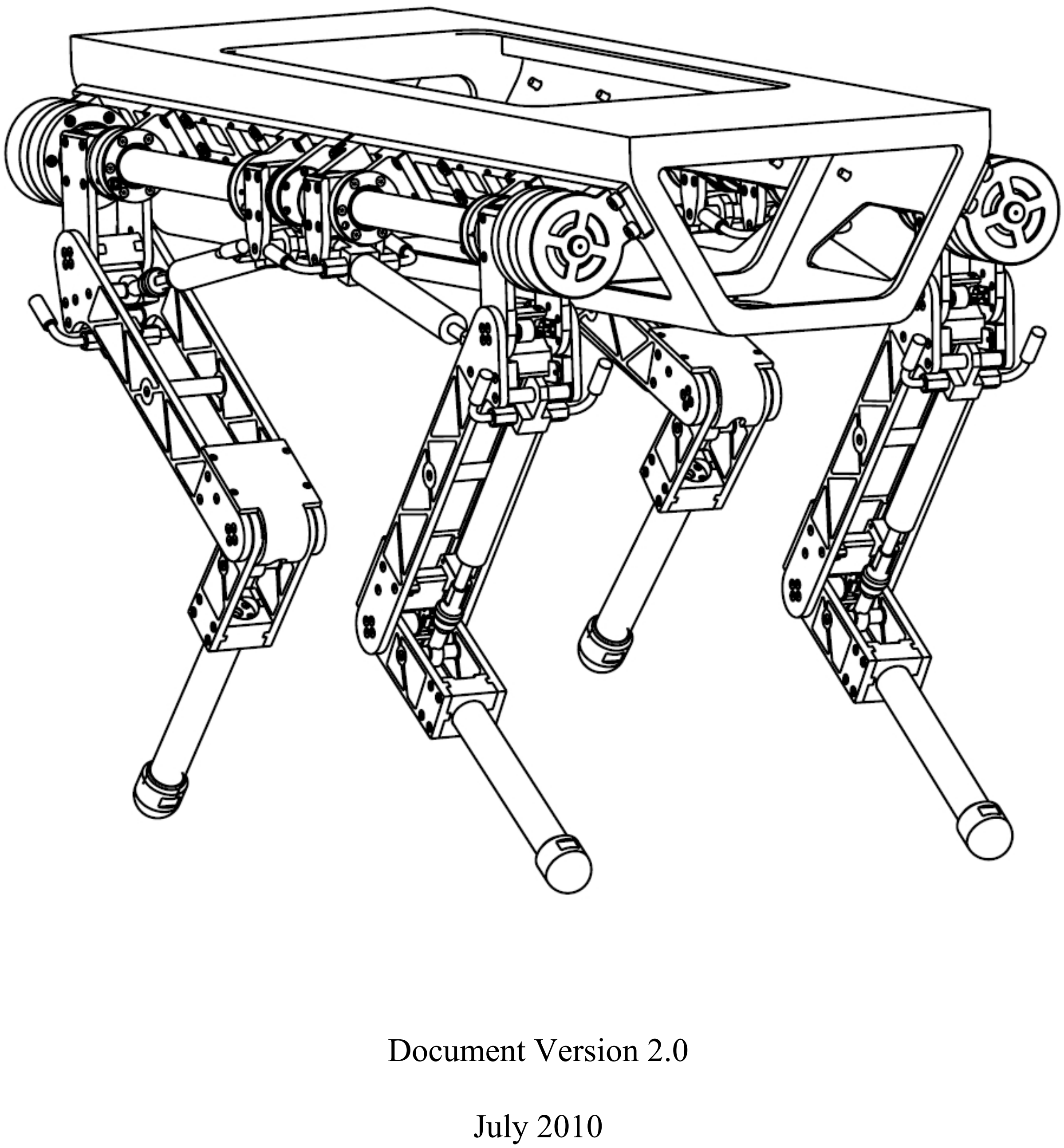
HyQ-Robot:
Standard Definition for Joint Angles and Kinematic Parameters of the Legs and Torso



Document Version 2.0

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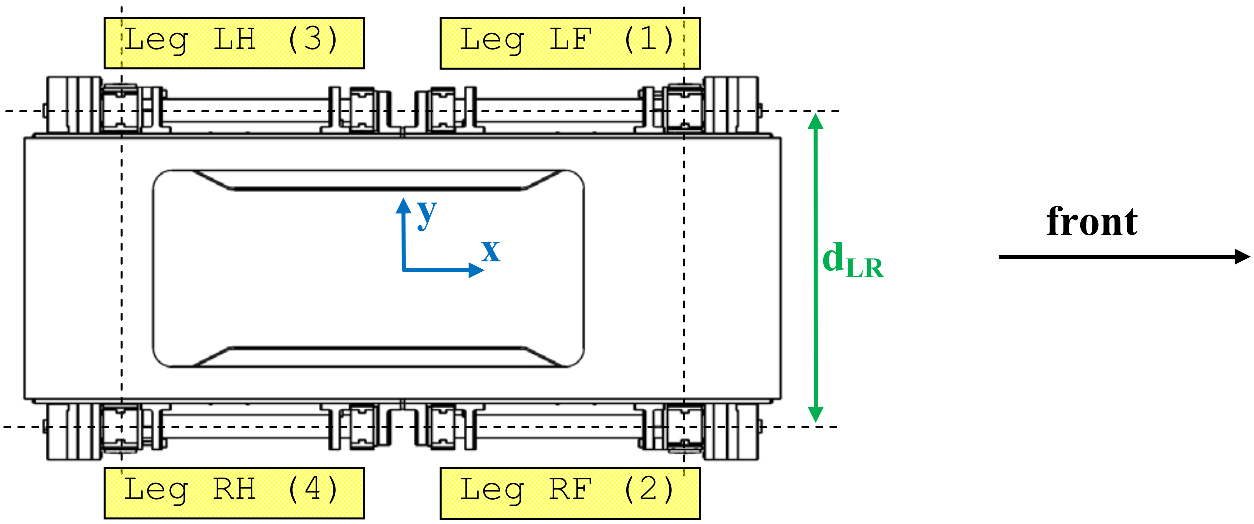
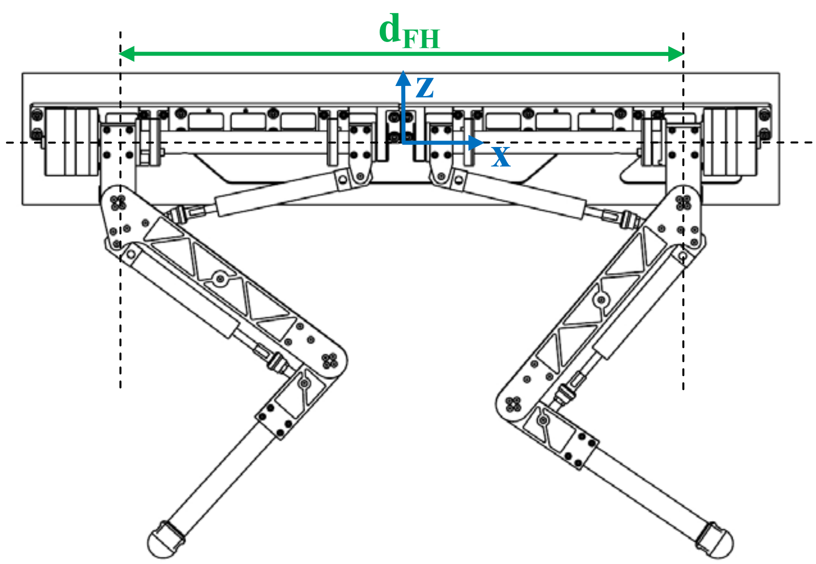
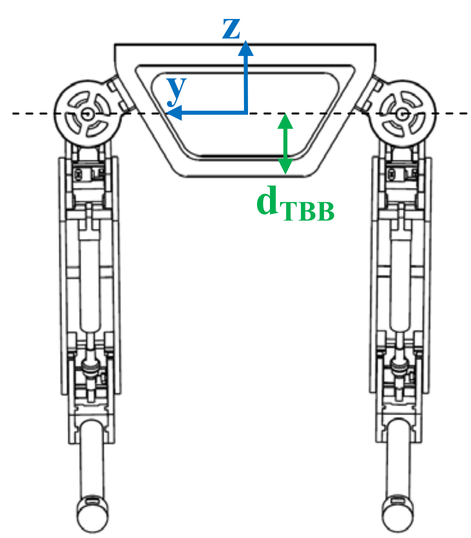
Leg Nomenclature, Location on Torso and Robot Base Coordinate Frame

top view







side view

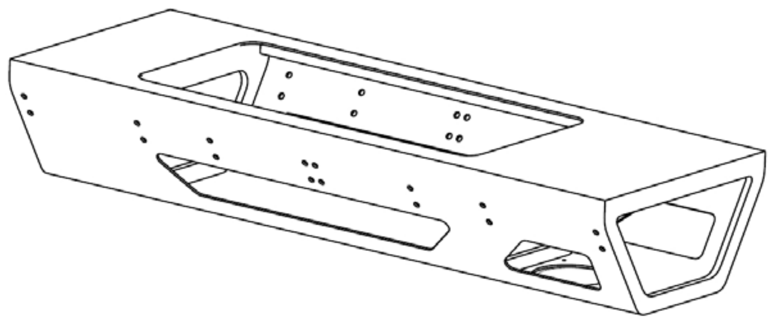
back view

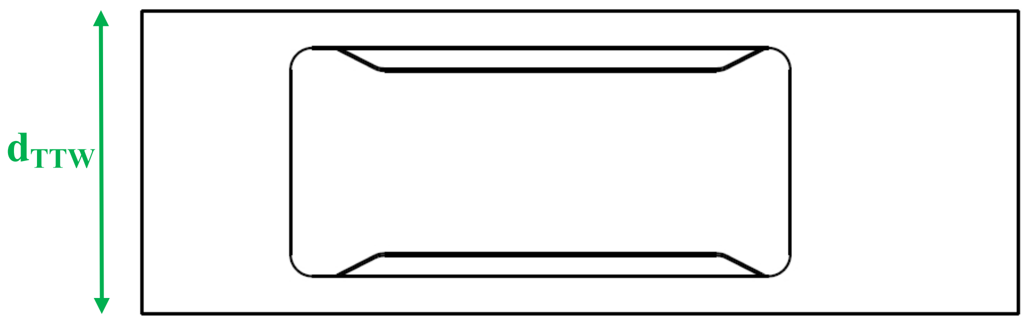
d_{LR} = 0.414 m (left to right)
d_{FH} = 0.747 m (front to hind) Located at or forming the back or rear
d_{TBB} = 0.082 m (torso bottom to base coordinate frame)

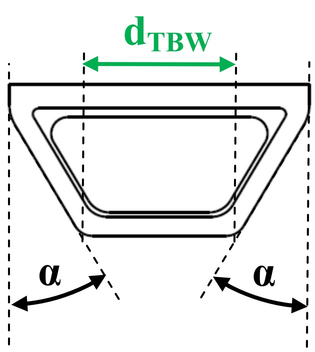
Leg 1: Left Front (LF)
Leg 2: Right Front (RF)
Leg 3: Left Hind (LH)
Leg 4: Right Hind (RH)

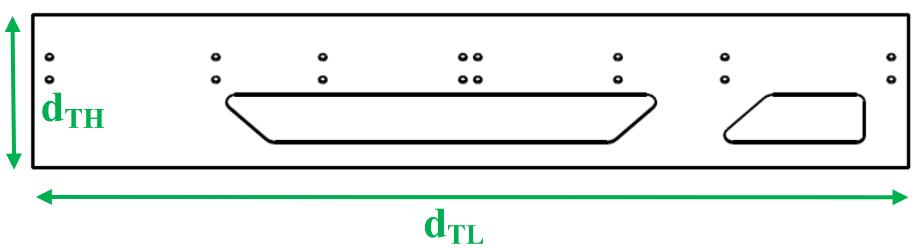
Definition of *hind*:
located at or forming the back or rear
e.g. an animal's hind legs

Dimensions/Mass of Robot Torso



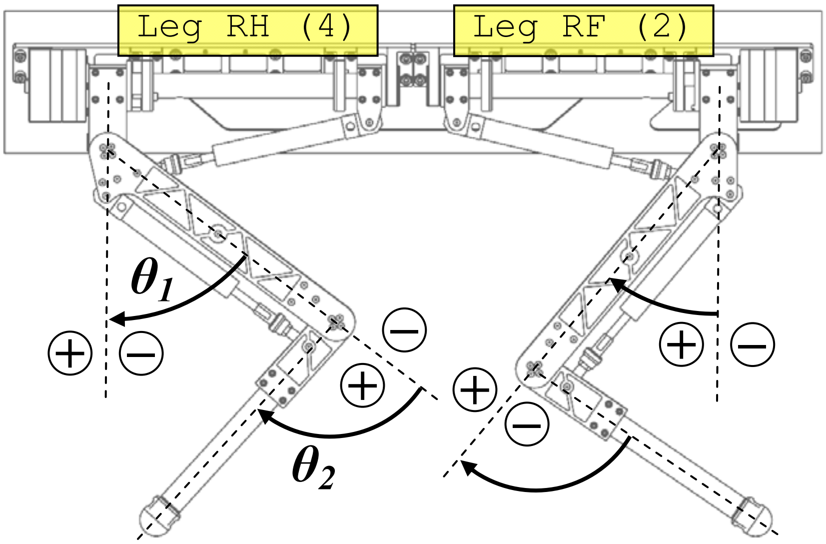






d_{TL} = 1.0 m (torso length)
d_{TH} = 0.17 m (torso height)
d_{TTW} = 0.34 m (torso top width)
d_{TBW} = 0.18 m (torso bottom width)
α = 30°
m_{TORSO} = 10.0 kg

Definition of Joint Angles and Range of Motion

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Leg RH (4):
θ1 = [-70deg .. +50deg]
θ2 = [+20deg .. +140deg]

Leg RF (2):
θ1 = [-50deg .. +70deg]
θ2 = [-140deg .. -20deg]
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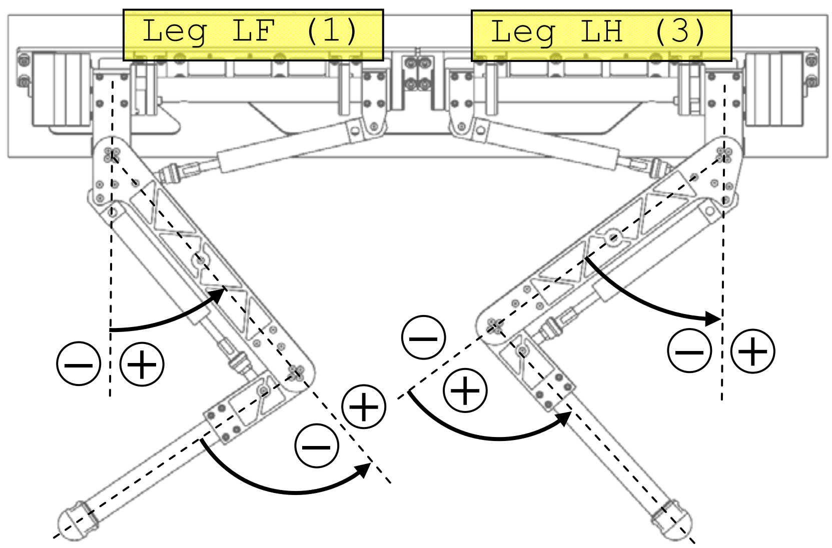


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Leg LF (1):
θ1 = [-50deg .. +70deg]
θ2 = [-140deg .. -20deg]

Leg LH (3):
θ1 = [-70deg .. +50deg]
θ2 = [+20deg .. +140deg]
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all legs:
θ0 = [-90deg .. +30deg]
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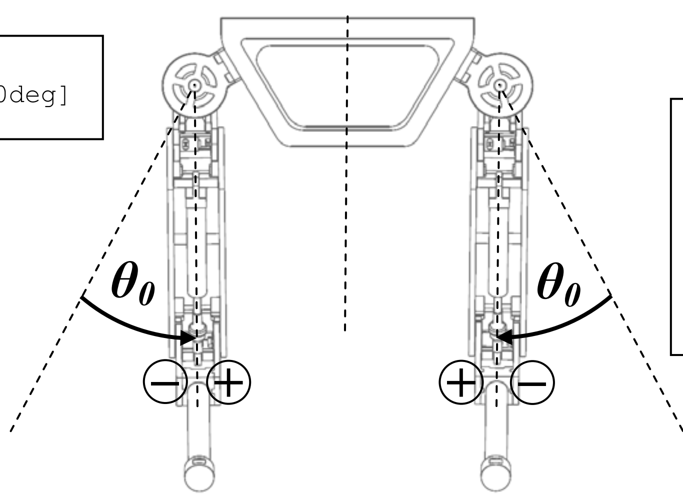
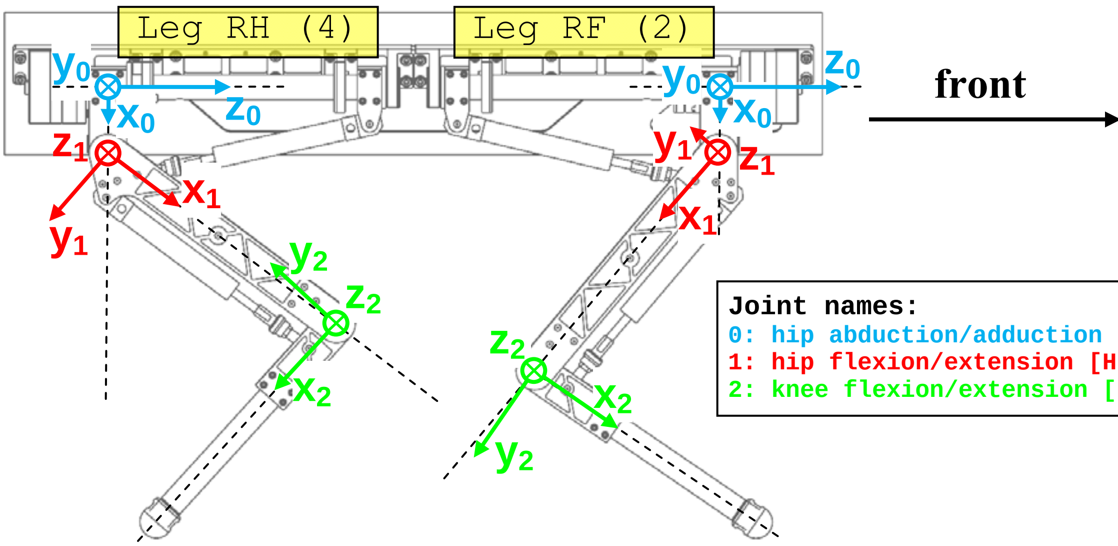


Example
The shown posture has the following angles:
(with $\theta=[\theta_0,\theta_1,\theta_2]$)

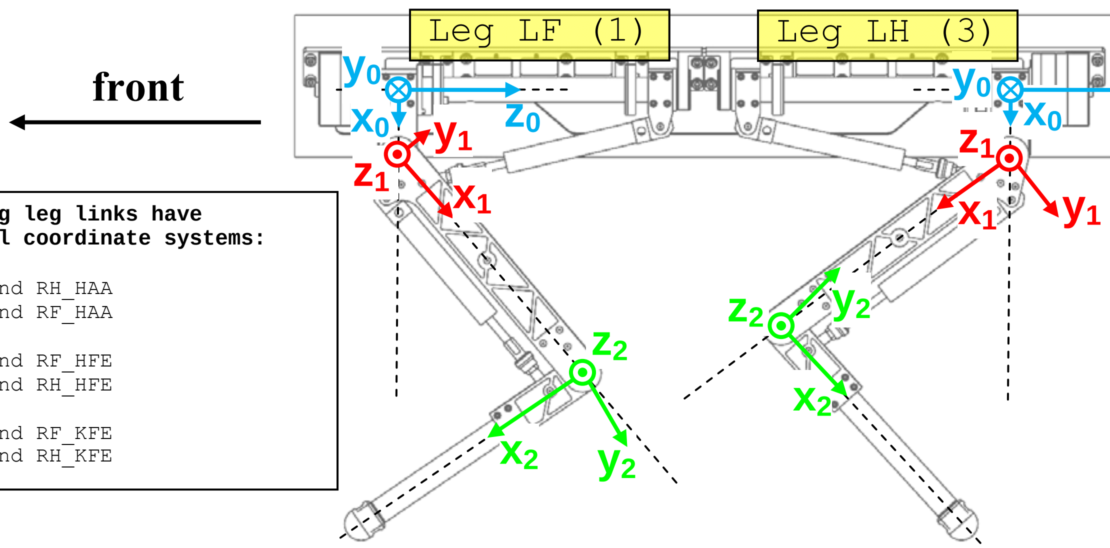
Leg LF: $\theta=[0, 40deg, -96deg]$
Leg RF: $\theta=[0, 40deg, -96deg]$
Leg LH: $\theta=[0, -53deg, 95deg]$
Leg RH: $\theta=[0, -53deg, 95deg]$

All angles are mirrored in the plane that splits the robot into an identical left and right half (sagittal plane). Therefore, both front legs (LF,RF) and both hind legs (LH,RH) have the same range of motion and definition of angles.

Definition of Link Coordinate Systems and Joint Names



Joint names:
0: hip abduction/adduction [HAA]
1: hip flexion/extension [HFE]
2: knee flexion/extension [KFE]

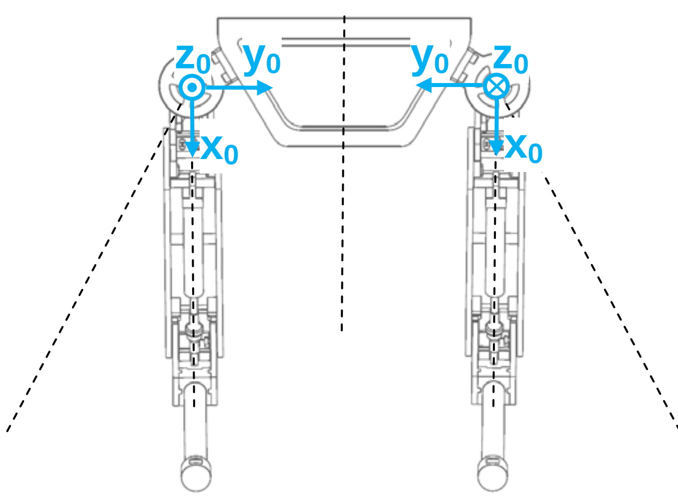


Following leg links have identical coordinate systems:

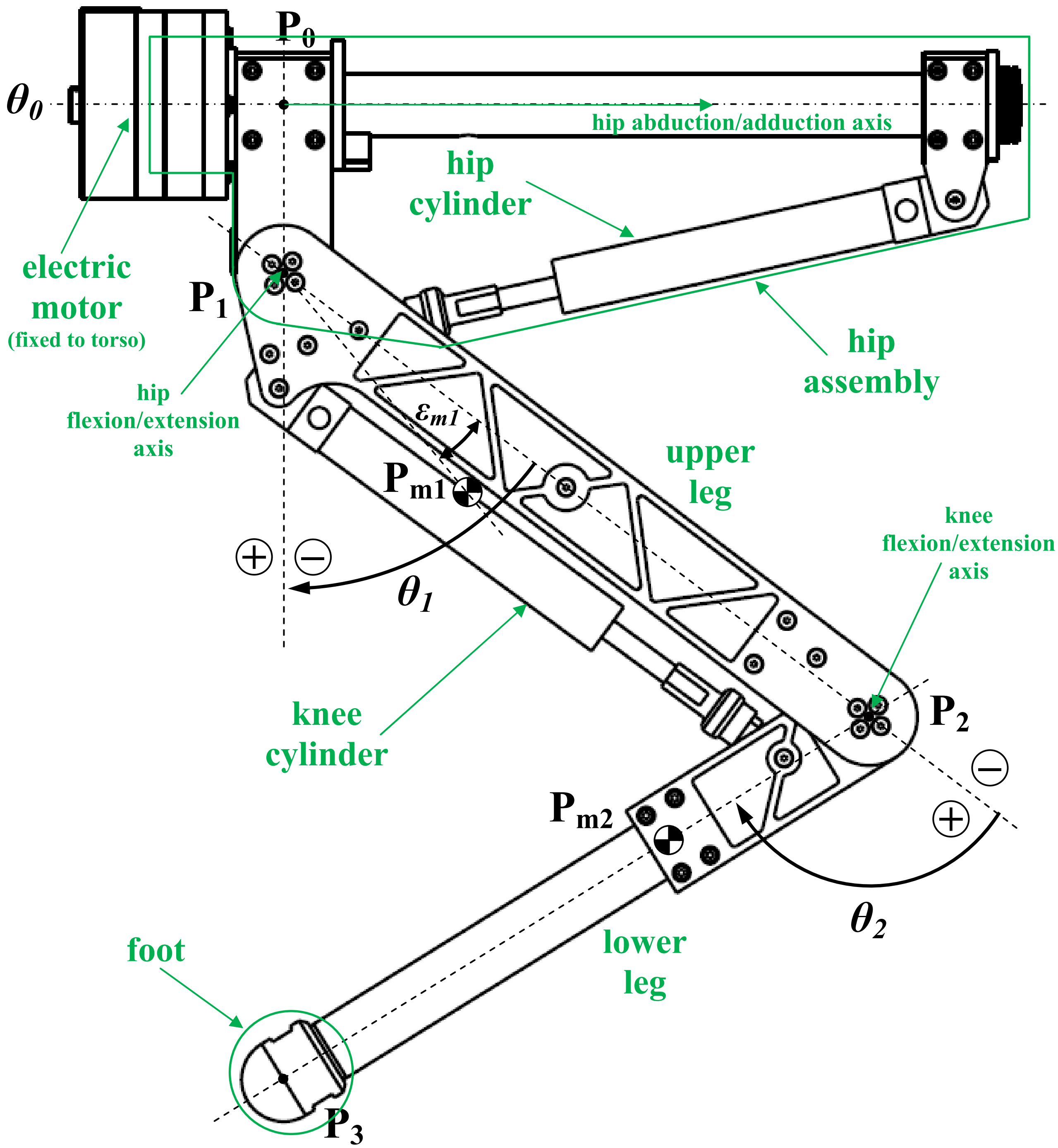
LF_HAA and RH_HAA
LH_HAA and RF_HAA

LF_HFE and RF_HFE
LH_HFE and RH_HFE

LF_KFE and RF_KFE
LH_KFE and RH_KFE

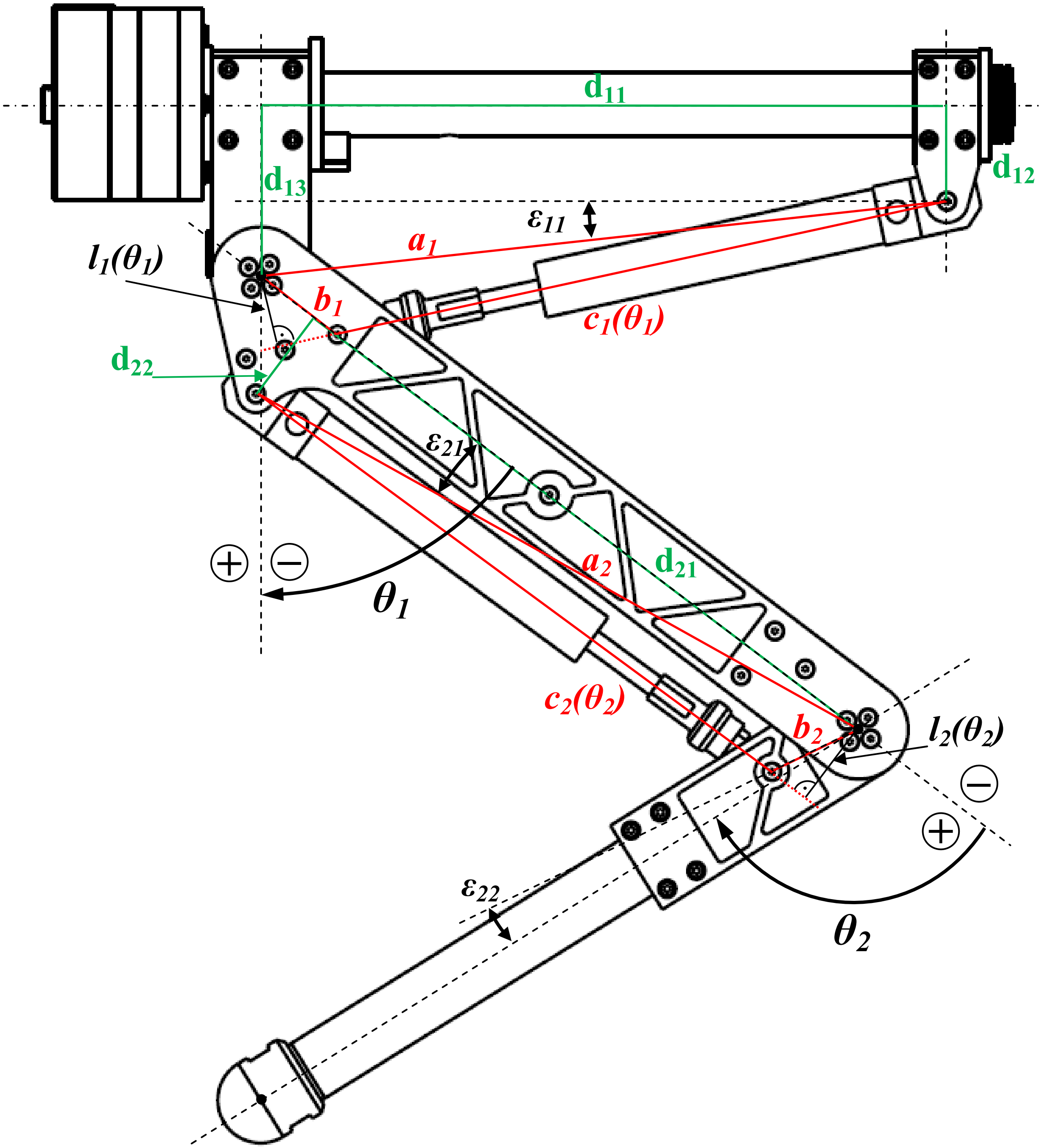


Leg Mass/Inertia, Range of Motion of RH-Leg



P_0P_1 = 0.08 m P_1P_2 = 0.35 m P_1P_{m1} = 0.164 m = sqrt(0.162^2+0.0225^2) ε_{m1} = 7.9 deg = atan(0.0225/0.162) m_1 = 1.772 kg [including knee cylinder] I_1 = 0.0713 kg*m^2 (with respect to hip flexion/extension axis, through P_1) Range of motion of θ_1=[-70deg..+50deg]	P_2P_3 = 0.33 m (foot radius: 0.02 m) P_2P_{m2} = 0.122 m [0.103 m without foot] (ε_{m2} = 0 deg) m_2 = 0.808 kg [0.739 kg without foot] I_2 = 0.0218 kg*m^2 [0.0145 kg*m^2 without foot] (with respect to knee flexion/extension axis, through P_2) Range of motion of θ_2 =[+20deg..+140deg]
mass of hip assembly (moving around θ_0) = 2.482 kg [including hip cylinder] I_0 = 0.00745 kg*m2 (with respect to hip abduction/adduction axis, through P_0)	

Geometry of Hydraulically Actuated Joints (RH-Leg)



$a_1 = 0.3219$ m $=$ sqrt$(d_{11}{}^\wedge 2+(d_{13}-d_{12}){}^\wedge 2)$ $b_1 = 0.045$ m $\varepsilon_{11} = 6.24$ deg $=$ atan$((d_{13}-d_{12})/d_{11})$ $(\varepsilon_{12} = 0$ deg$)$ $c_1(\theta_1) =$ sqrt$(a_1{}^\wedge 2 + b_1{}^\wedge 2 - 2*a_1*b_1*\cos(\pi/2+\theta_1+\varepsilon_{11}))$ $l_1(\theta_1) = a_1*\sin(\mathrm{acos}((a_1{}^\wedge 2+c_1(\theta_1){}^\wedge 2-b_1{}^\wedge 2)/(2*a_1*c_1(\theta_1))))$	$d_{11} = 0.32$ m $d_{12} = 0.045$ m $d_{13} = 0.08$ m
$a_2 = 0.3218$ m $=$ sqrt$(d_{21}{}^\wedge 2+d_{22}{}^\wedge 2)$ $b_2 = 0.045$ m $\varepsilon_{21} = 8.04$ deg $=$ atan(d_{22}/d_{21}) $\varepsilon_{22} = 6.0$ deg $c_2(\theta_2) =$ sqrt$(a_2{}^\wedge 2 + b_2{}^\wedge 2 - 2*a_2*b_2*\cos(\pi-\theta_2-\varepsilon_{21}-\varepsilon_{22})))$ $l_2(\theta_2) = a_2*\sin(\mathrm{acos}((a_2{}^\wedge 2+c_2(\theta_2){}^\wedge 2-b_2{}^\wedge 2)/(2*a_2*c_2(\theta_2))))$	$d_{21} = 0.3186$ m $d_{22} = 0.045$ m

Document Revision History:

version	date	author	changes/comments
V1.0	01/2010	Semini	initial version.
V2.0	9/7/2010	Semini	added one page with definition of link coordinate systems, and added the labels to define *upper leg* and *lower leg*.