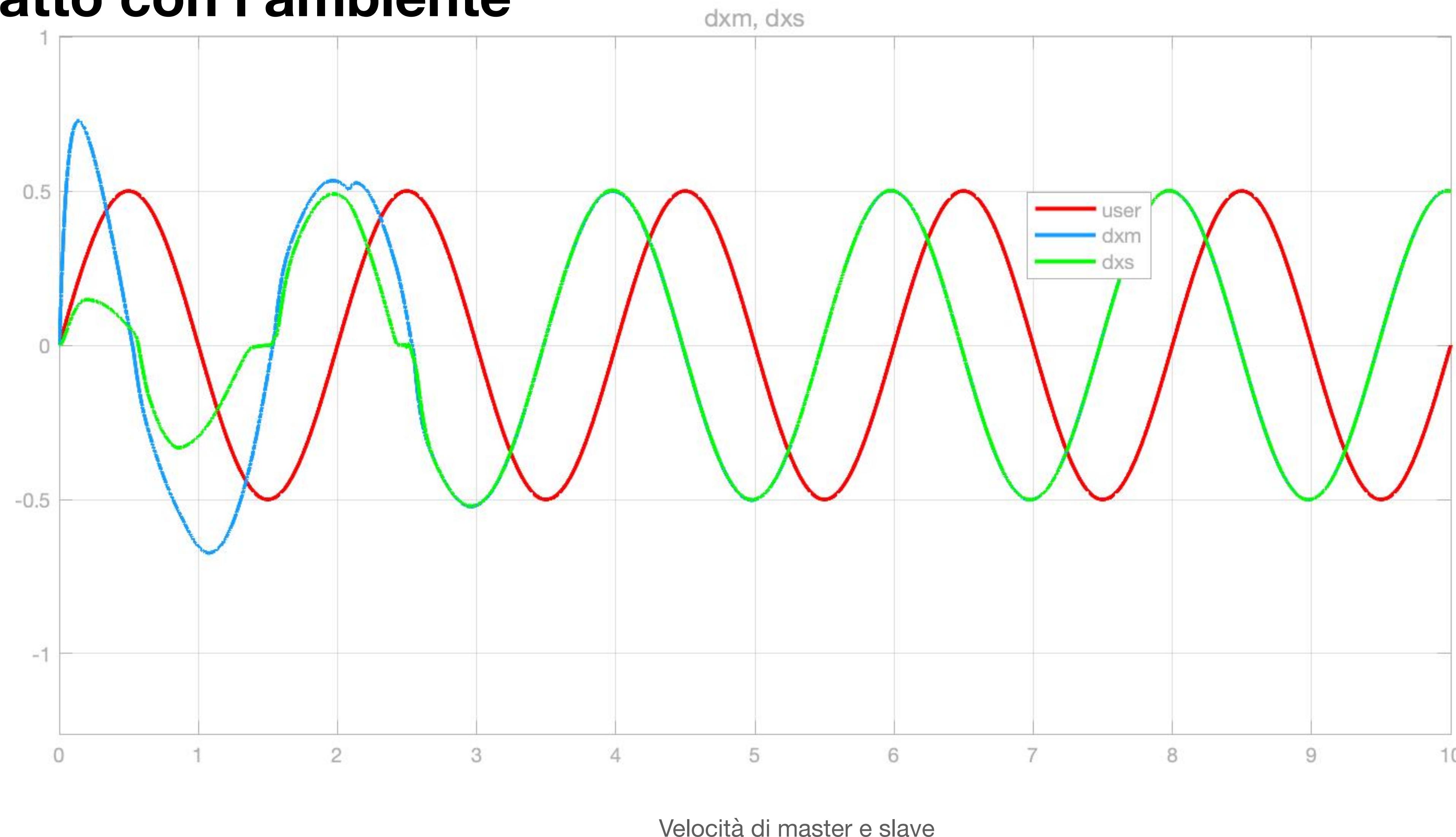
Free motion



Confronto tra tau richiesta (transparency layer) e tau inviata (passivity layer)

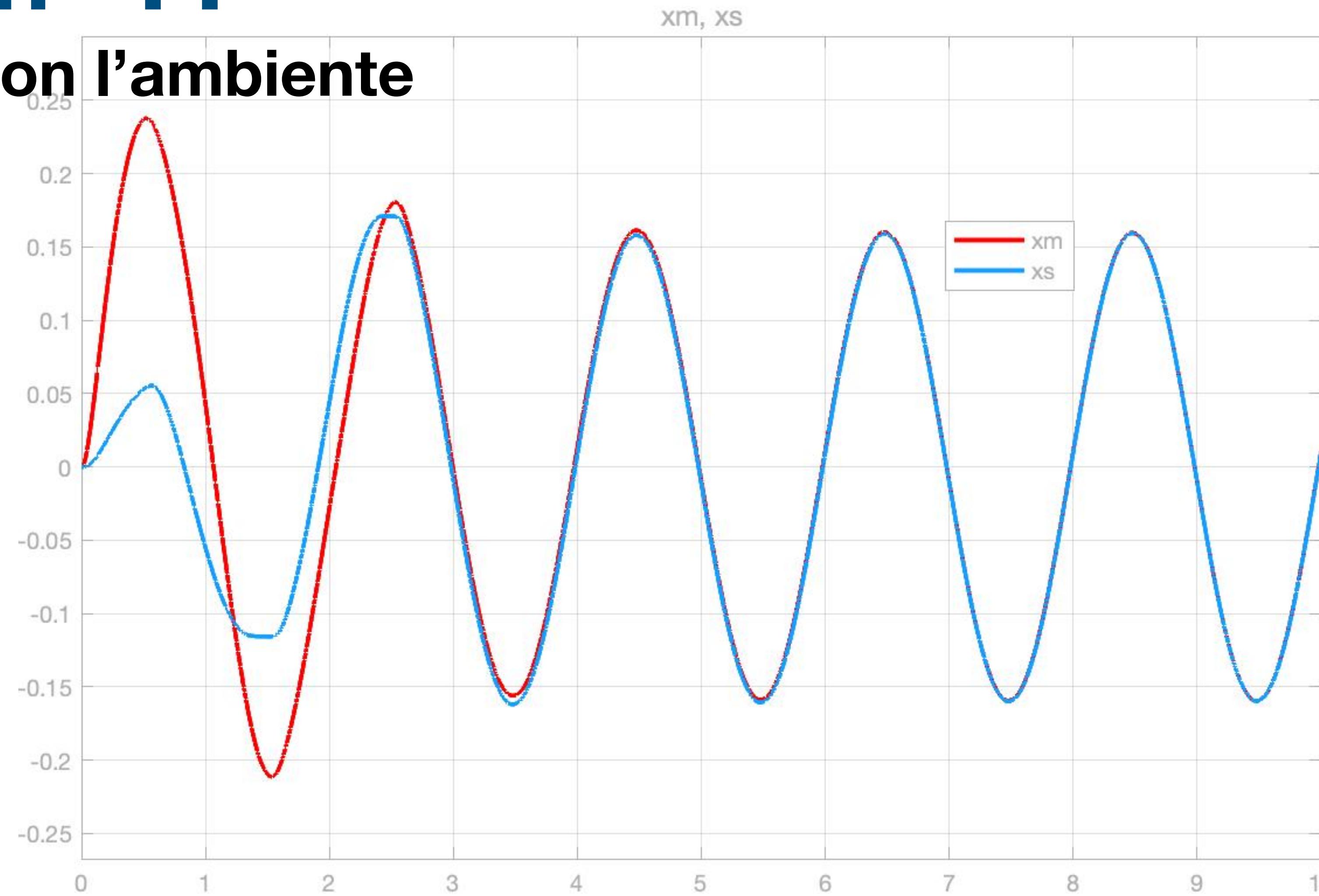
Franken - FP

Contatto con l'ambiente



Franken - FP

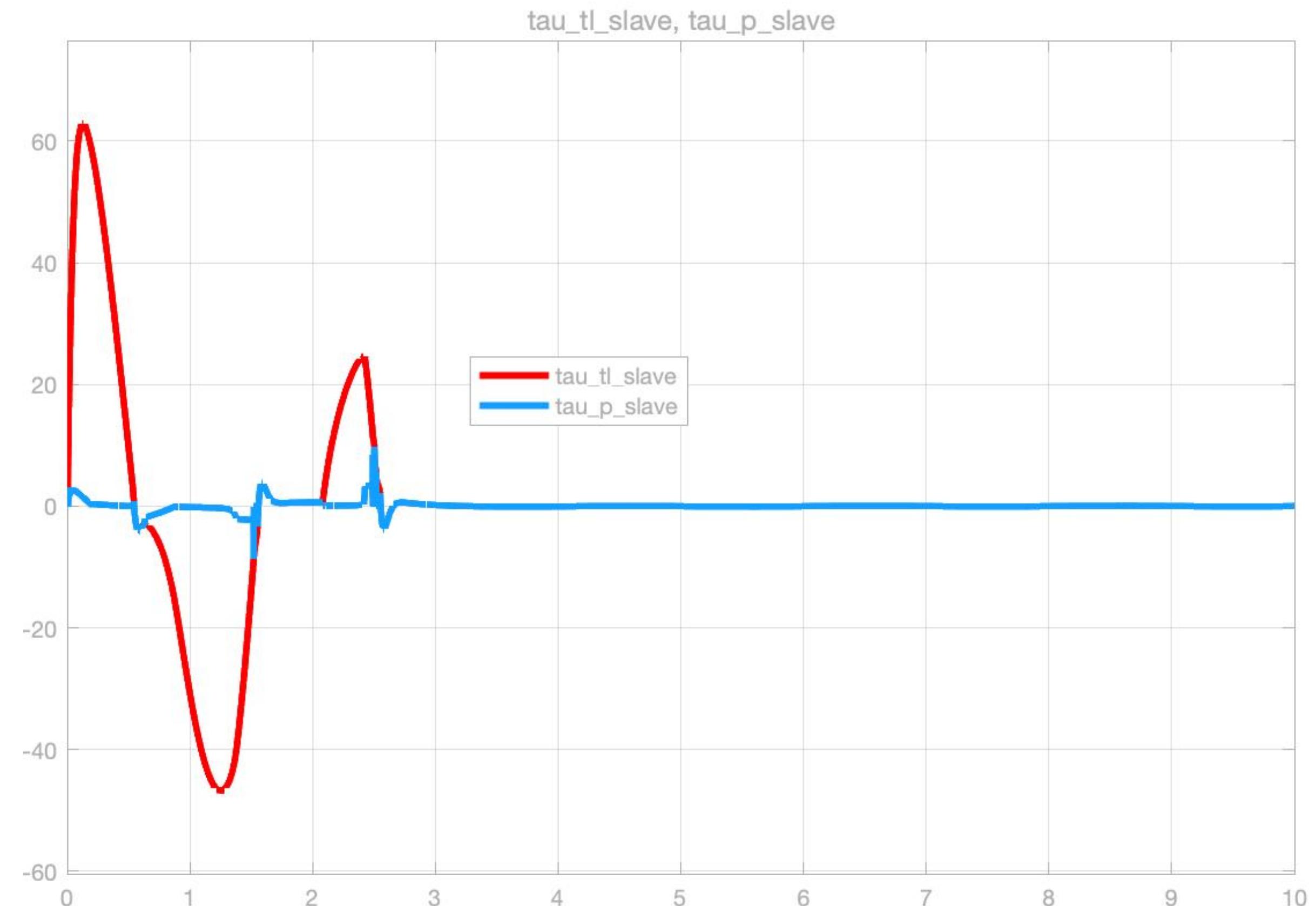
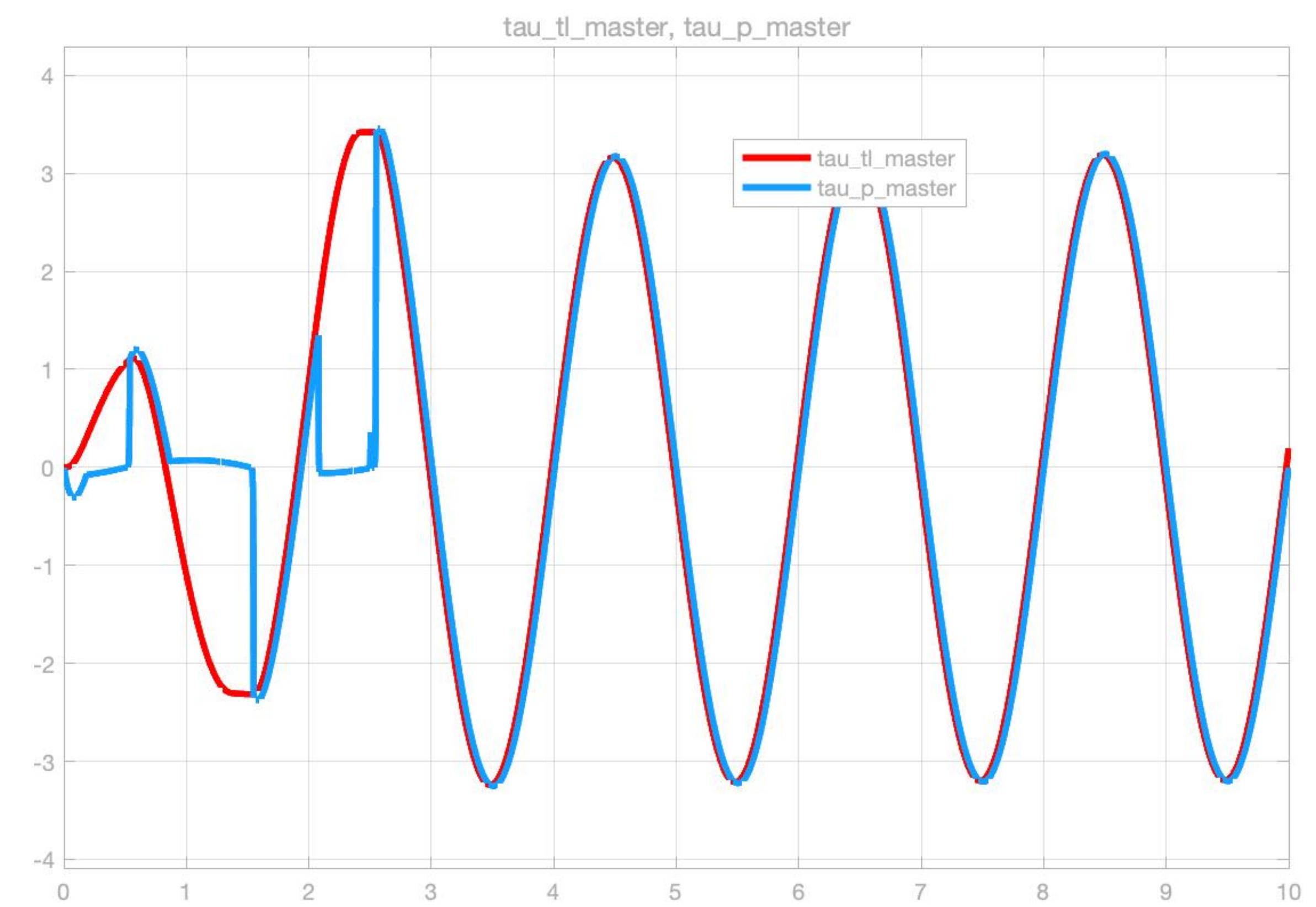
Contatto con l'ambiente



Posizioni di master e slave

Franken - FP

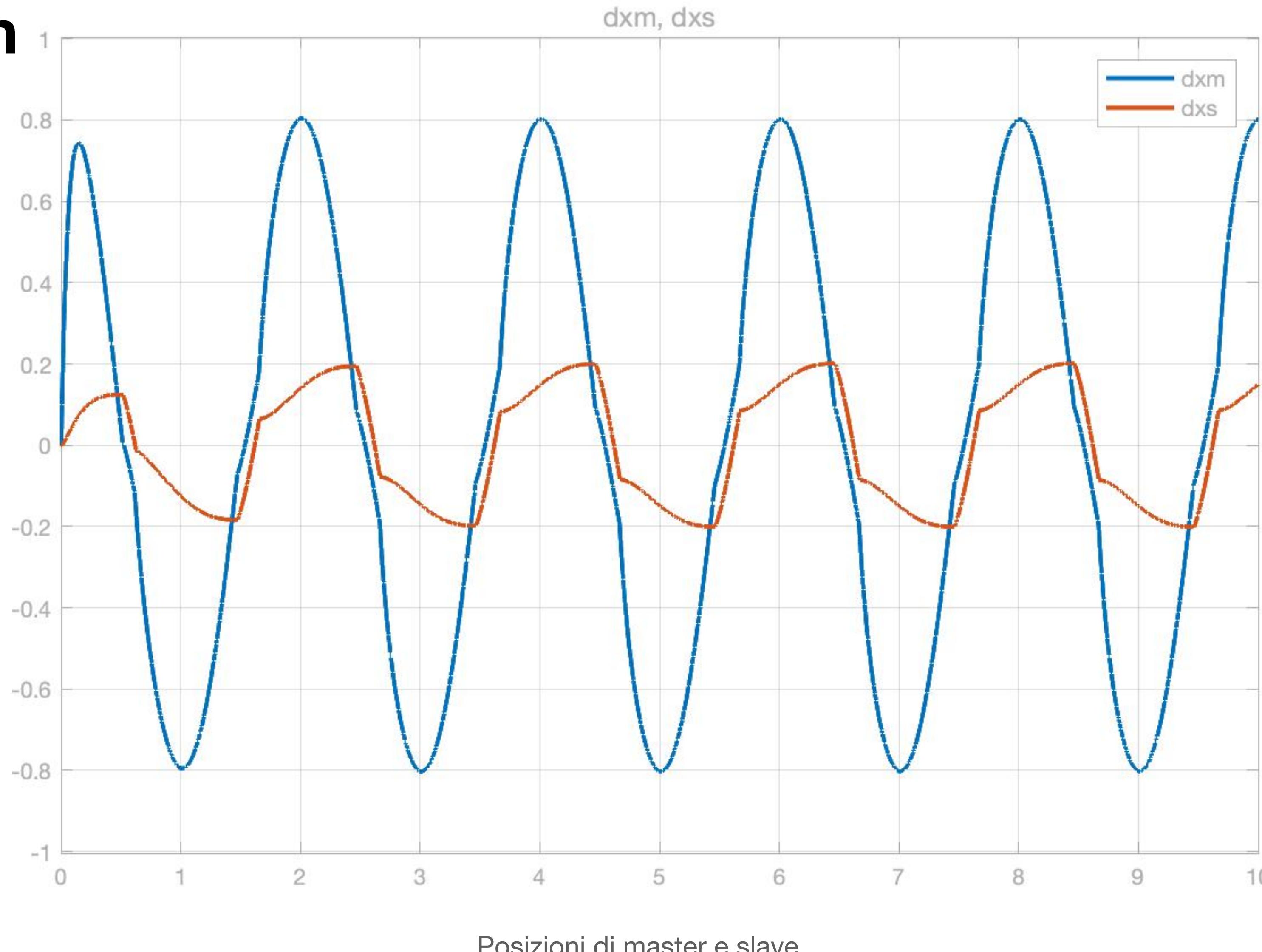
Contatto con l'ambiente



Confronto tra tau richiesta (transparency layer) e tau inviata (passivity layer)

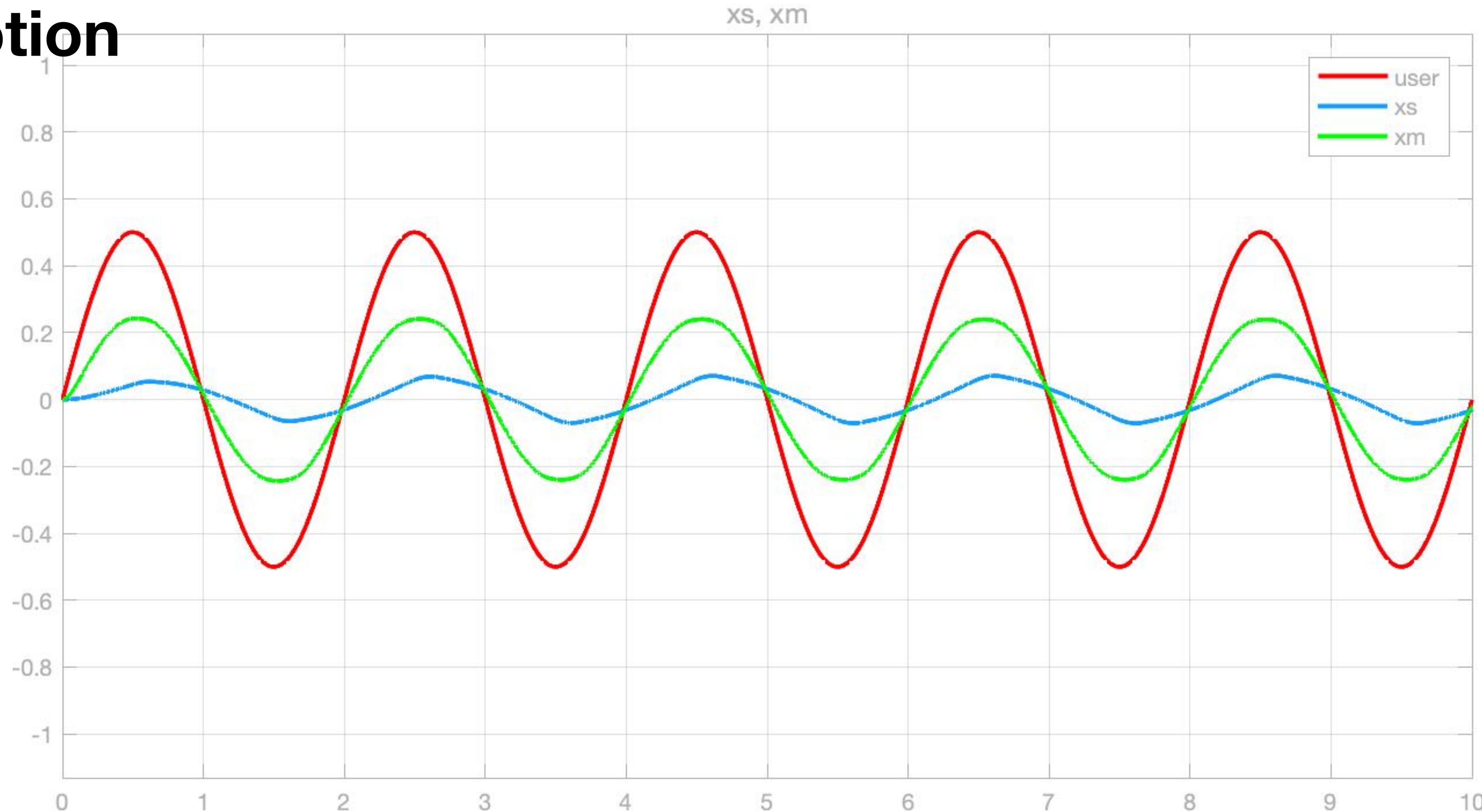
Franken - PP

Free motion



Franken - PP

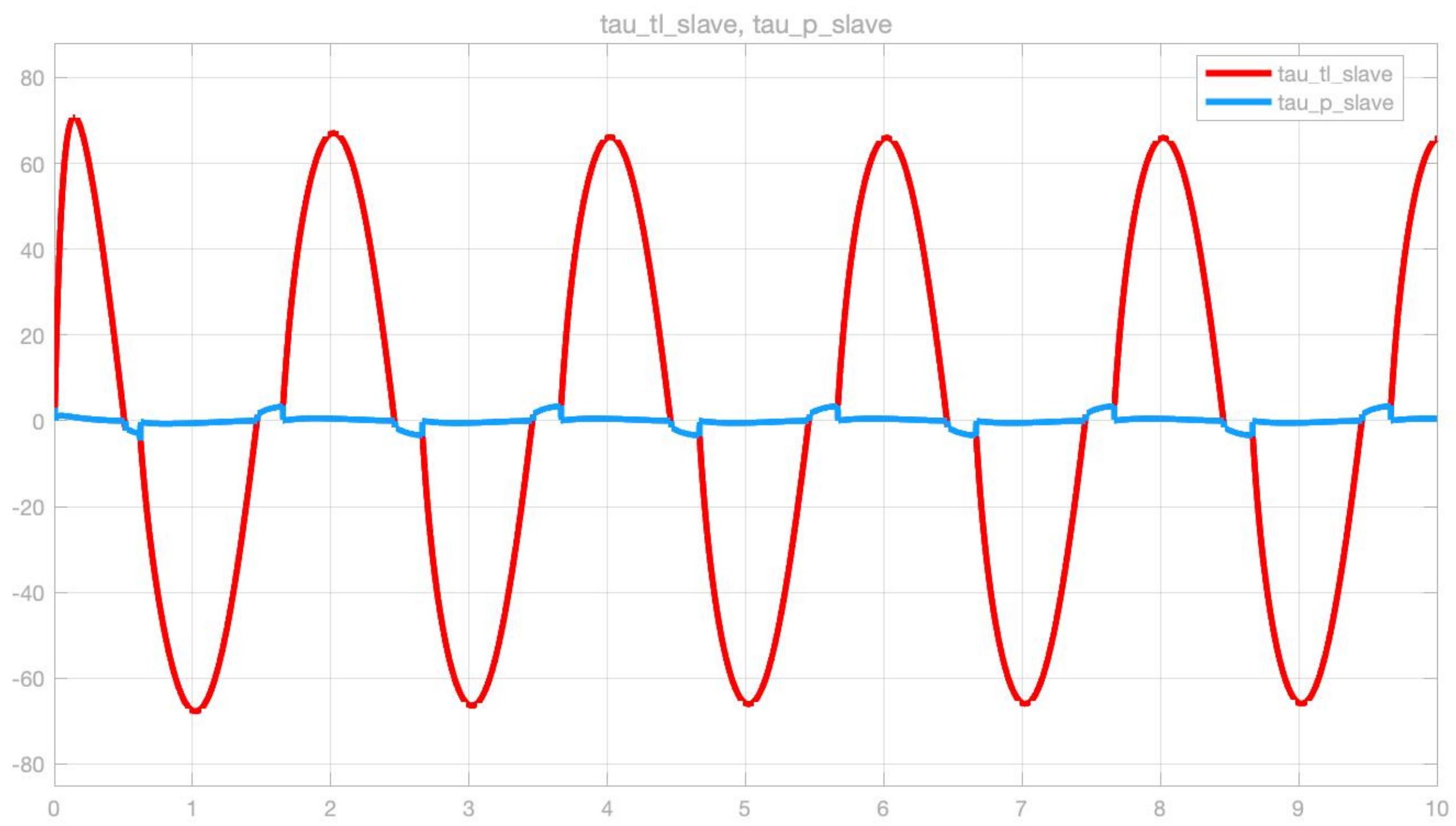
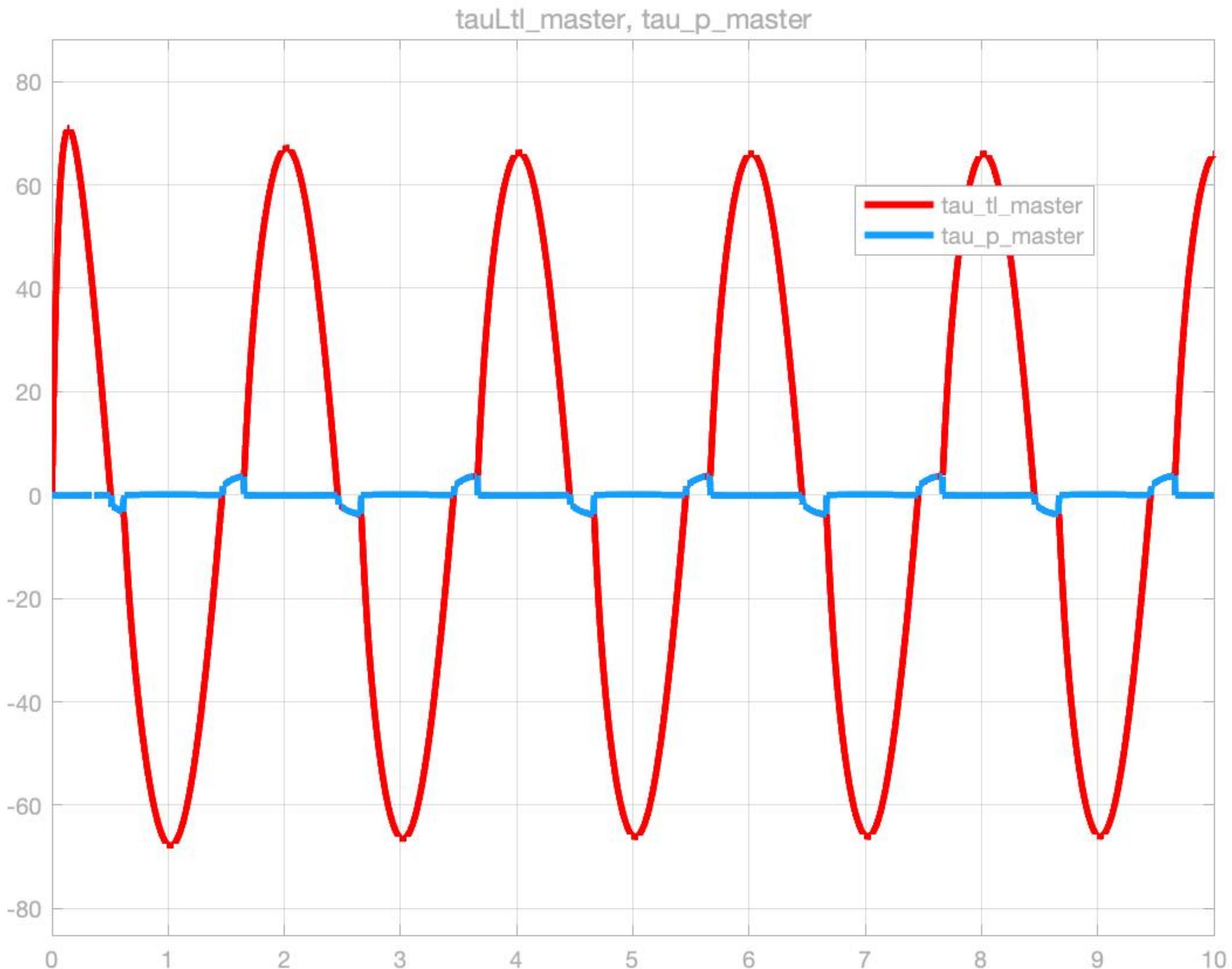
Free motion



Velocità di master e slave

Franken - PP

Free motion

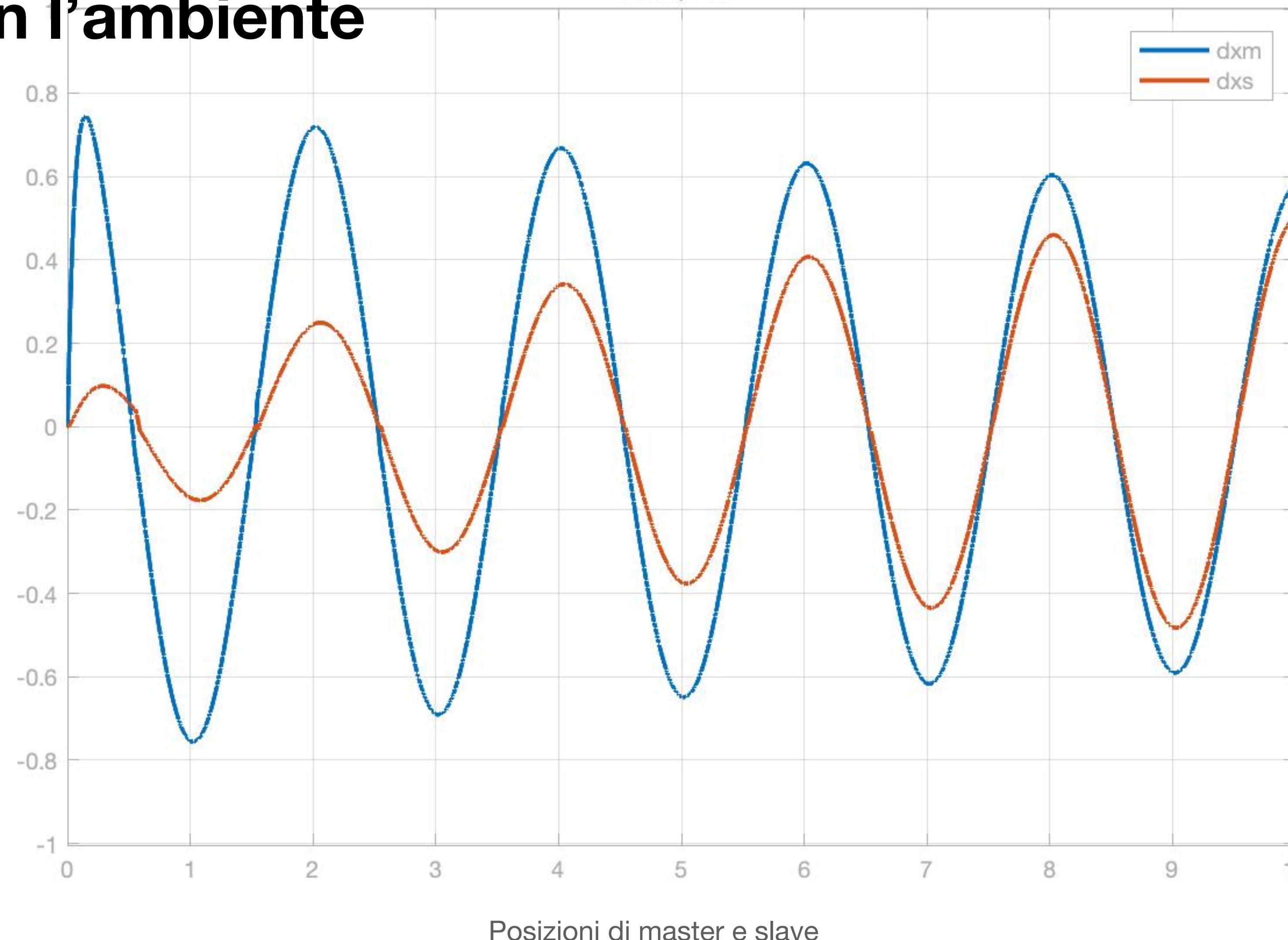


Confronto tra tau richiesta (transparency layer) e tau inviata (passivity layer)

Franken - PP

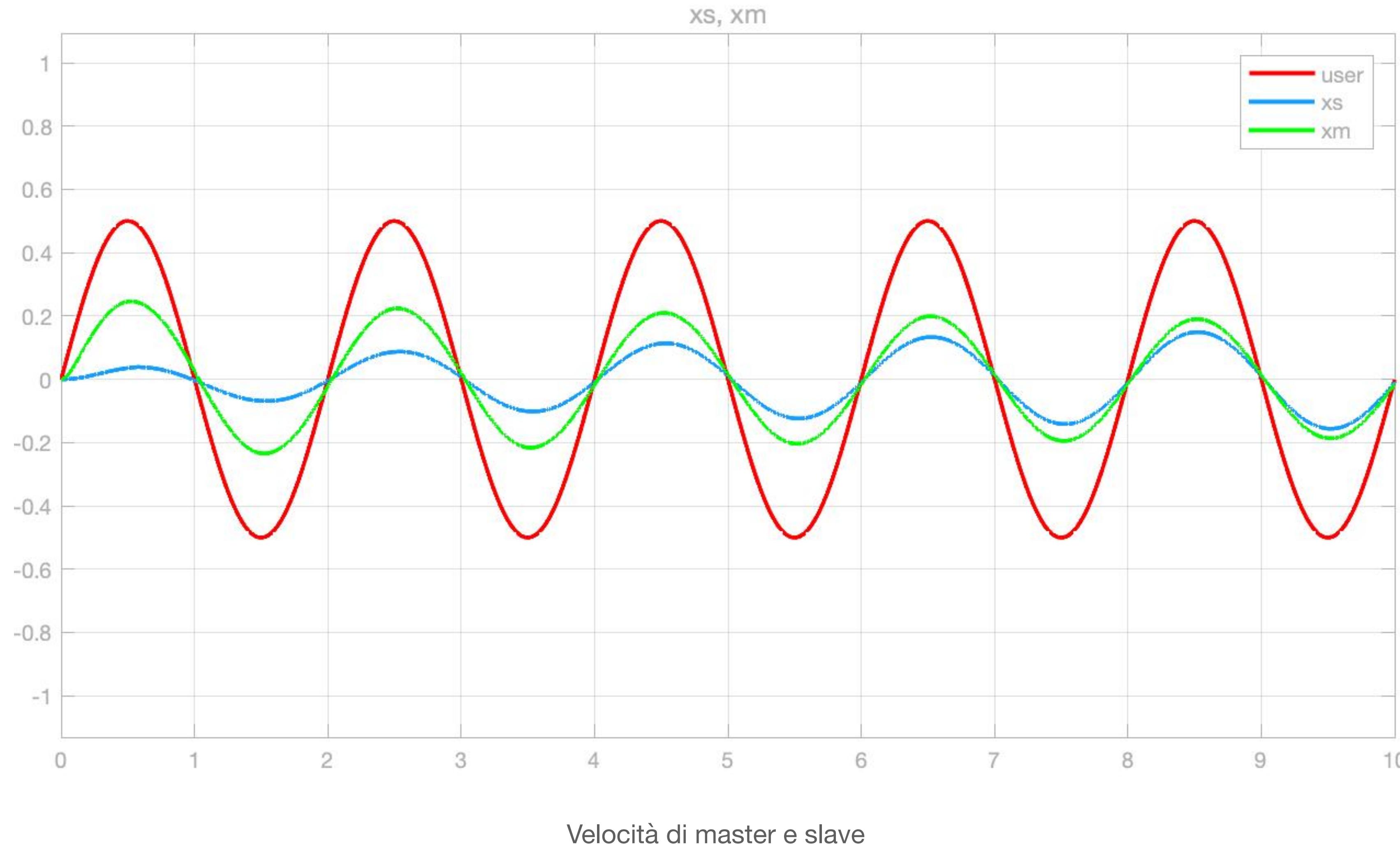
Contatto con l'ambiente

dxm, dxs



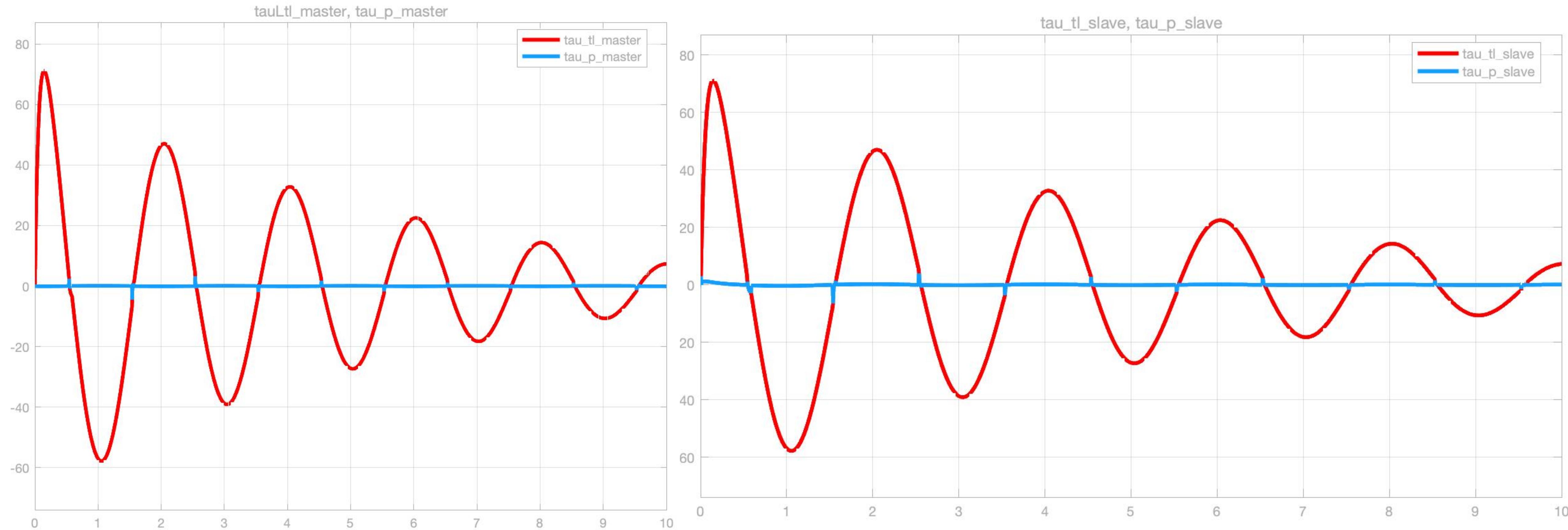
Franken - PP

Contatto con l'ambiente



Franken - PP

Contatto con l'ambiente



Confronto tra tau richiesta (transparency layer) e tau inviata (passivity layer)