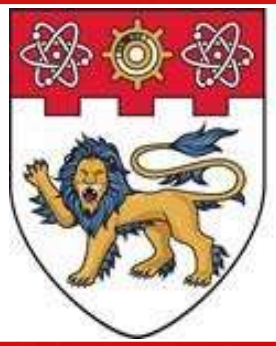


NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

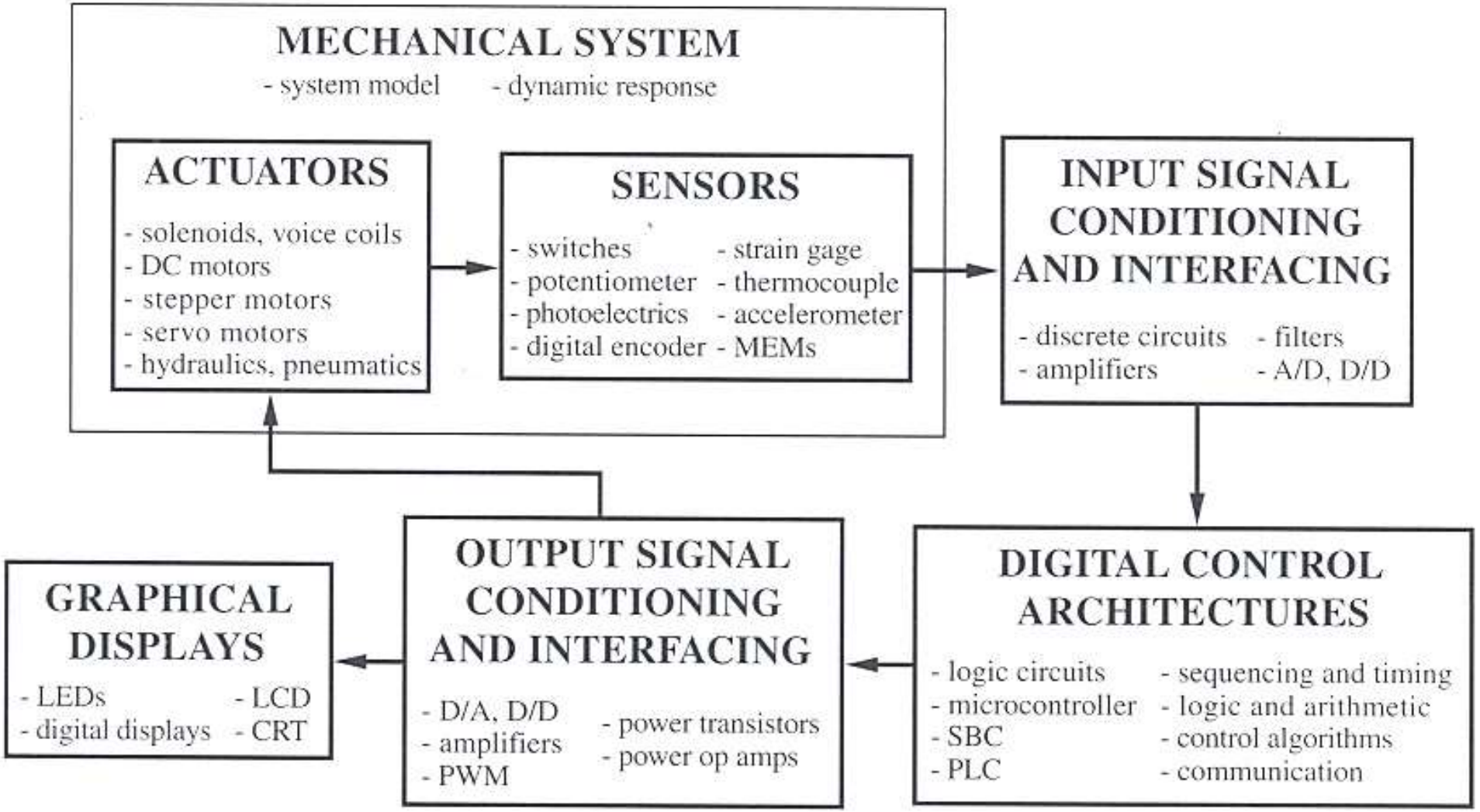
MA2012 INTRODUCTION TO MECHATRONICS SYSTEMS DESIGN

Lecture 7

Prof Ang Wei Tech

College of Engineering
School of Mechanical and Aerospace Engineering

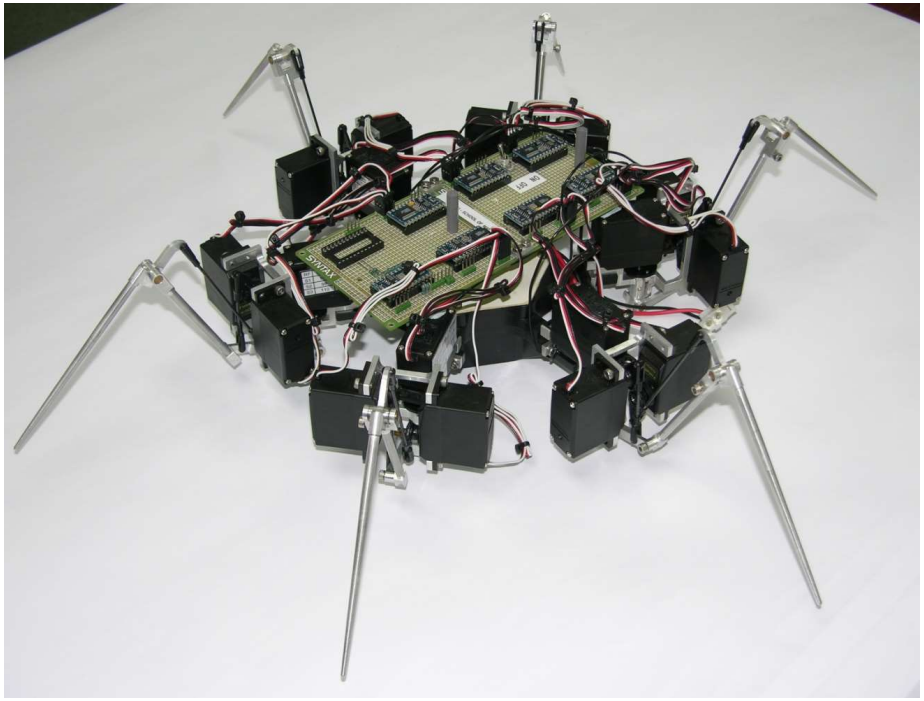
MECHATRONICS SYSTEM COMPONENTS



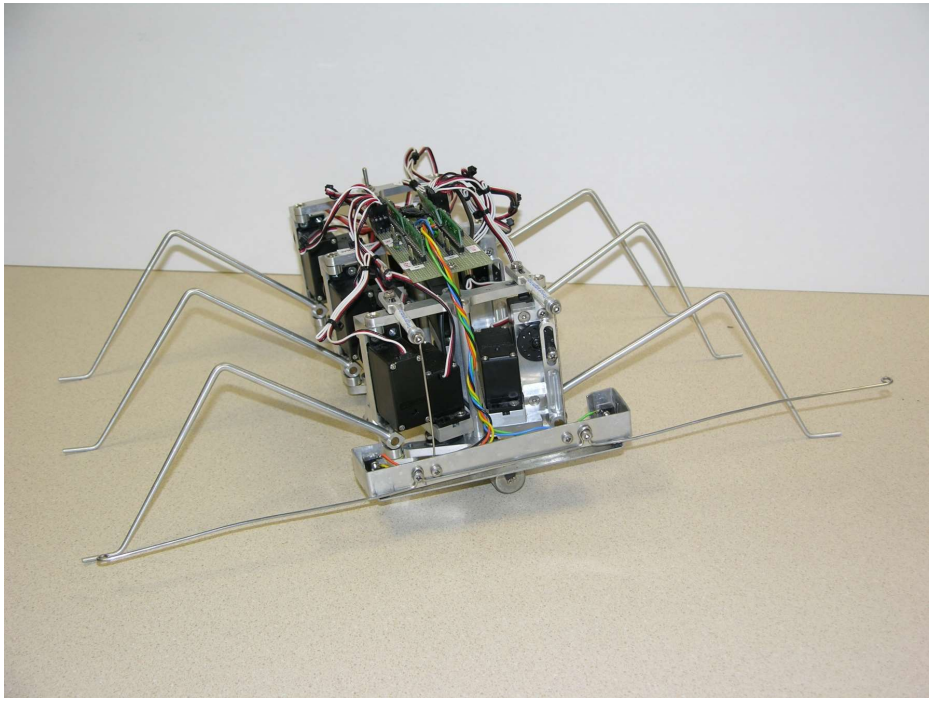
MECHATRONICS SYSTEMS DESIGN

1. Understand the task, define the problem
2. Sketch a functional block diagram
3. Decide & select mechatronics components (type, number, communication protocol, etc.) :
   - Digital control architecture
   - Sensors & input interfacing
   - Actuators & output interfacing
   - Display
4. Construct hardware prototype
5. Programme software / firmware

EXAMPLE: SIX-LEGGED WALKING ROBOTS

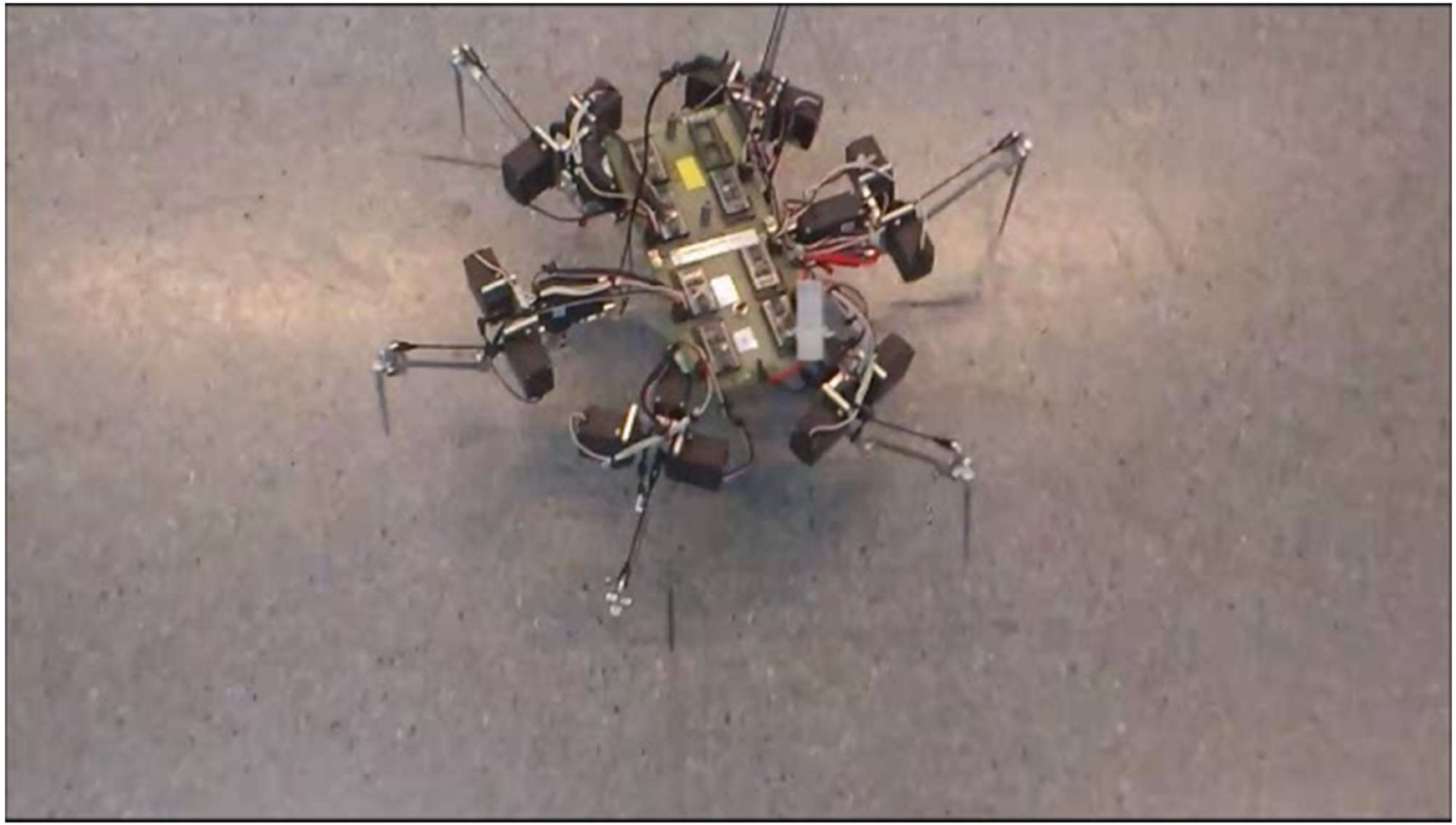


Hexapod robot with 3 DOF robot legs



Hexapod robot with 2 DOF robot legs

HEXAPOD ROBOT WITH 3 DOF LEGS



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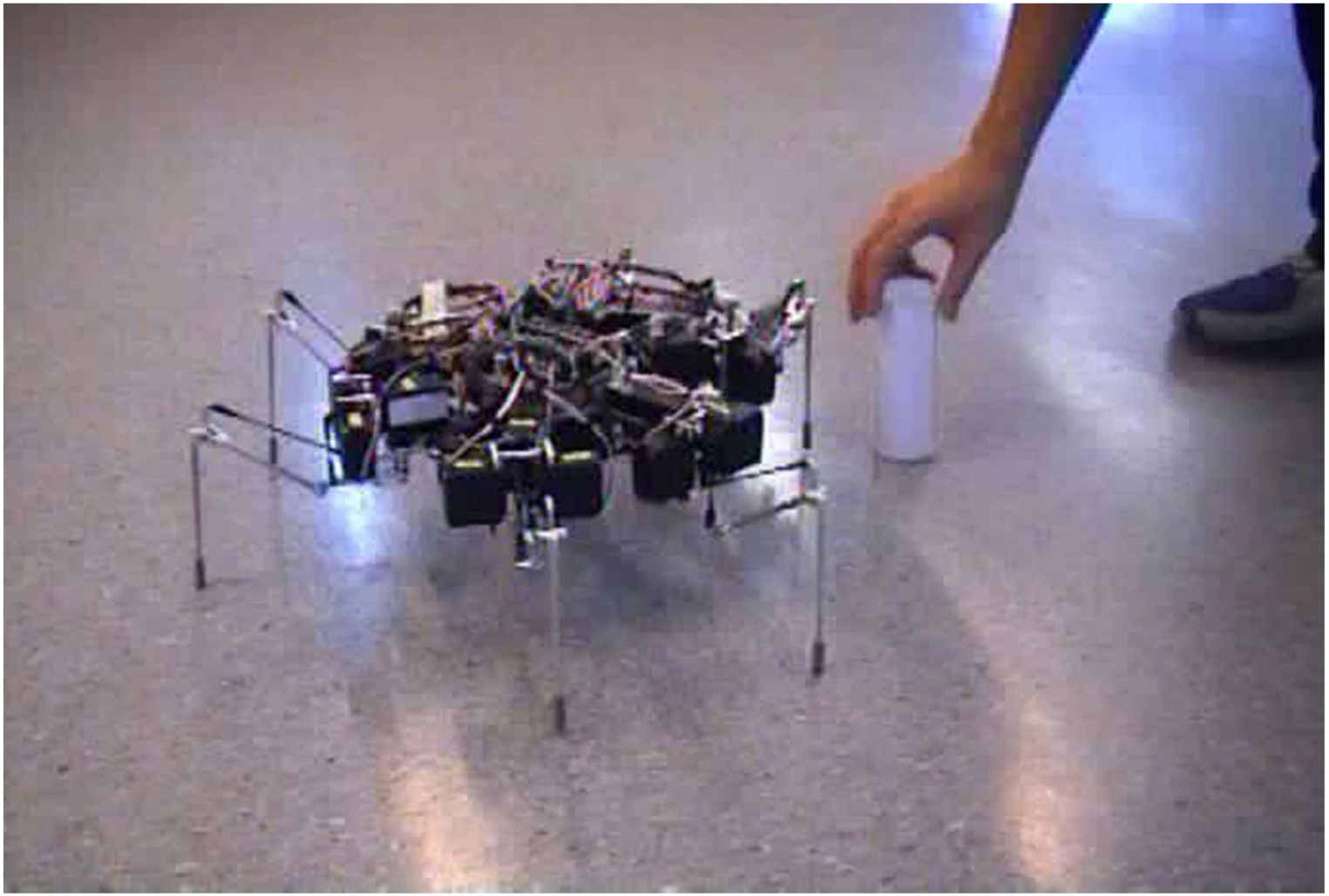
INTELLIGENT HEXAPOD ROBOT WITH 3 DOF LEGS



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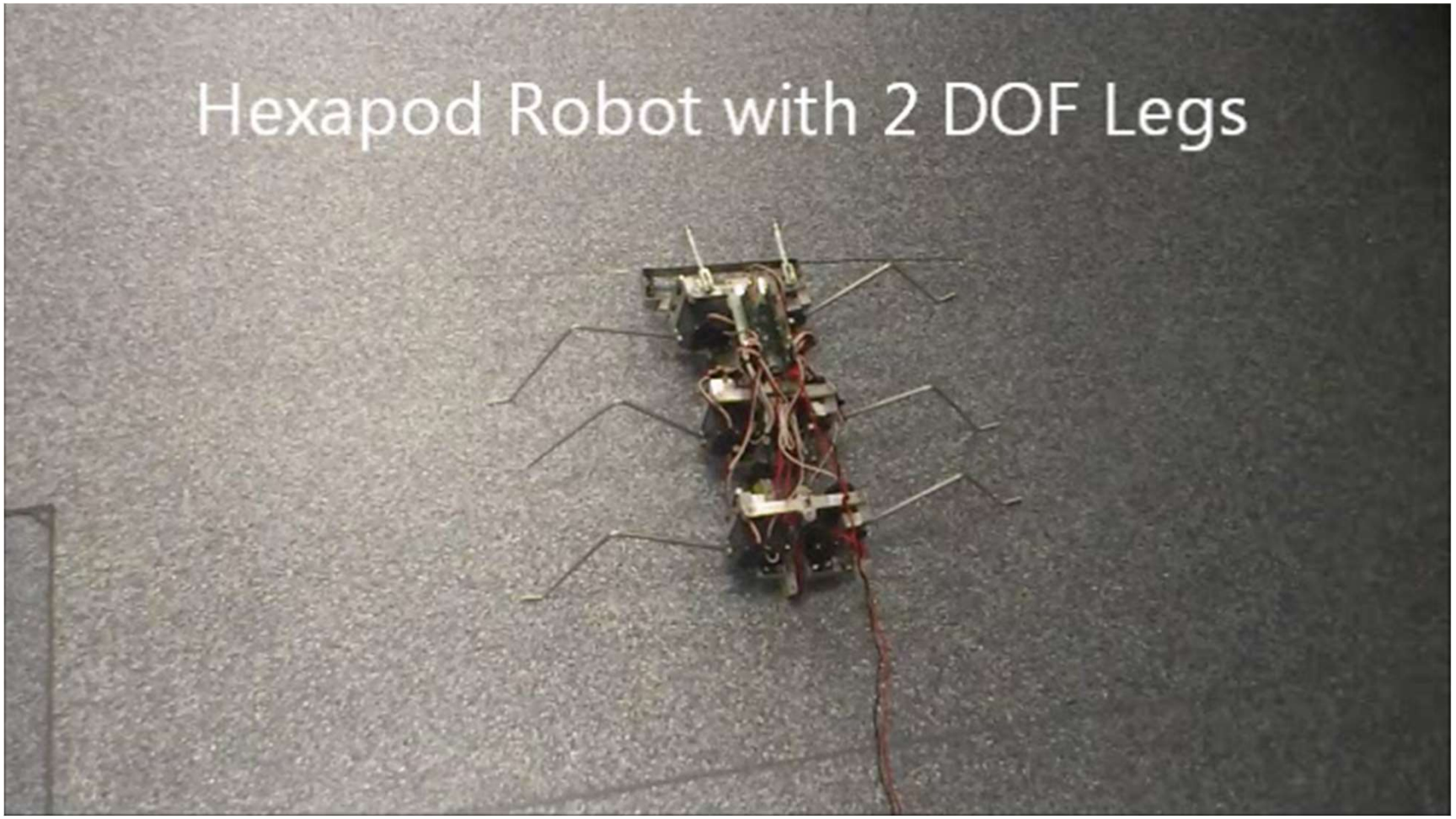
HEXAPOD ROBOT WITH 2 DOF LEGS



Click this image to play video

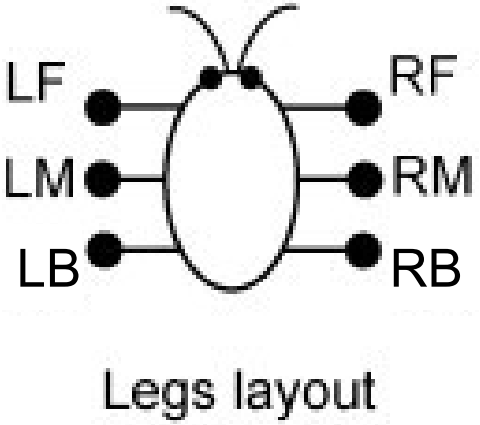
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

HOW DOES A BEETLE WALK WITH 6 LEGS?

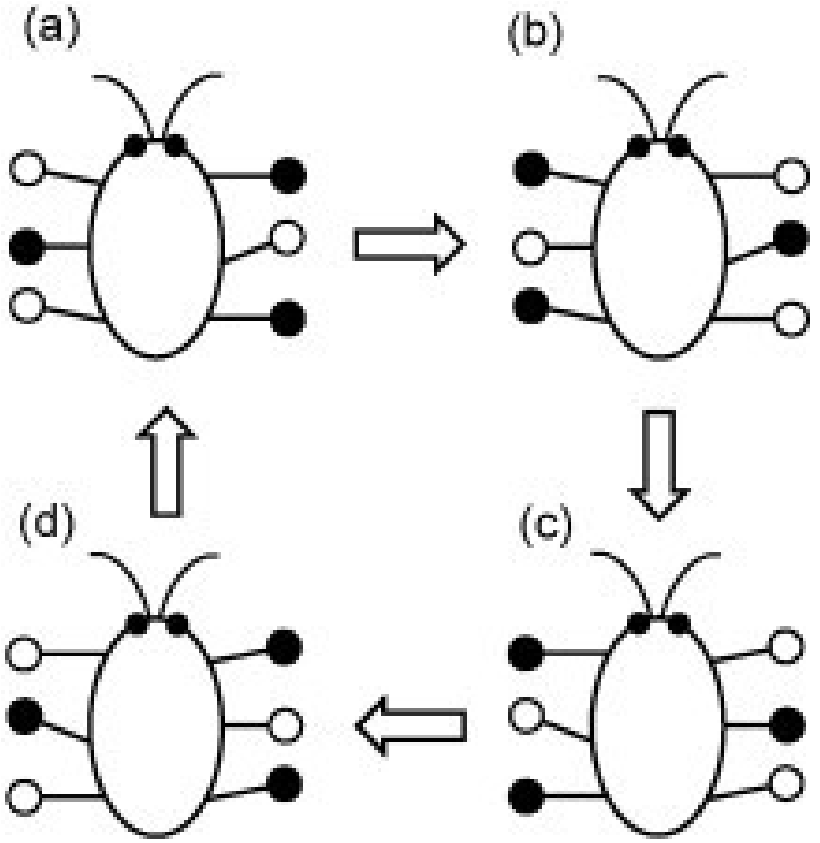
Click this image to play video

STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

TRIPOD GAIT

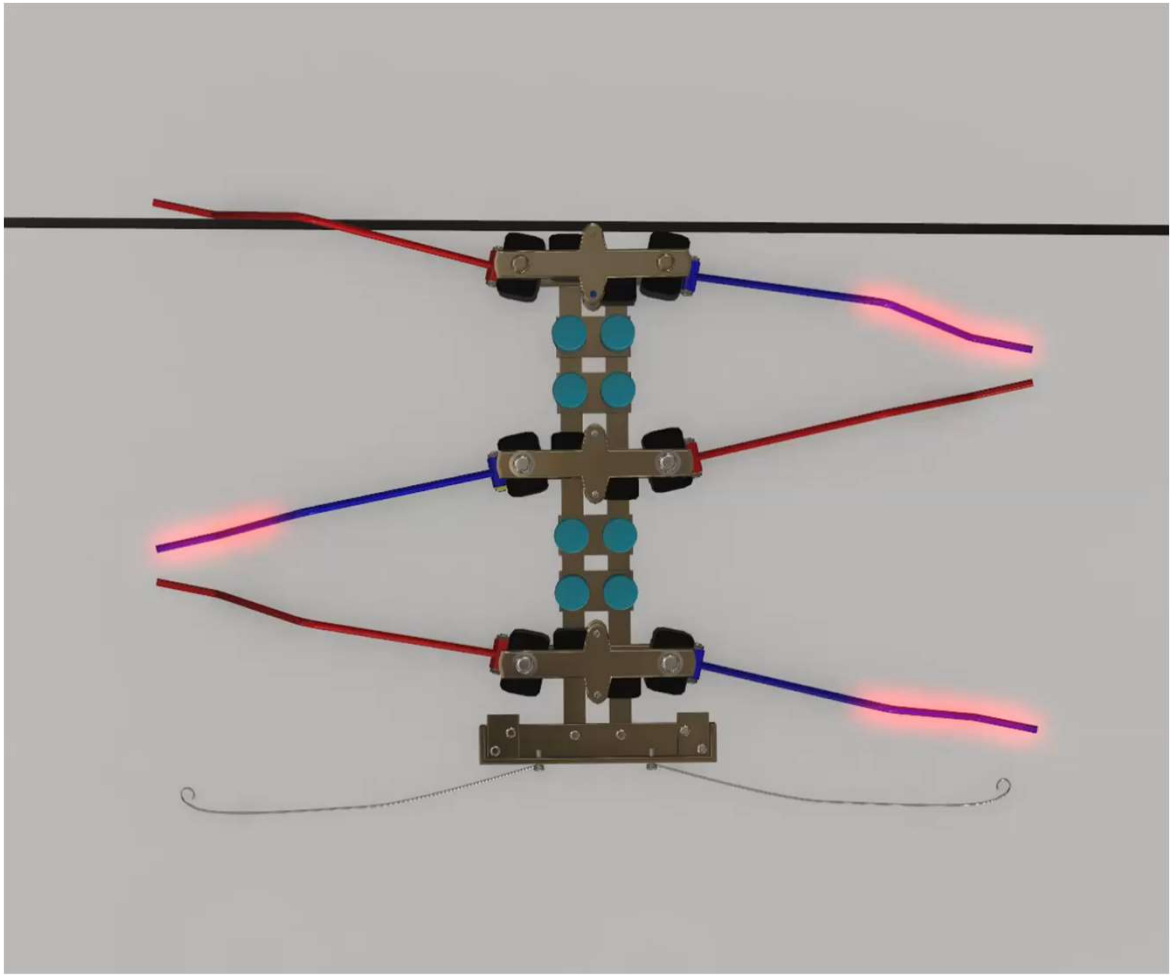


Legs layout



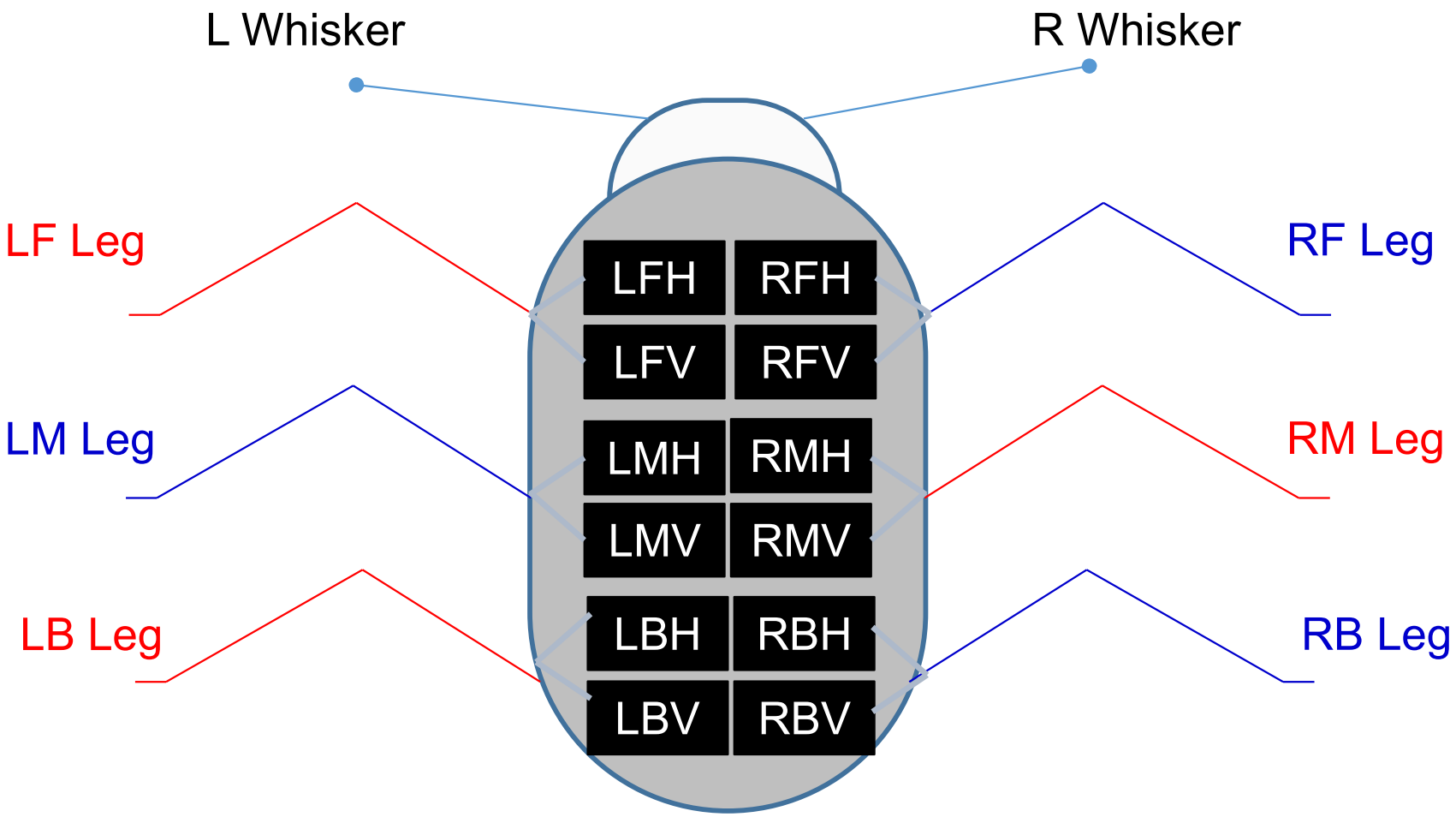
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

TRIPOD GAIT



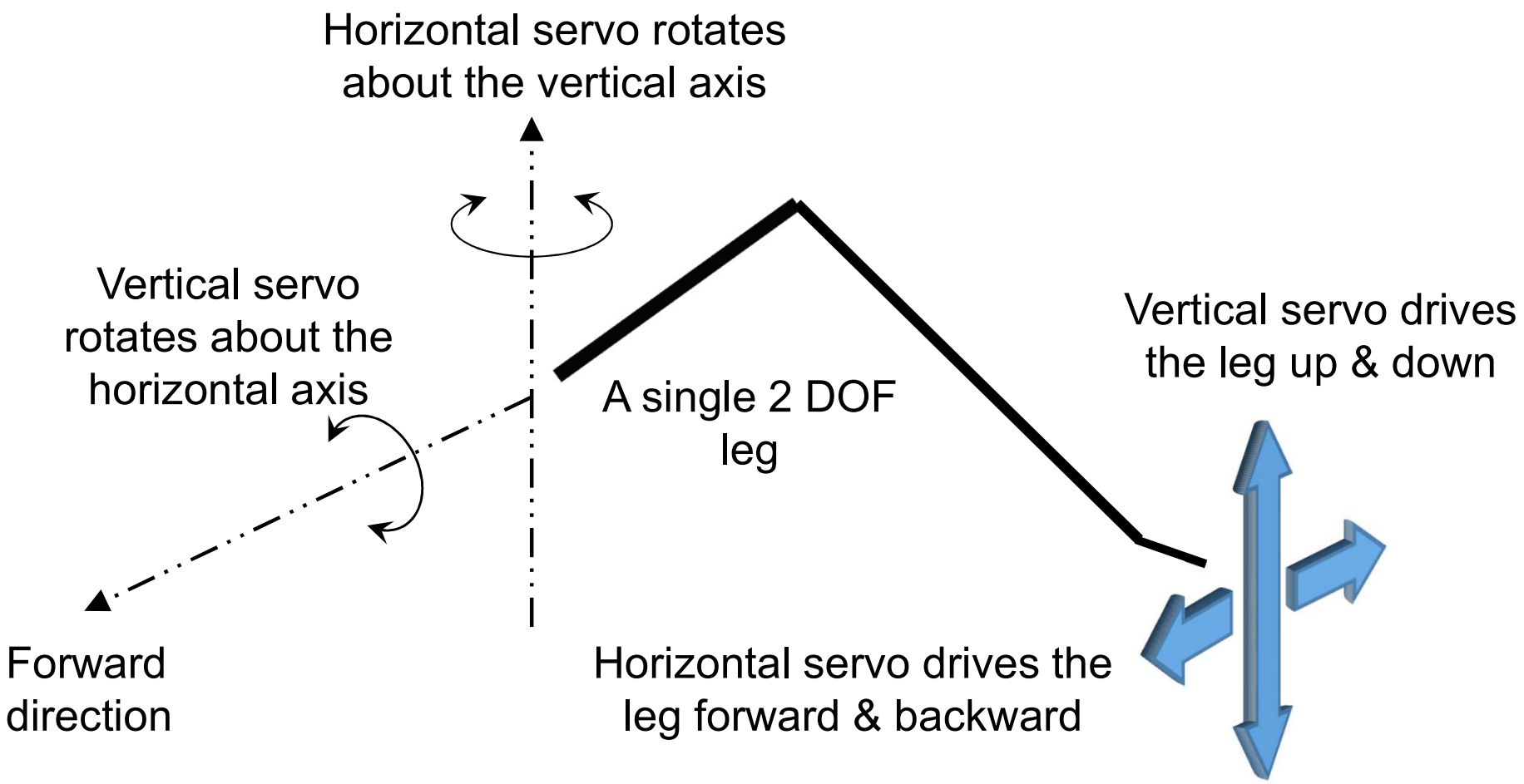
Click this image to play animation

STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

LEG ACTUATION METHOD

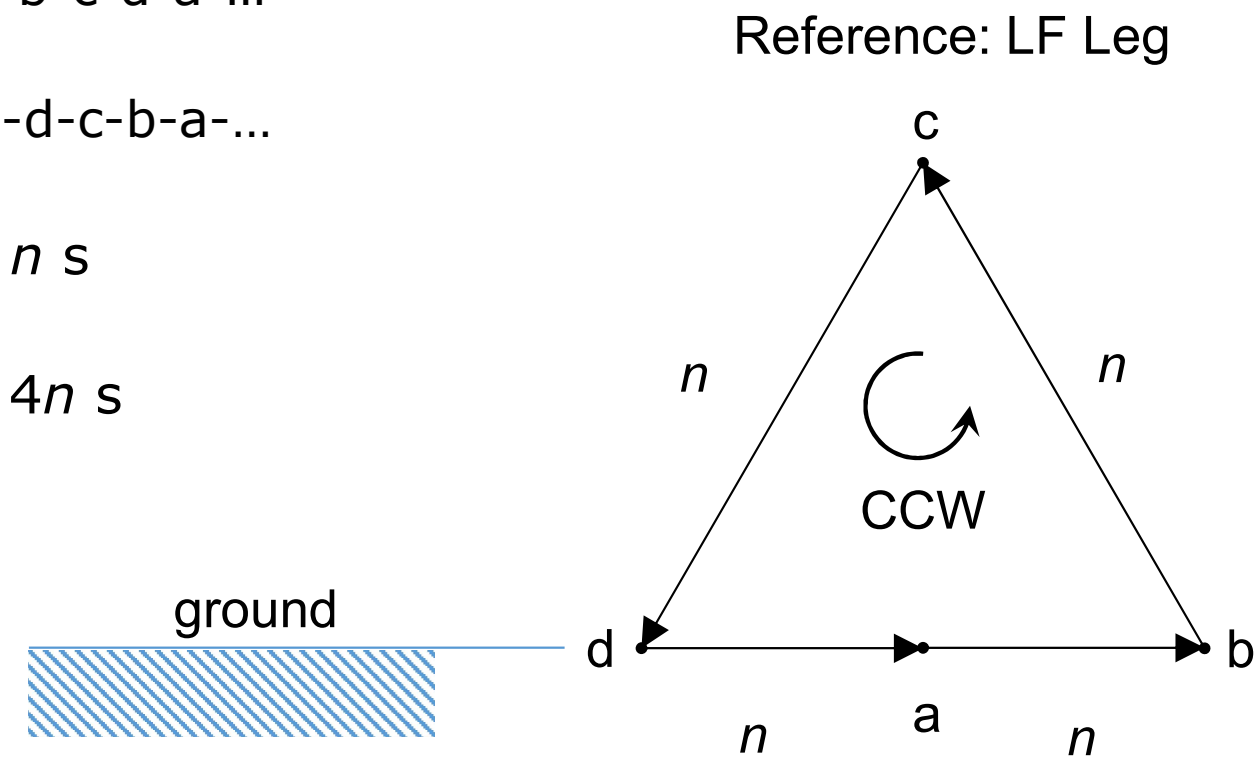


STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

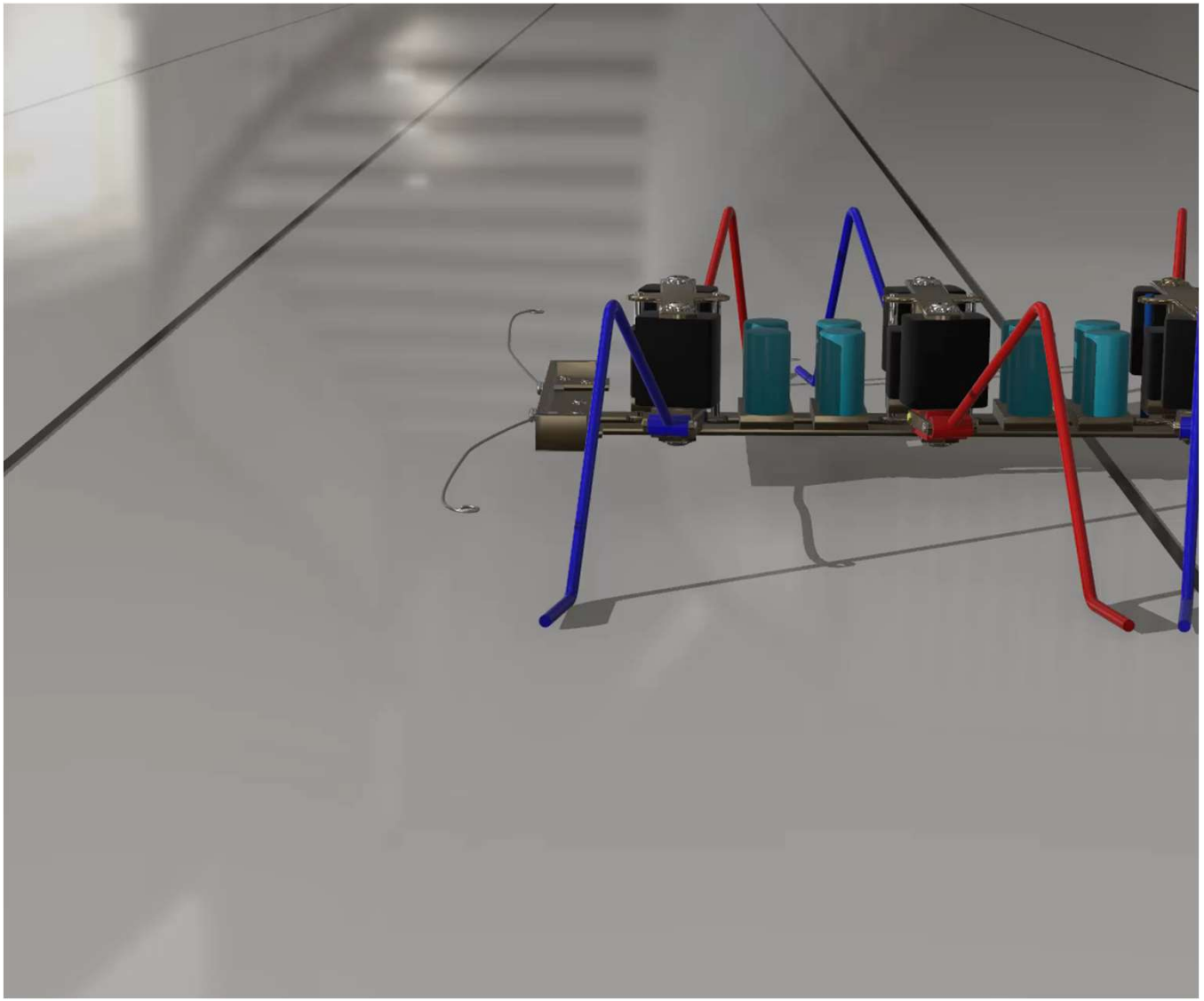
- Leg tip locus
  - Triangle profile passing through 4 nodes:

    a, b, c & d

  - Forward (CCW): a-b-c-d-a-…
  - Backward (CW): a-d-c-b-a-…
- Time per stage, $t = n$ s
- Time per cycle, $T = 4n$ s

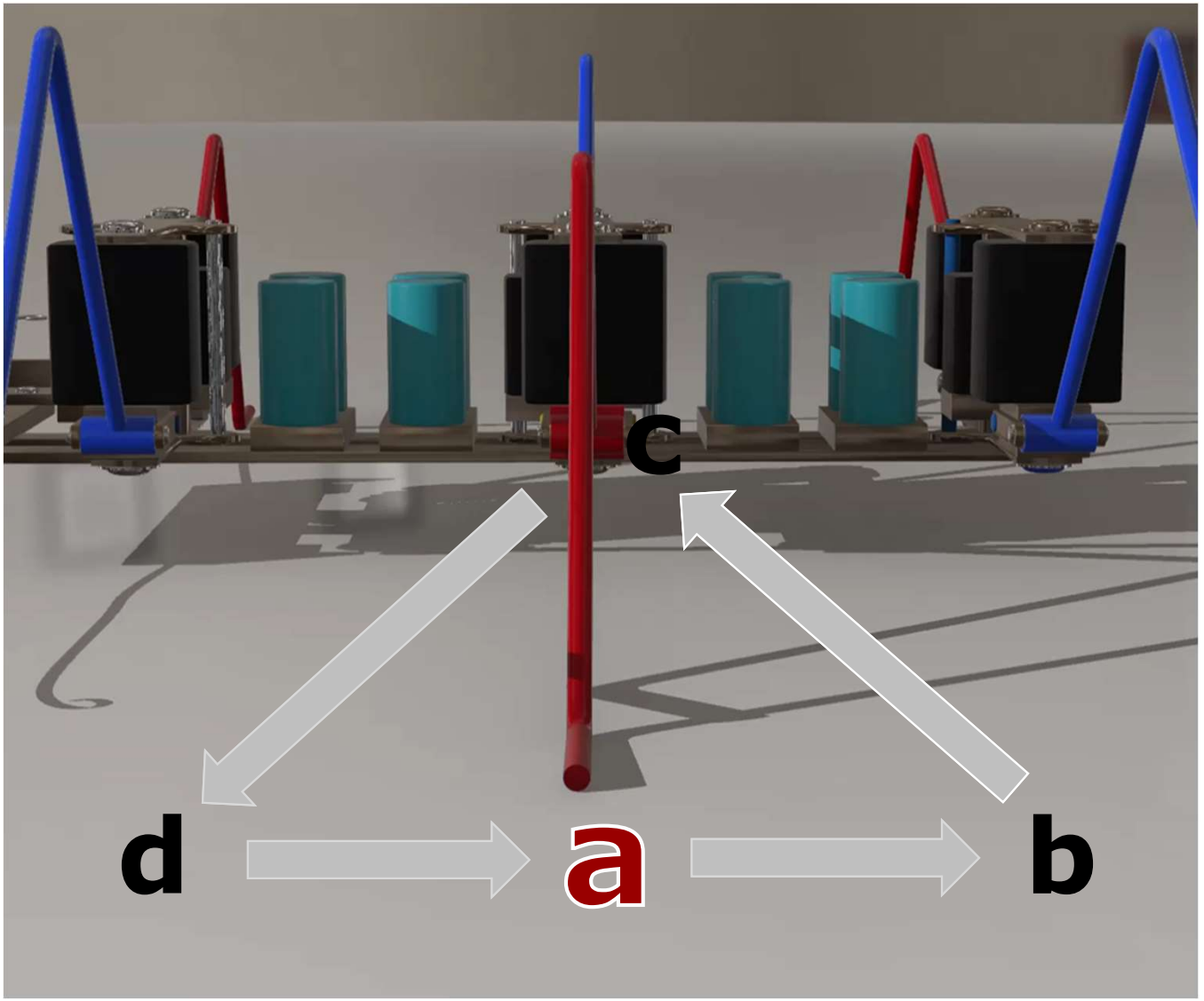


STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



Click this image to play animation

STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



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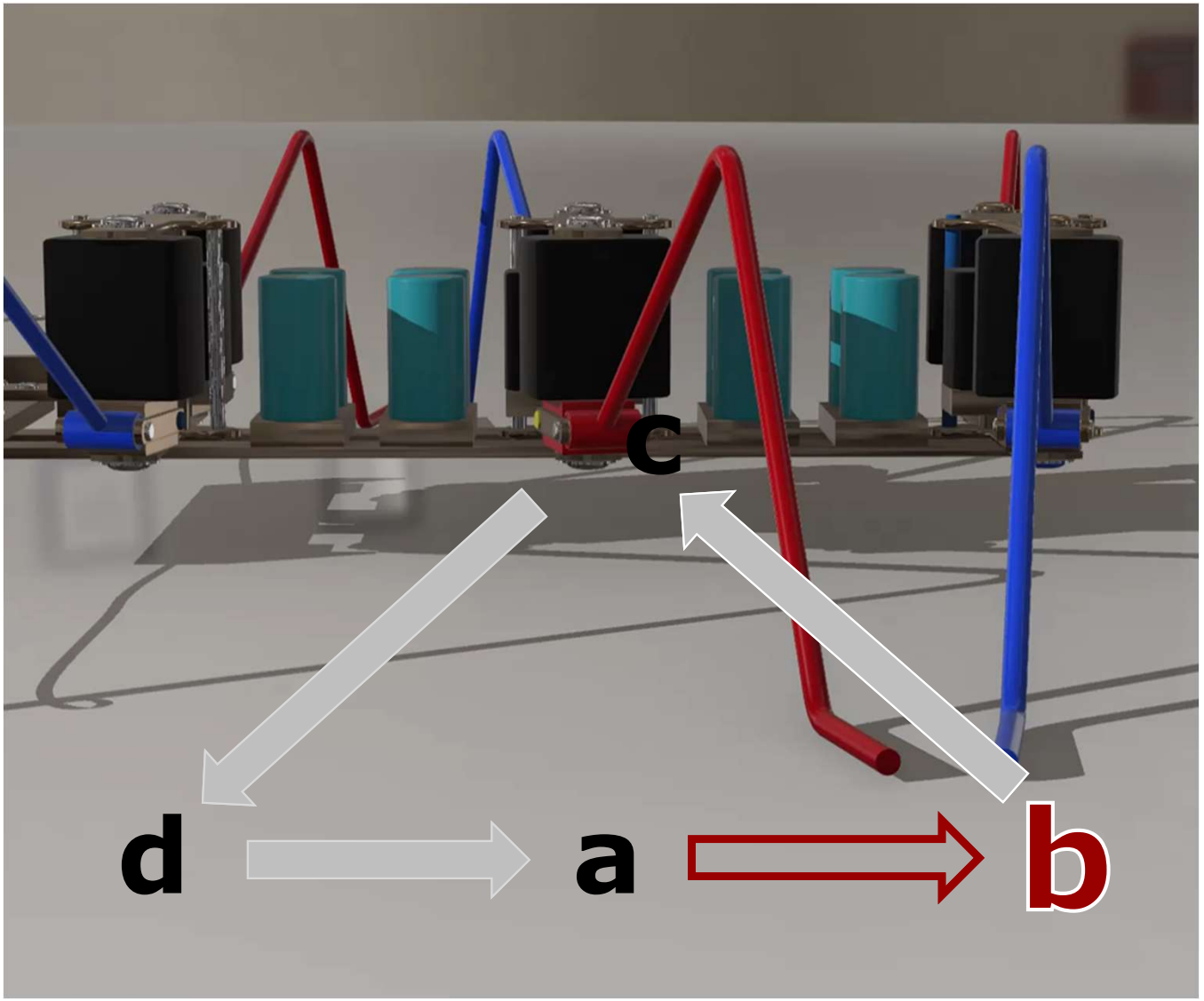
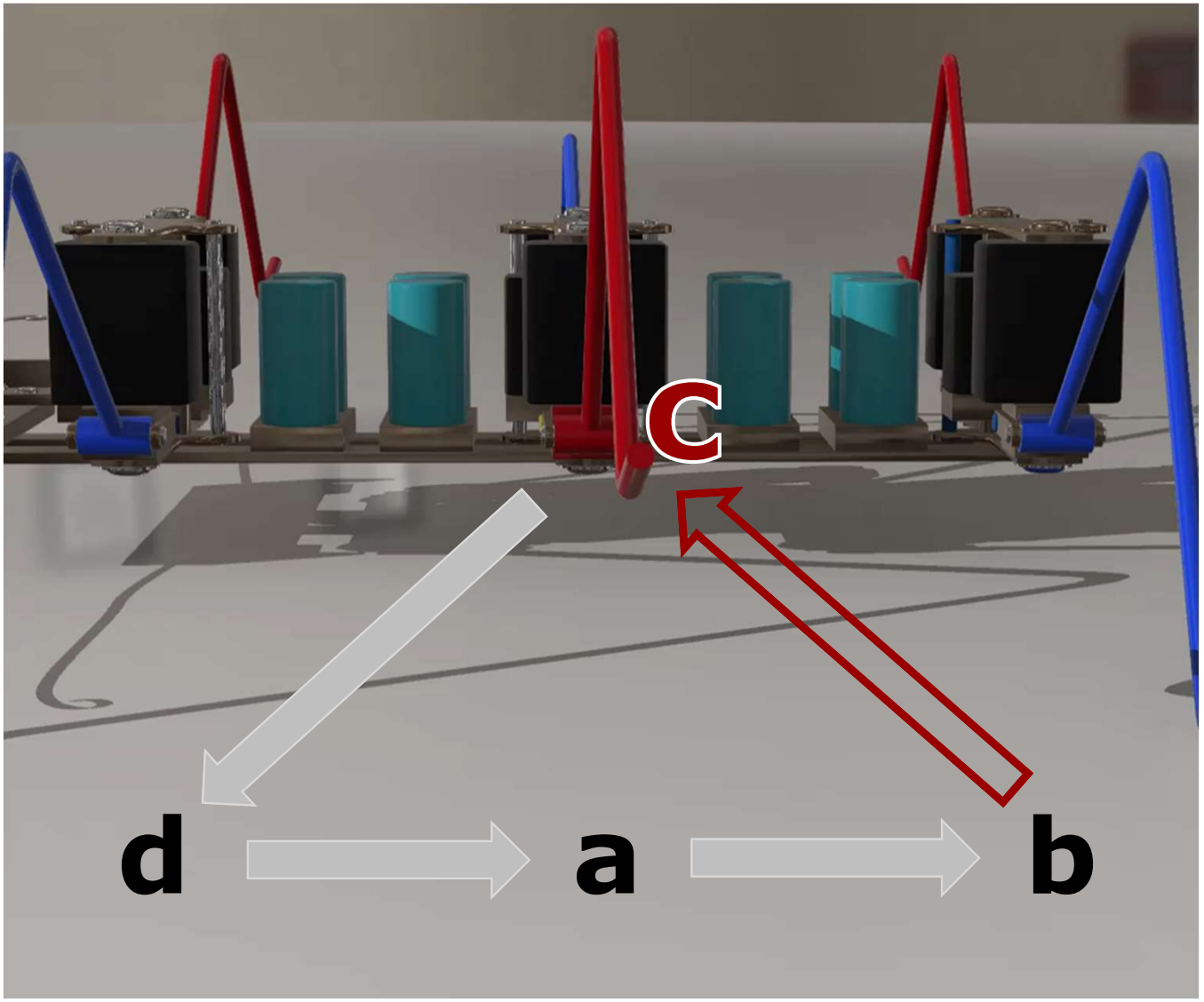
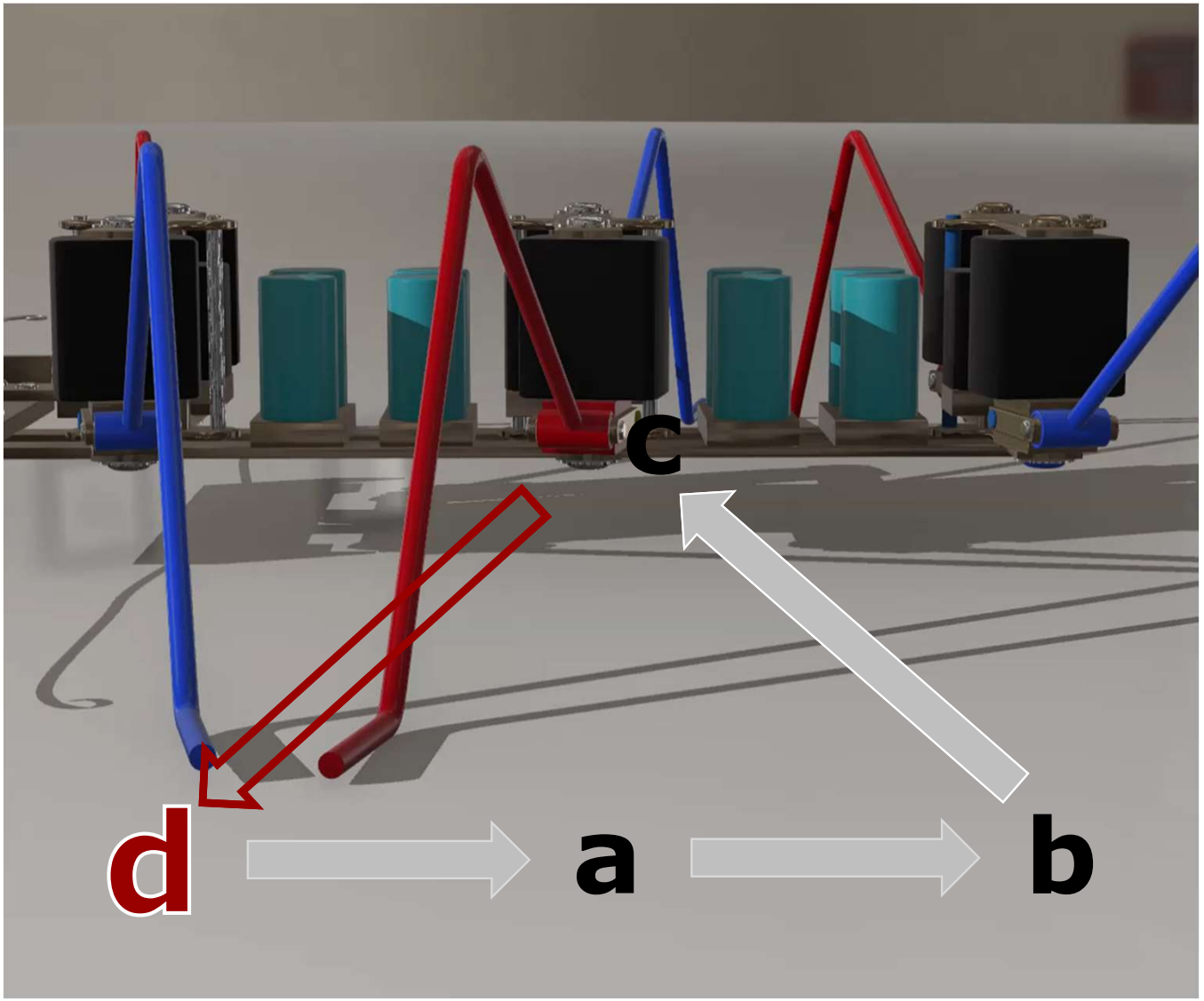


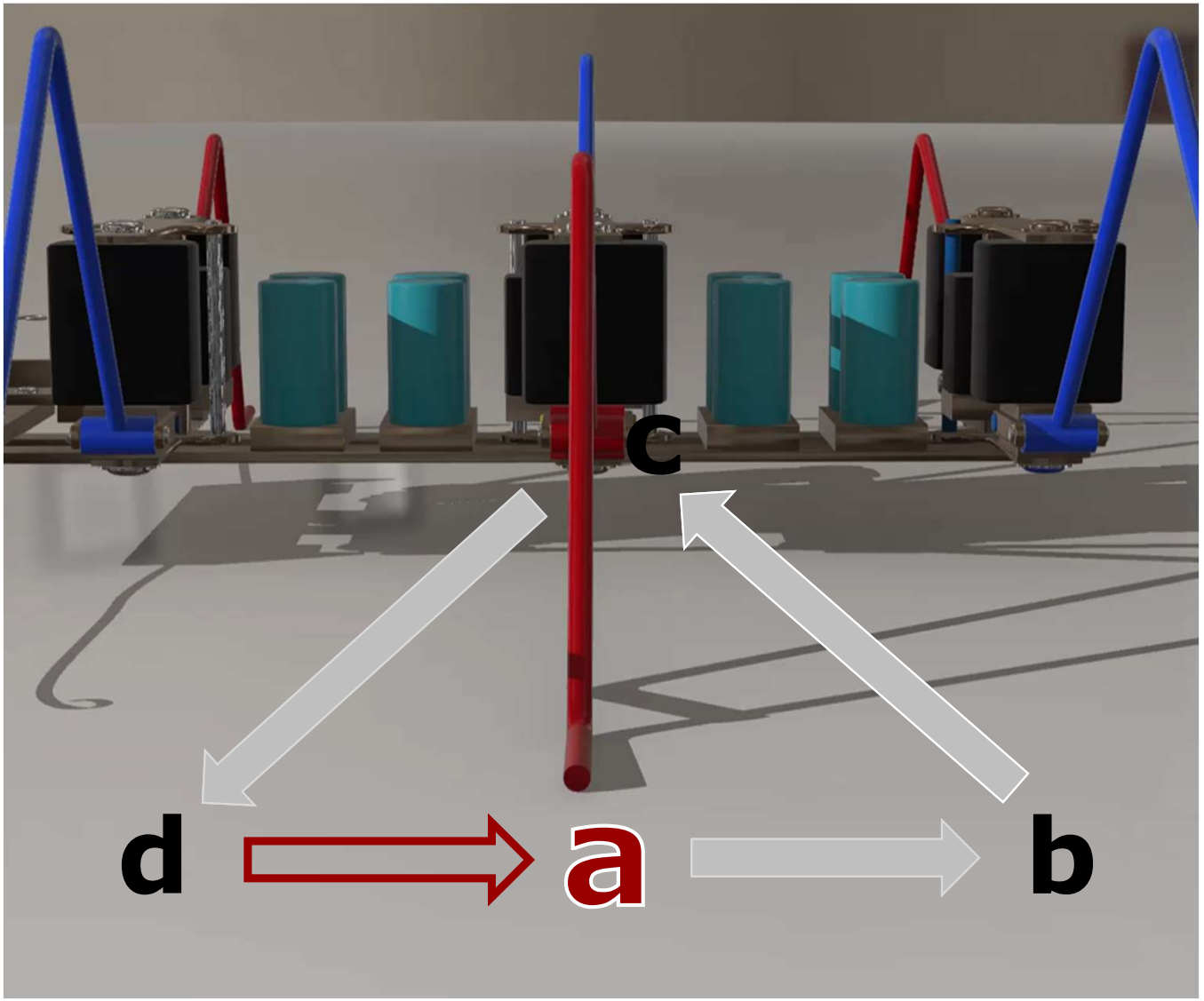
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



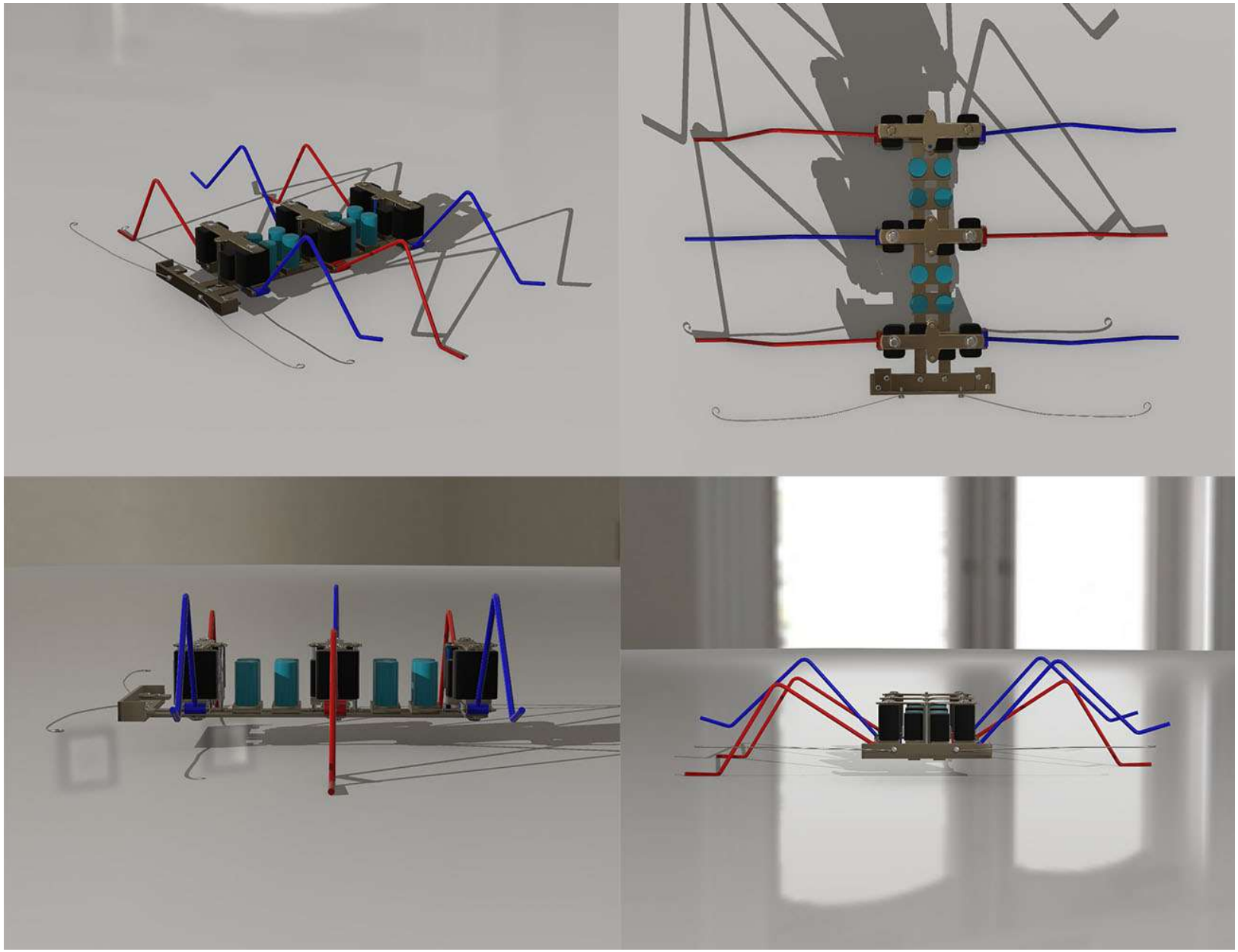
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



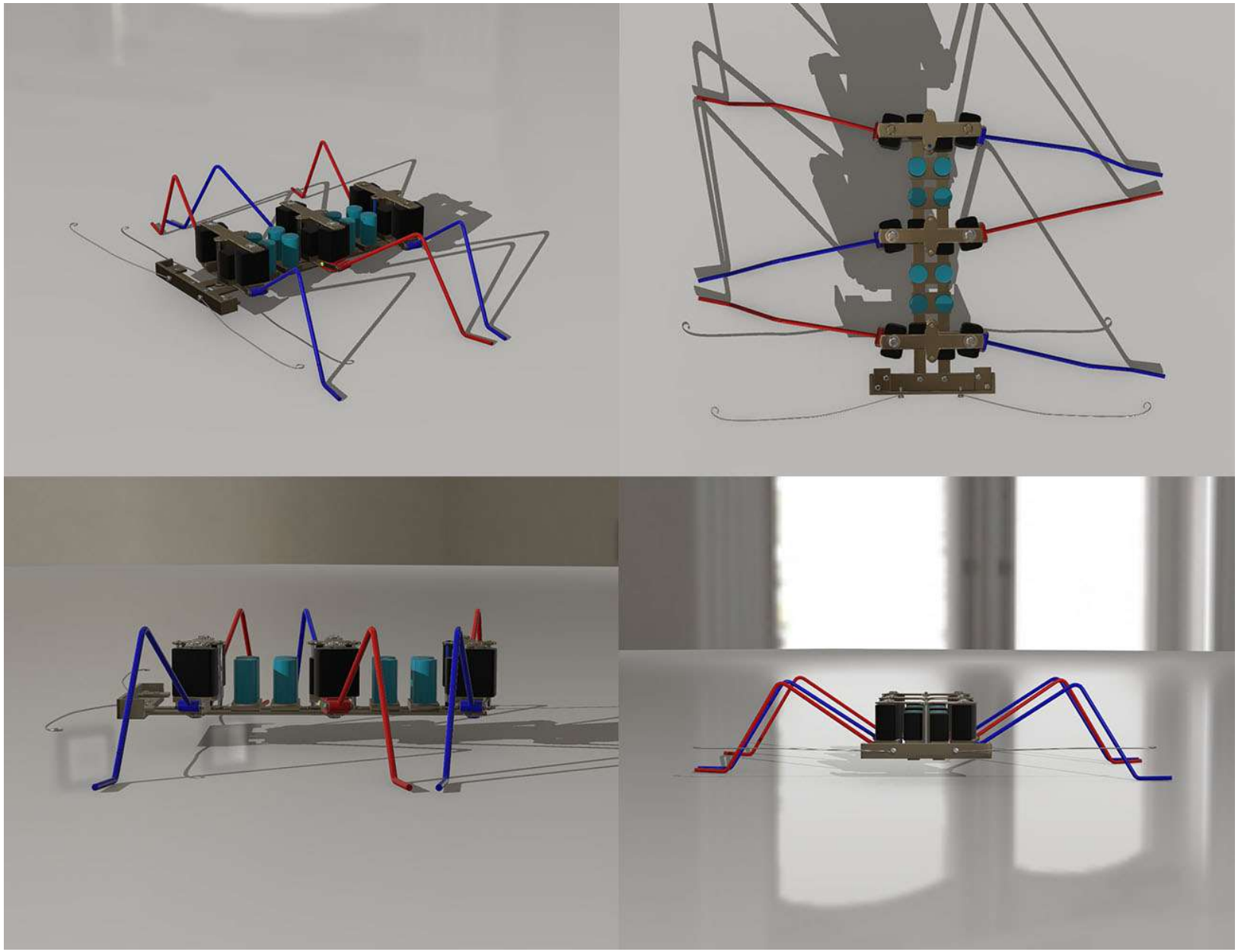
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



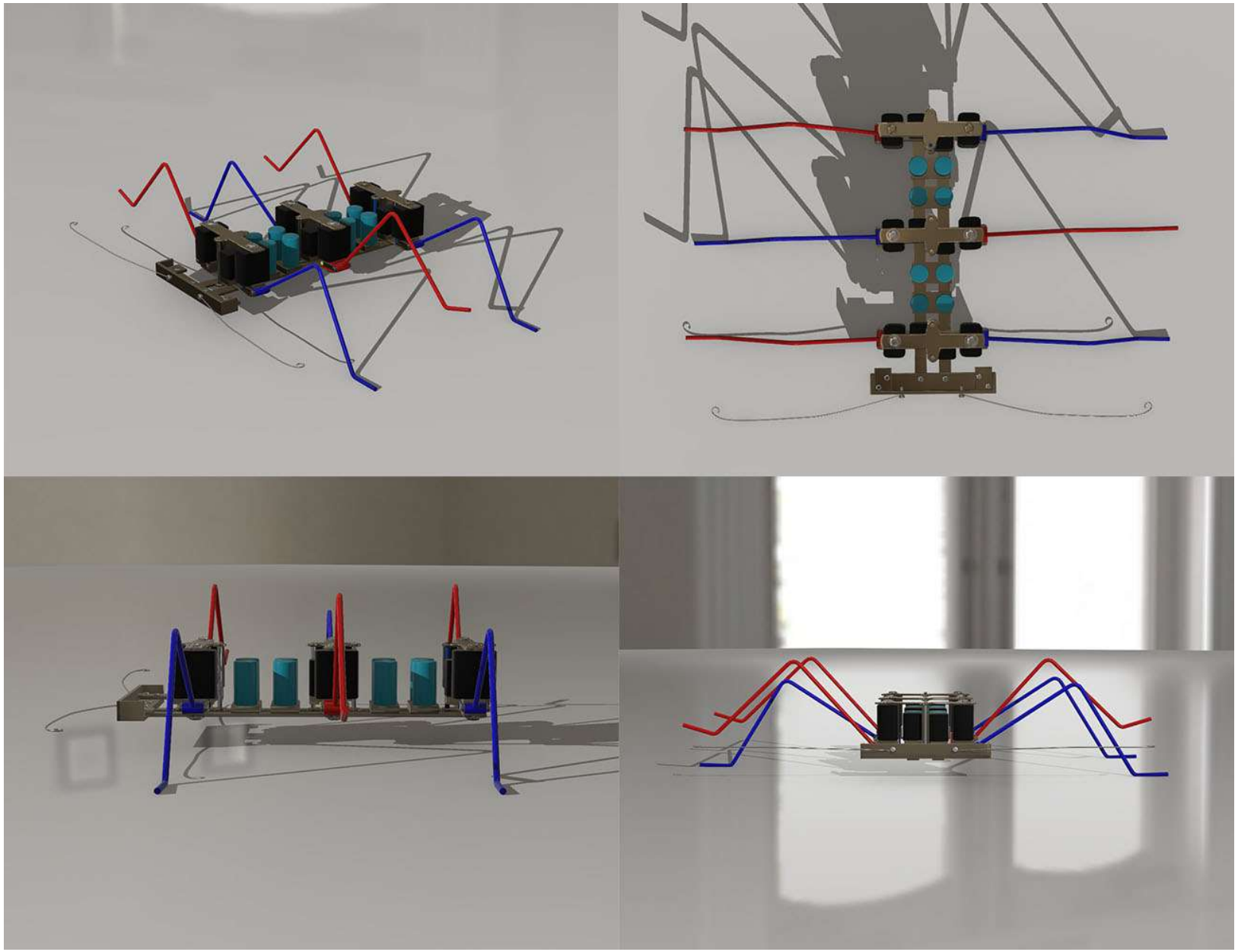
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



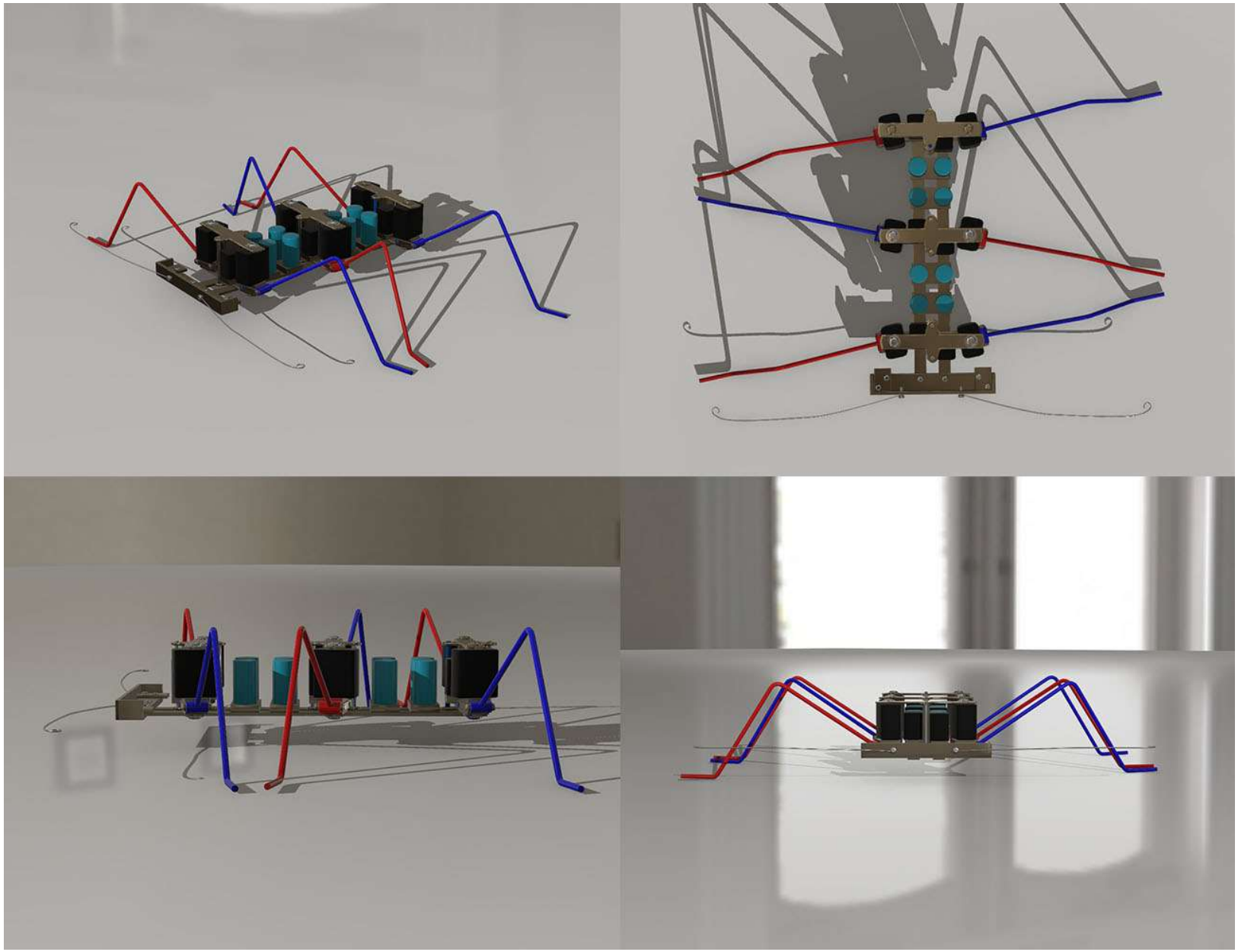
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



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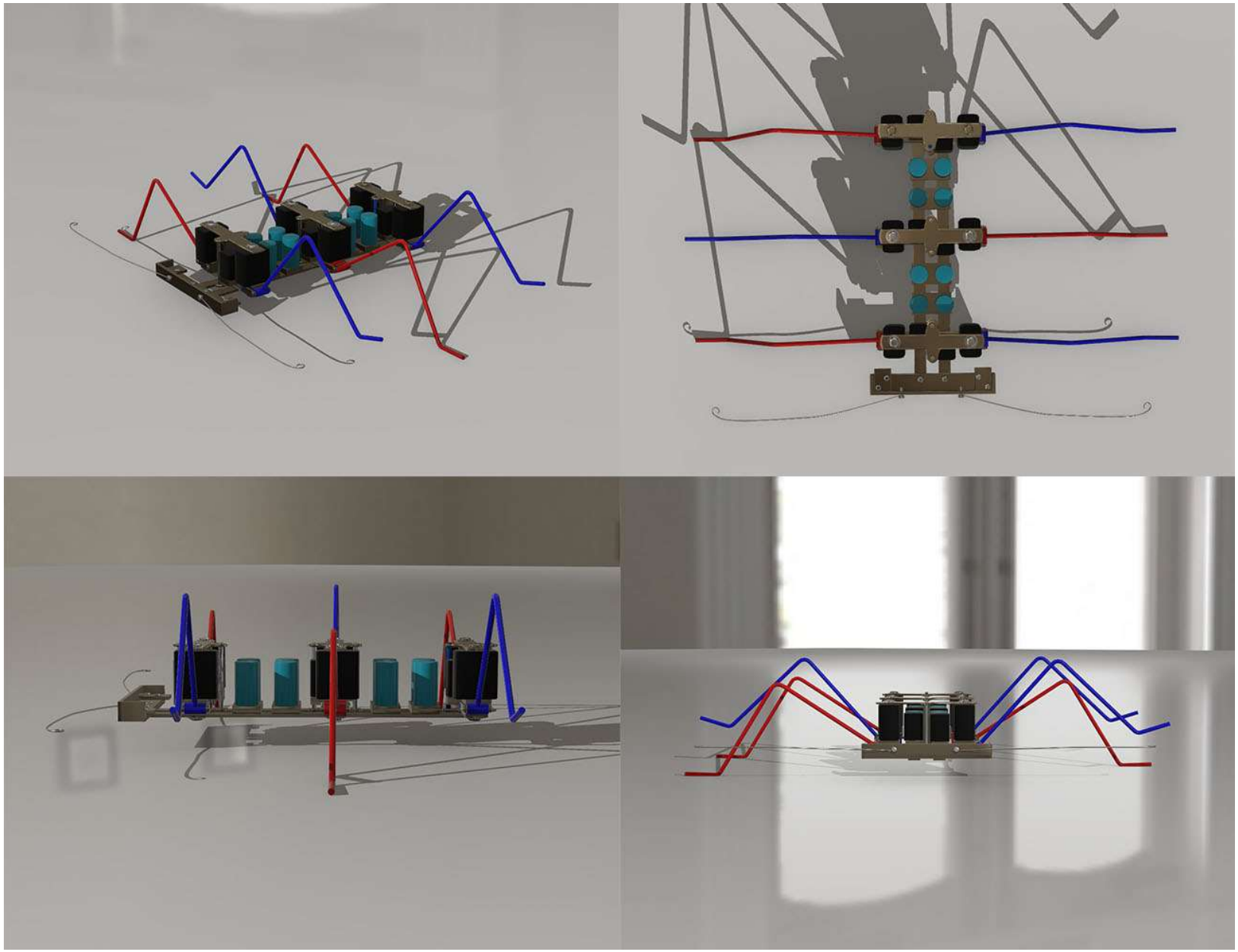
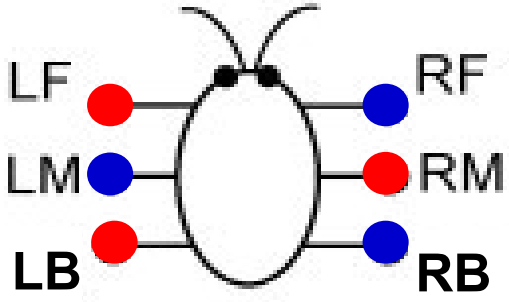


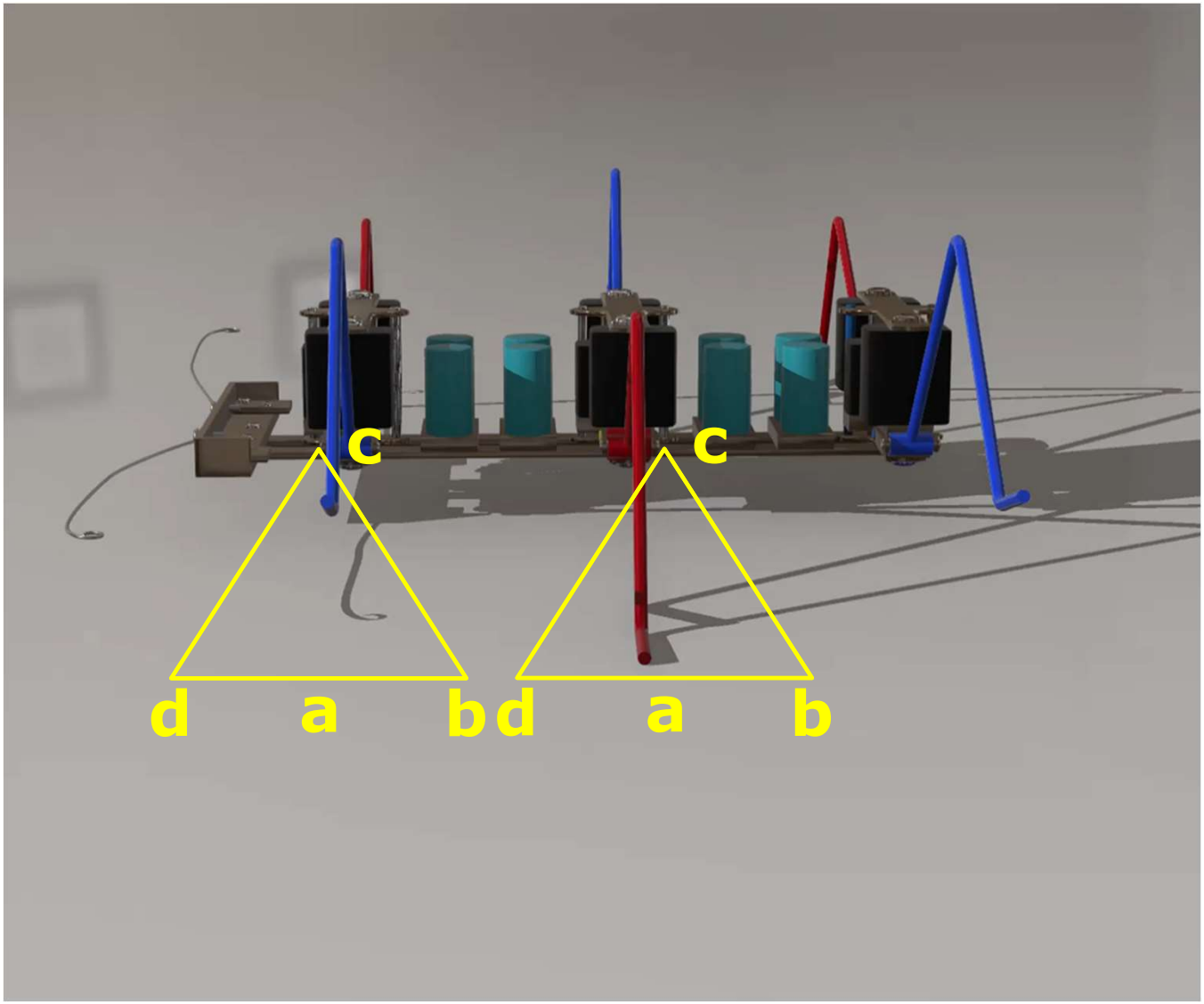
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

TRIPOD GAIT CYCLE

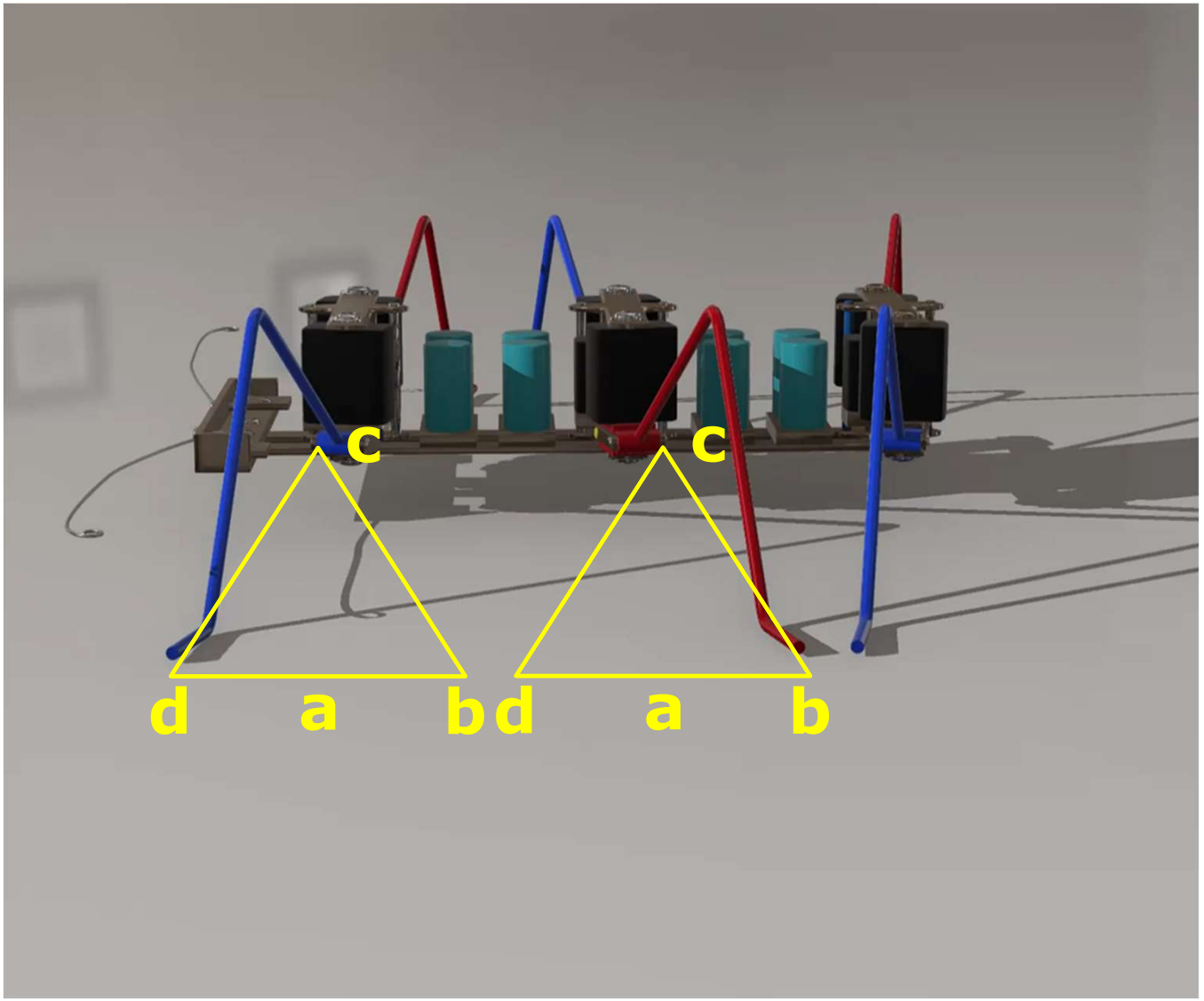


Leg \ Time	*n*	2*n*	3*n*	4*n*	5*n*	Comment
LF	a	b	c	d	a	Phase = 0°
RM						
LB						
RF	c	d	a	b	c	Phase = 180°
LM						
RB						

STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



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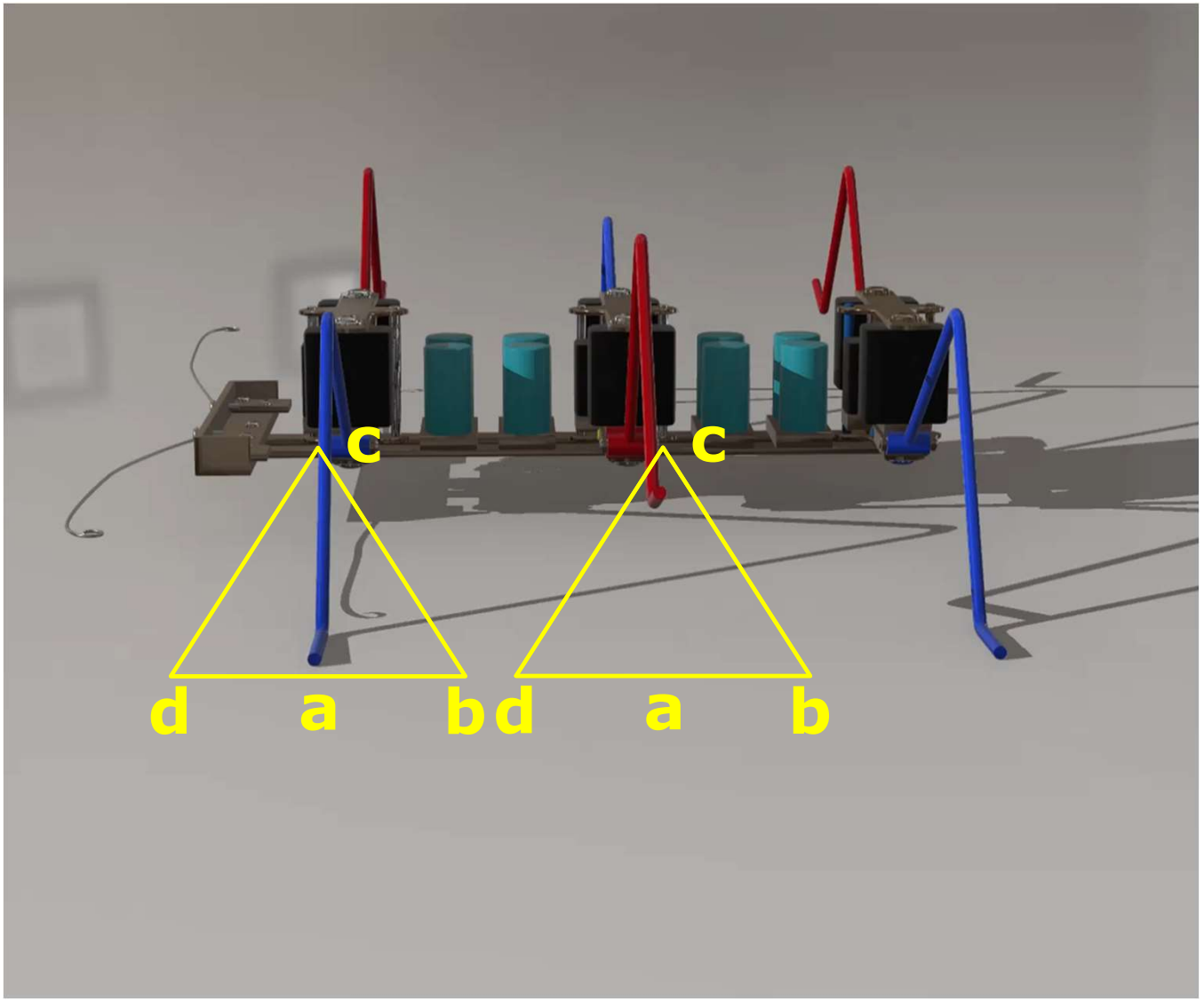

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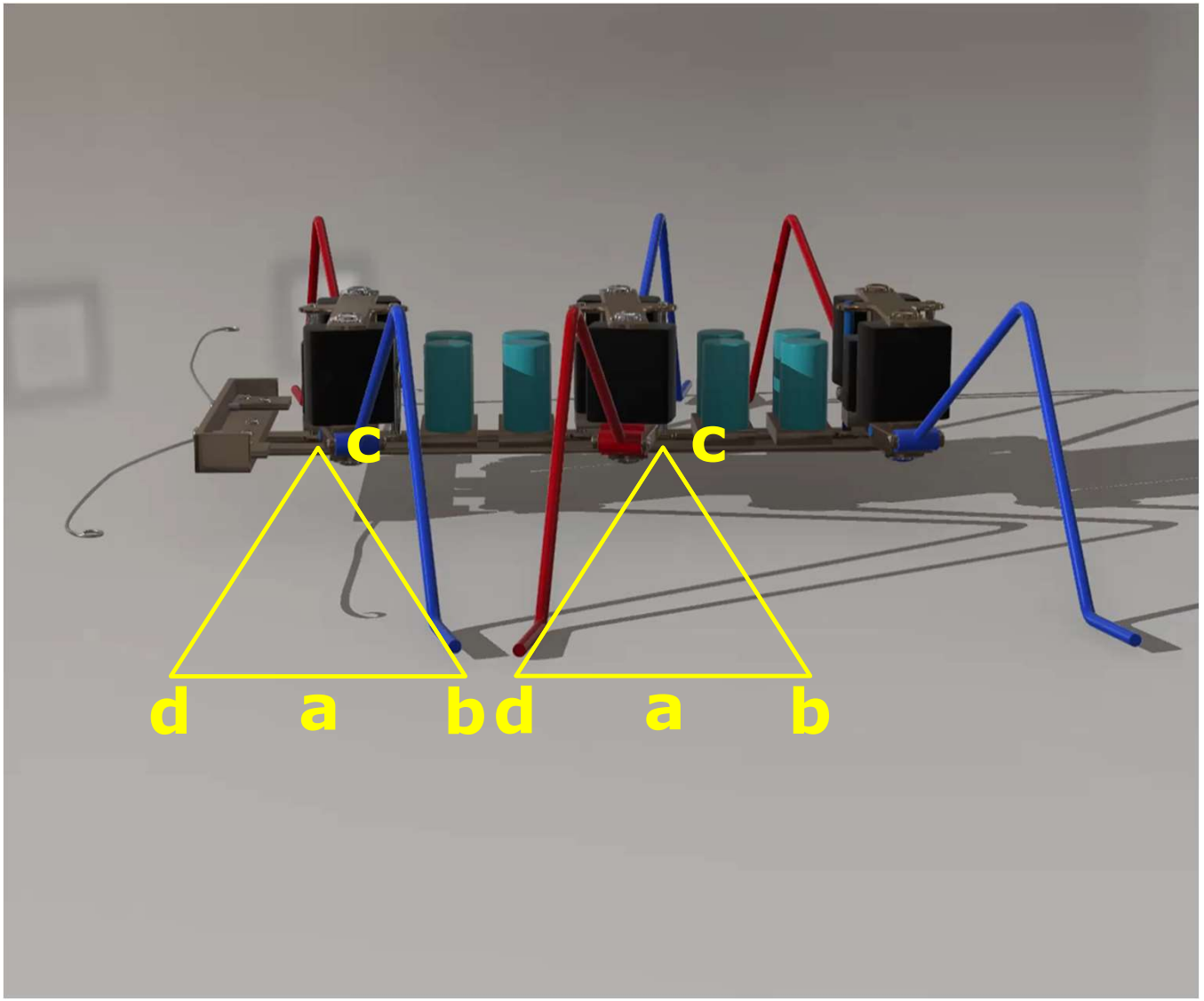

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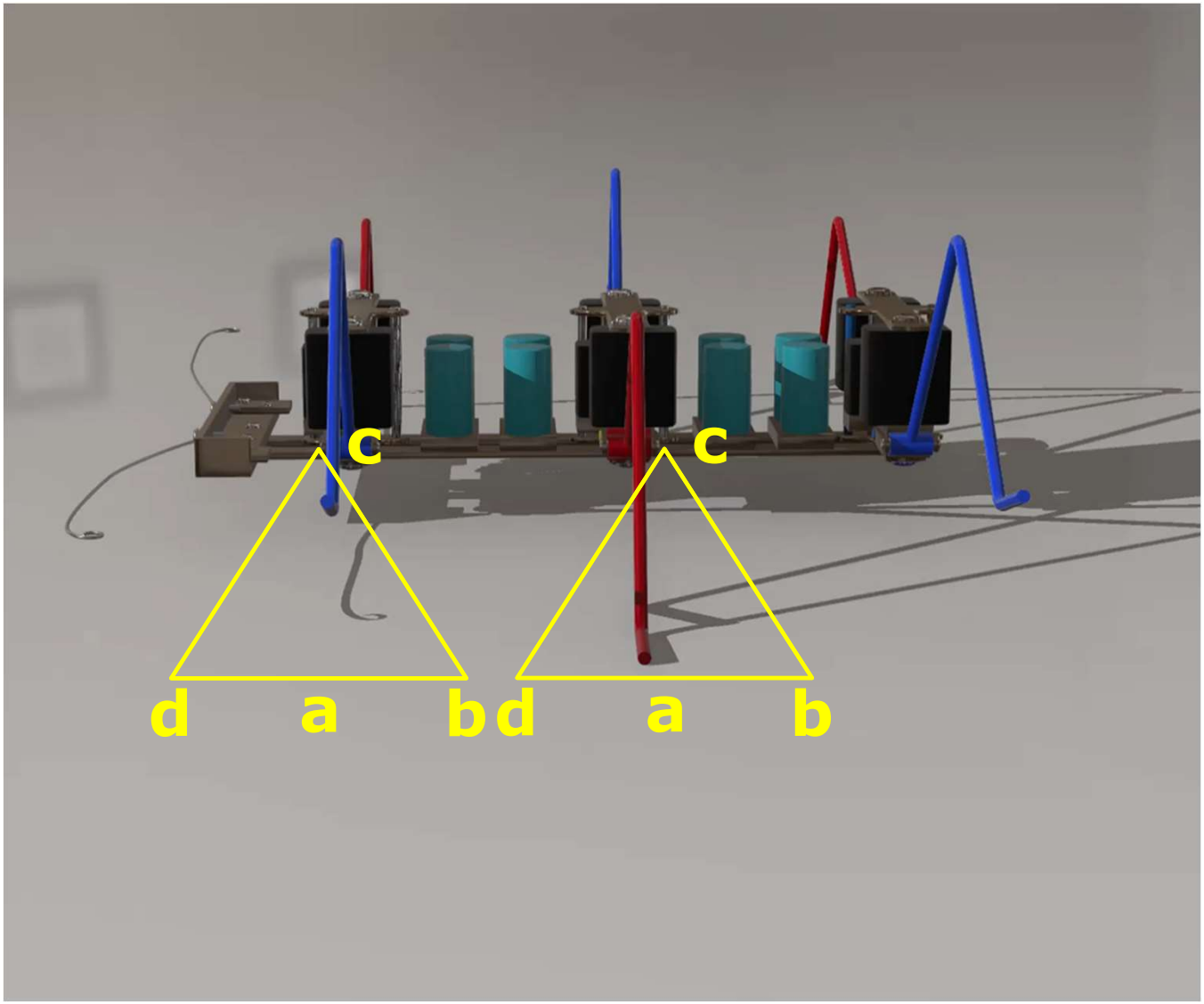
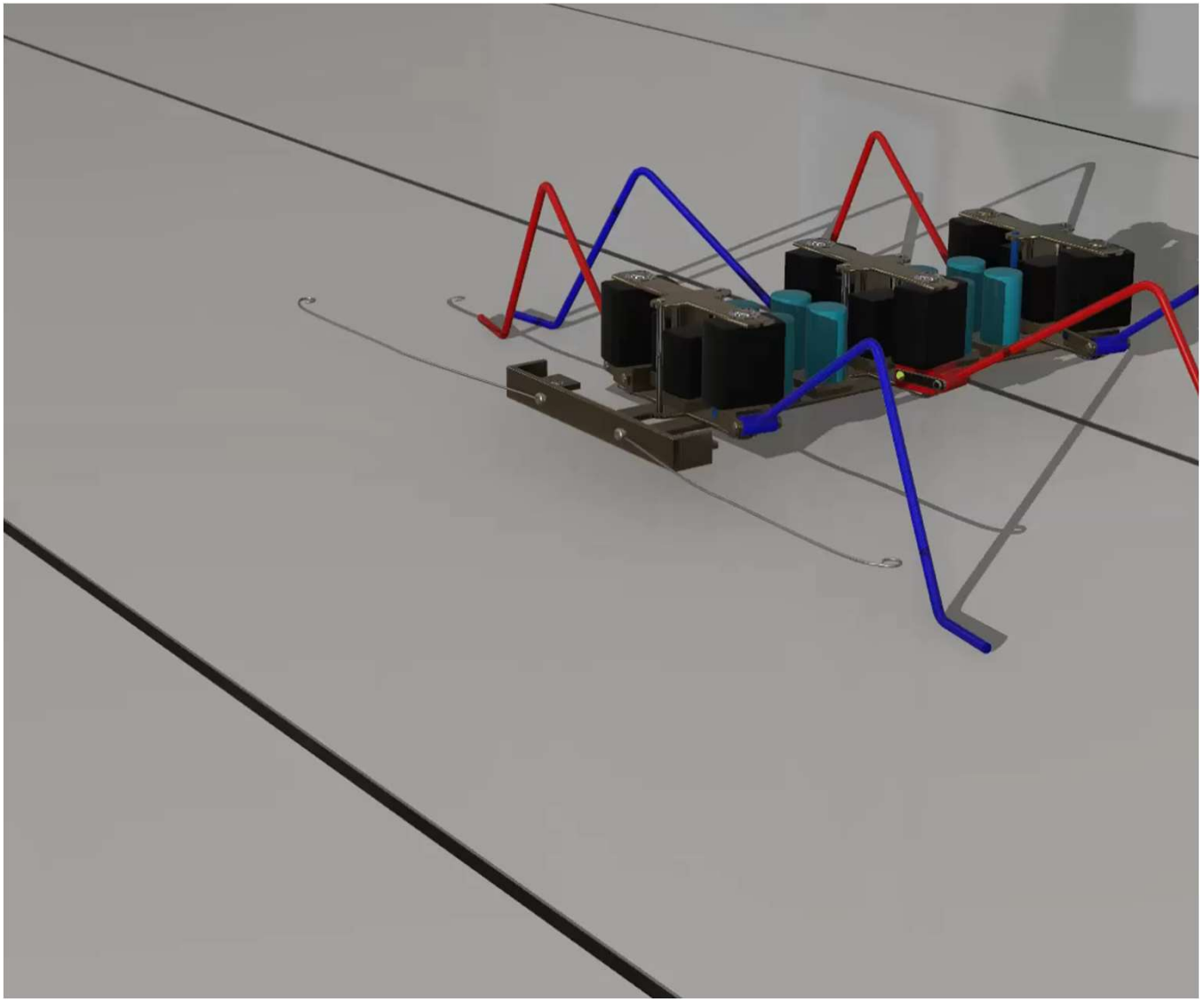


STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM



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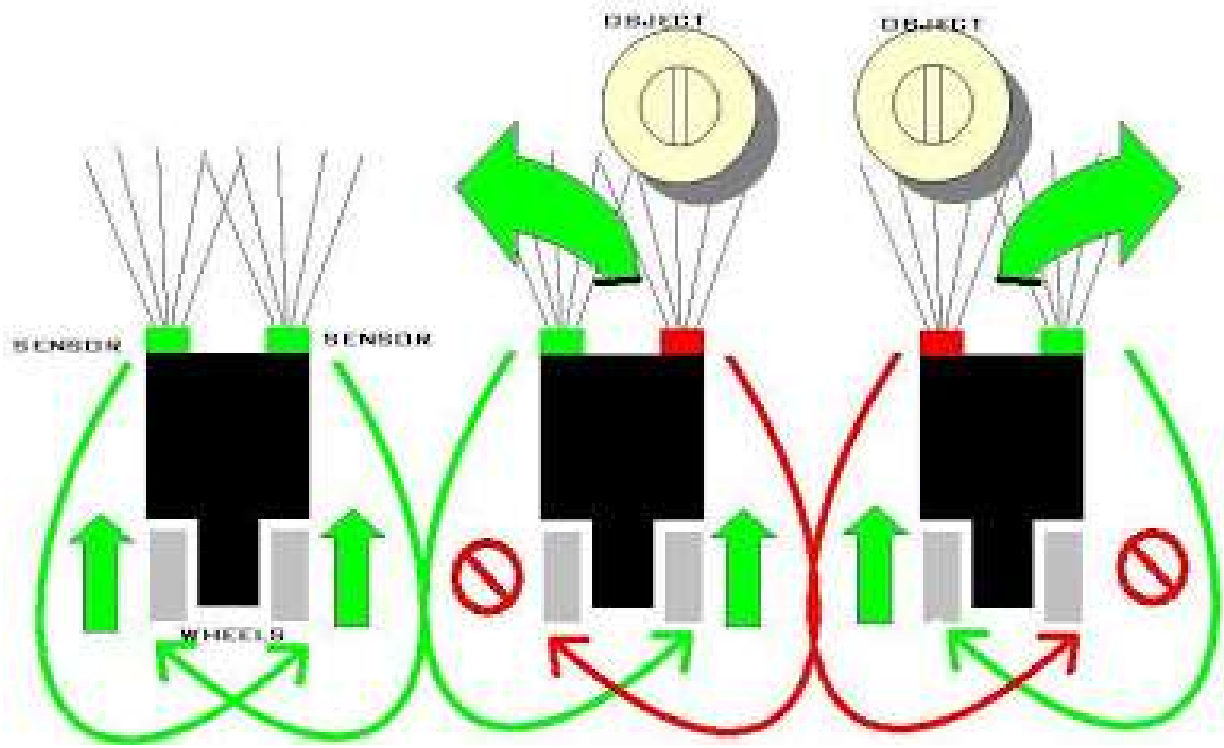
STEP 1: UNDERSTAND THE TASK, DEFINE THE PROBLEM

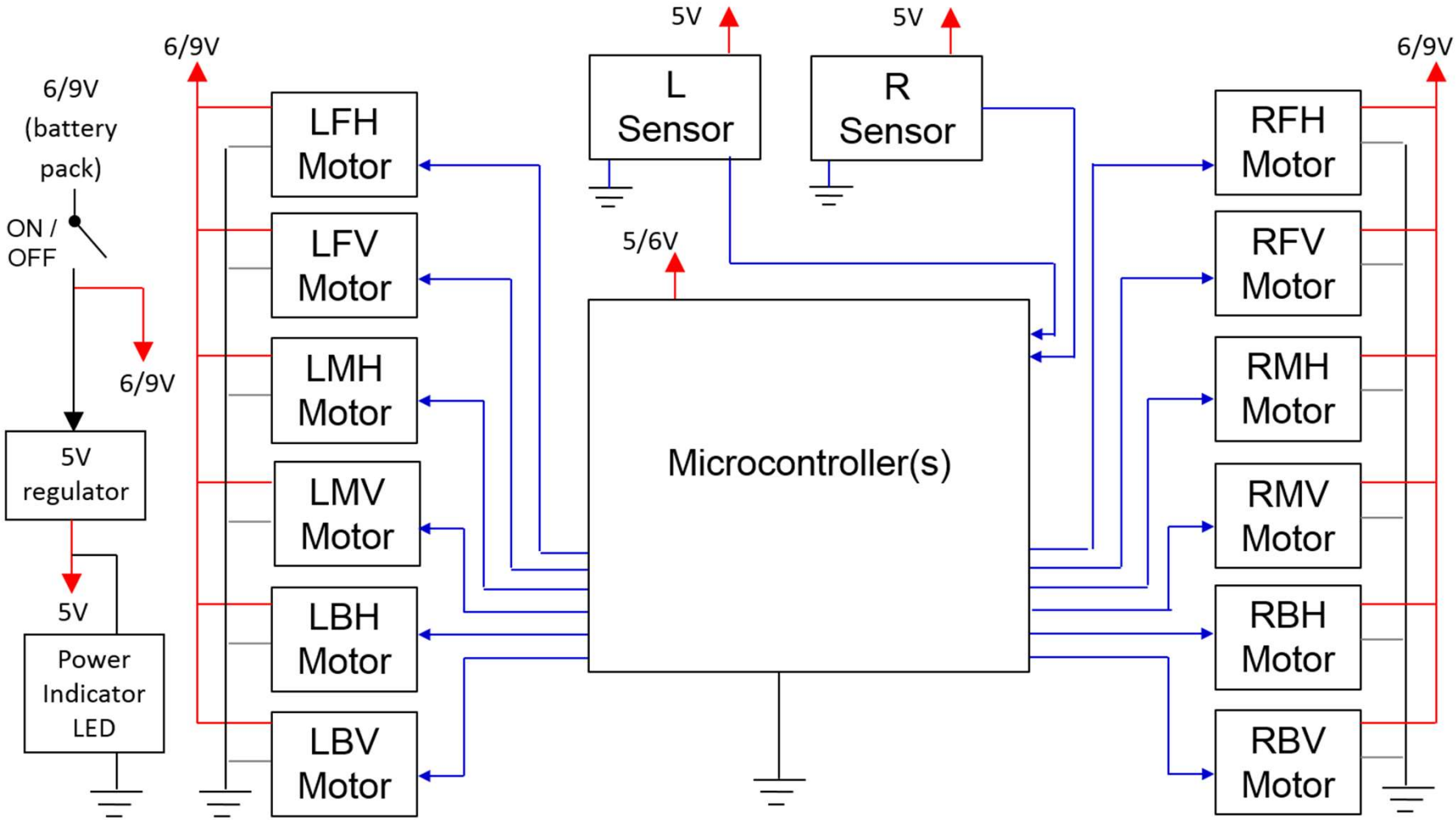
OBSTACLE AVOIDANCE

– Contact or non-contact sensors

– Avoidance strategy



STEP 2: SKETCH A FUNCTIONAL BLOCK DIAGRAM



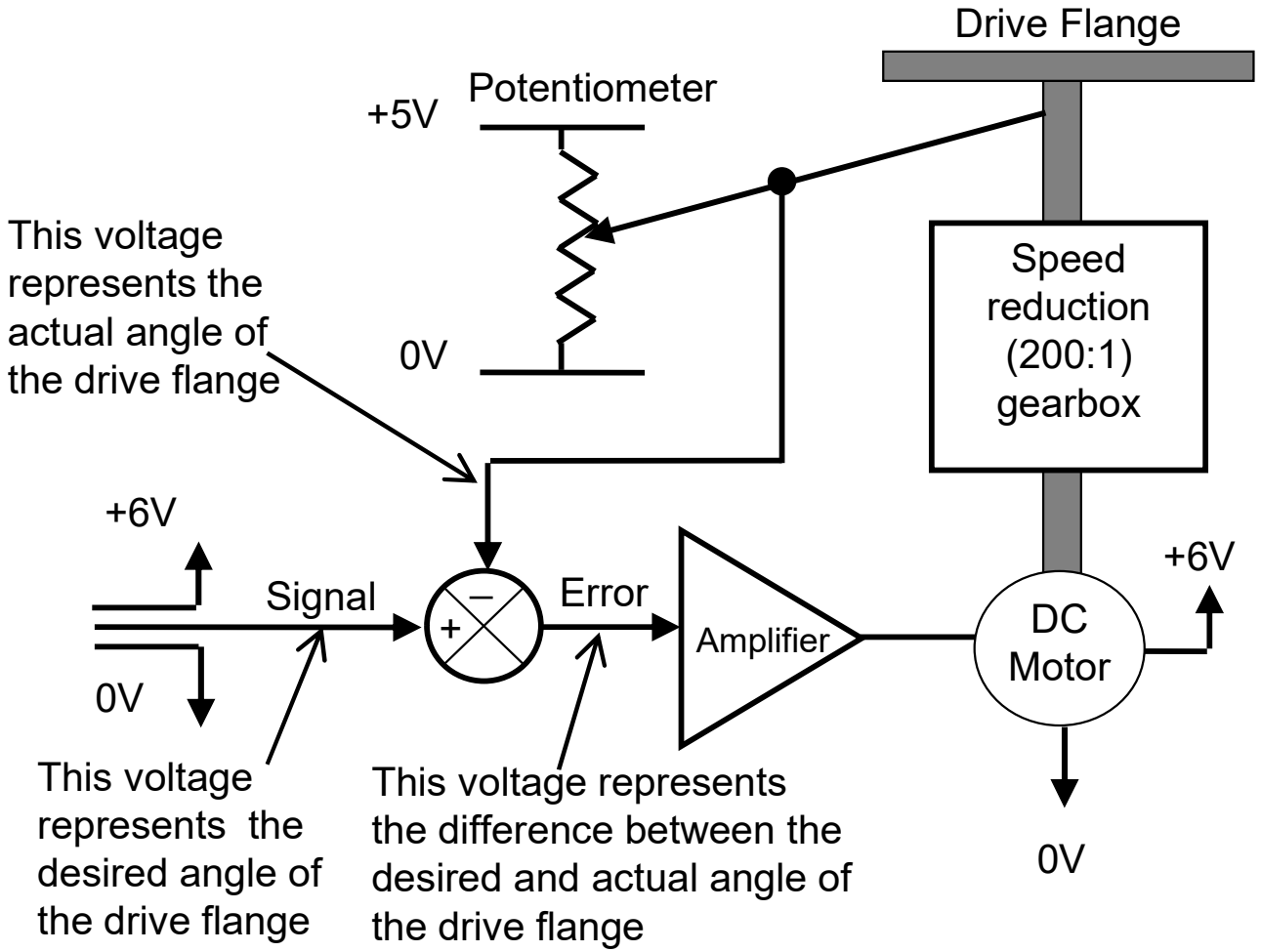
STEP 3: DECIDE & SELECT MECHATRONICS COMPONENTS

ACTUATORS: SERVO X 12

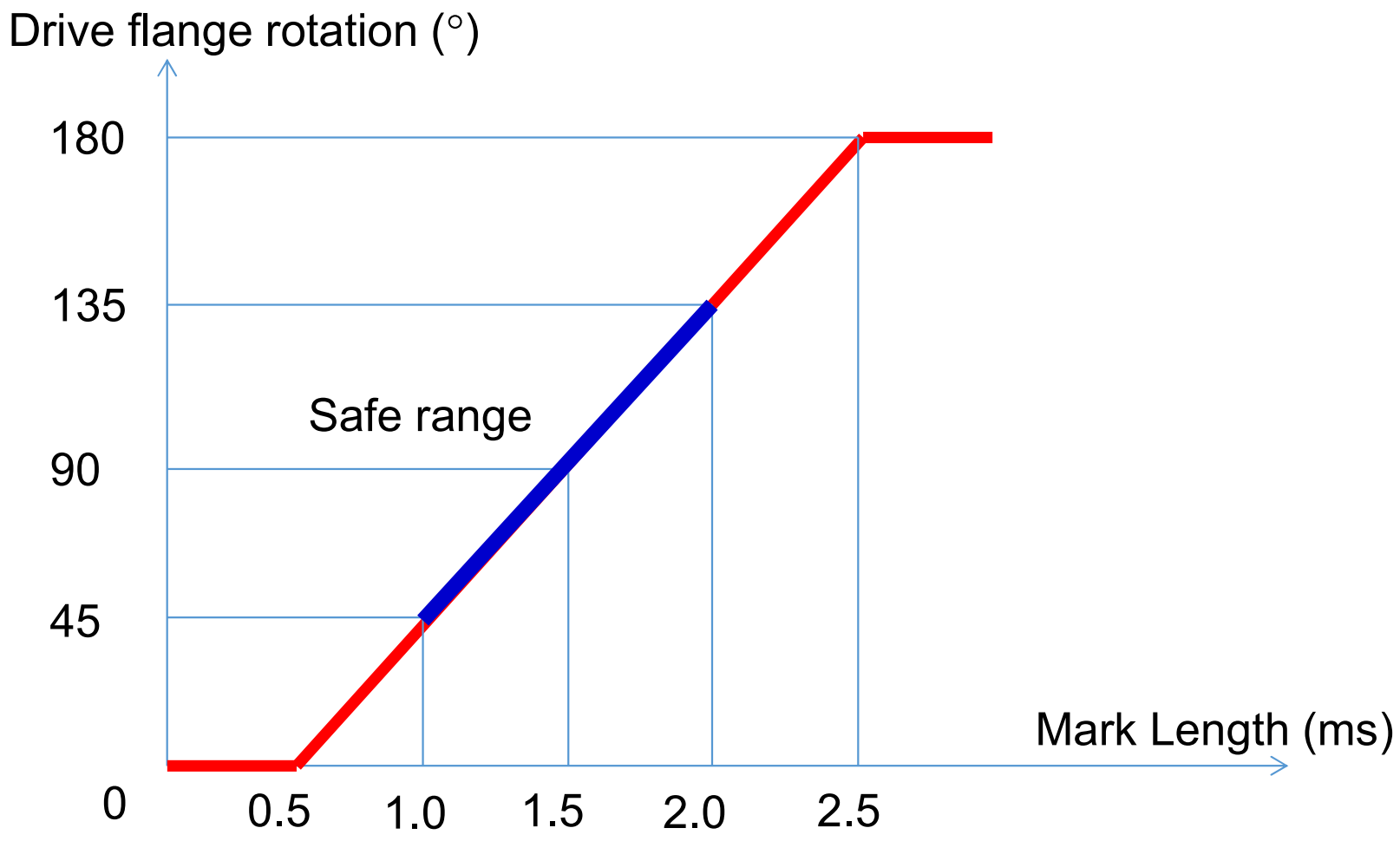
- The drive flange can rotate ½ revolution
- It is driven by width of high pulse (Logic 1) called 'Mark' length

ACTUATORS: SERVO

-90° to +90°

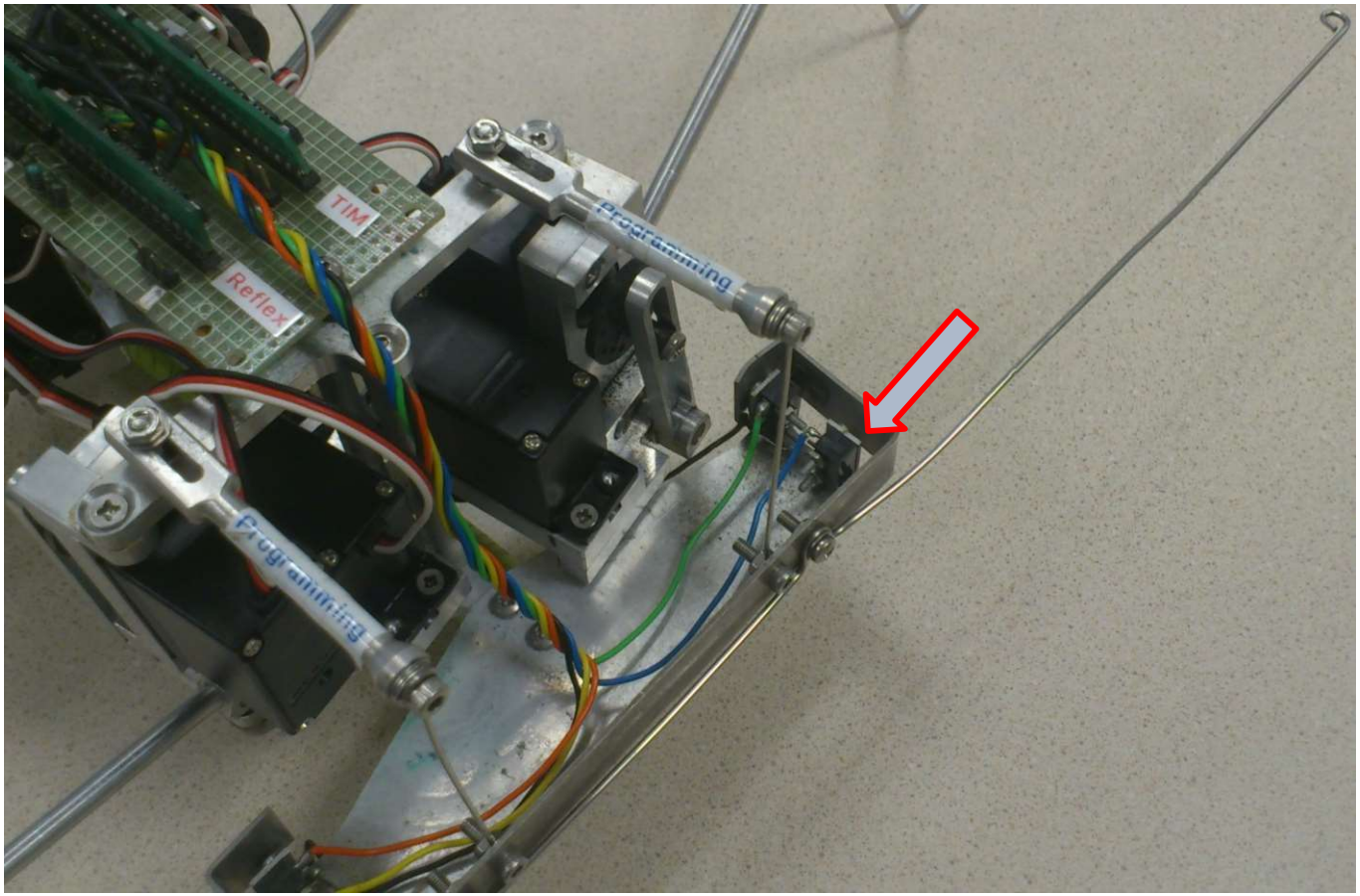


STEP 3: DECIDE & SELECT MECHATRONICS COMPONENTS

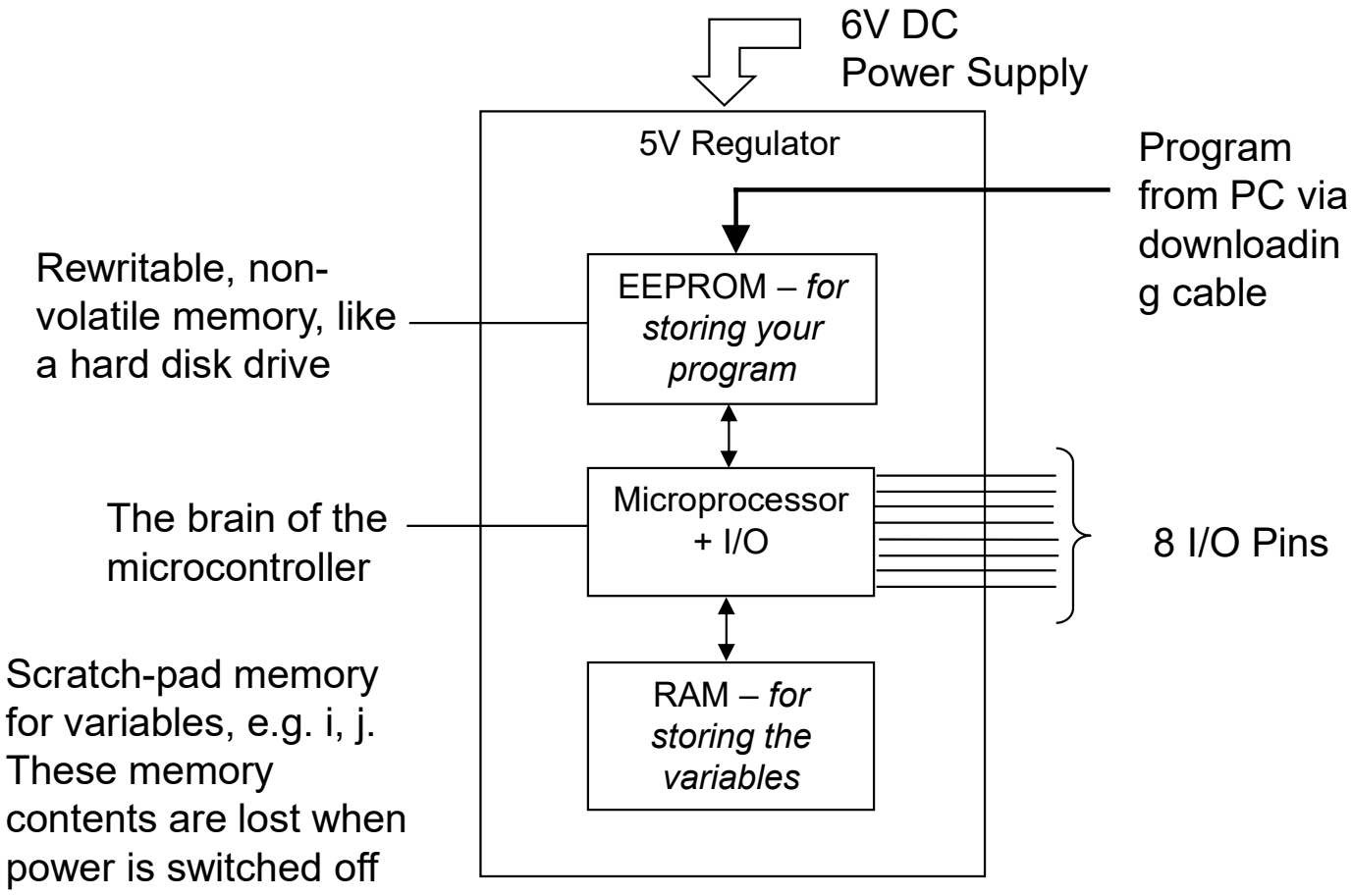


STEP 3: DECIDE & SELECT MECHATRONICS COMPONENTS

SENSORS: LIMIT SWITCH (CONTACT SENSOR) X 2

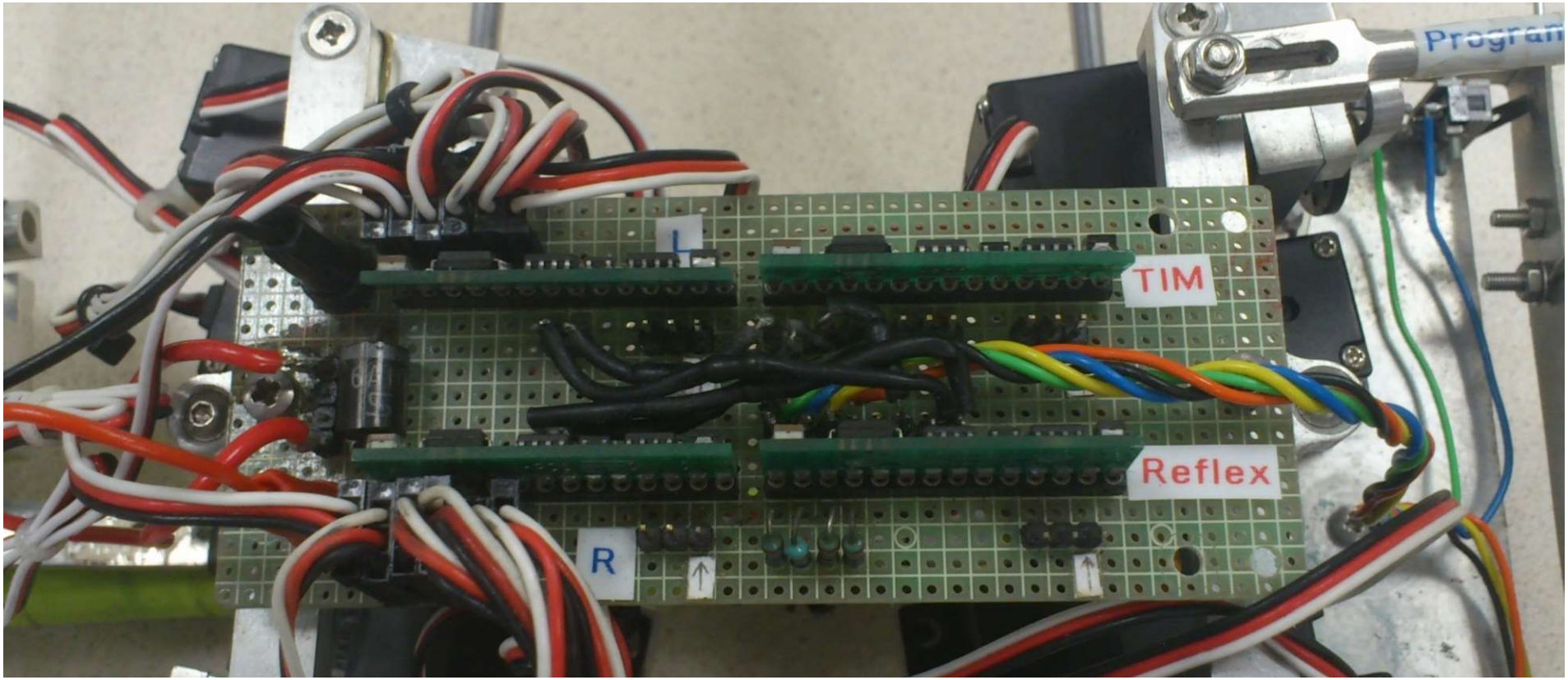


CONTROL ARCHITECTURE: BASIC STAMP BS1 X 4



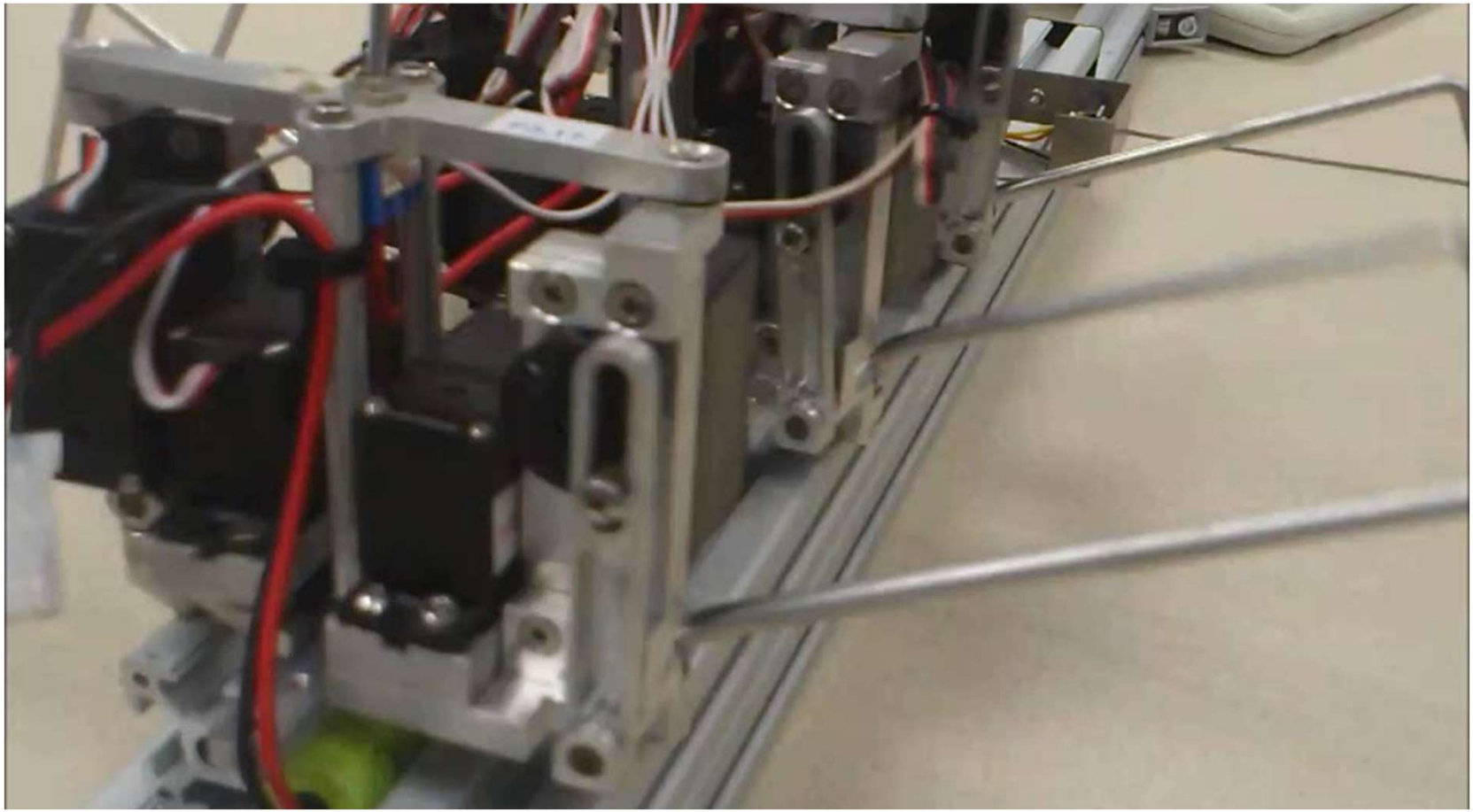
STEP 4: CONSTRUCT HARDWARE PROTOTYPE

CONTROL CIRCUIT PCB



STEP 4: CONSTRUCT HARDWARE PROTOTYPE

2 DOF LEG MECHANISM



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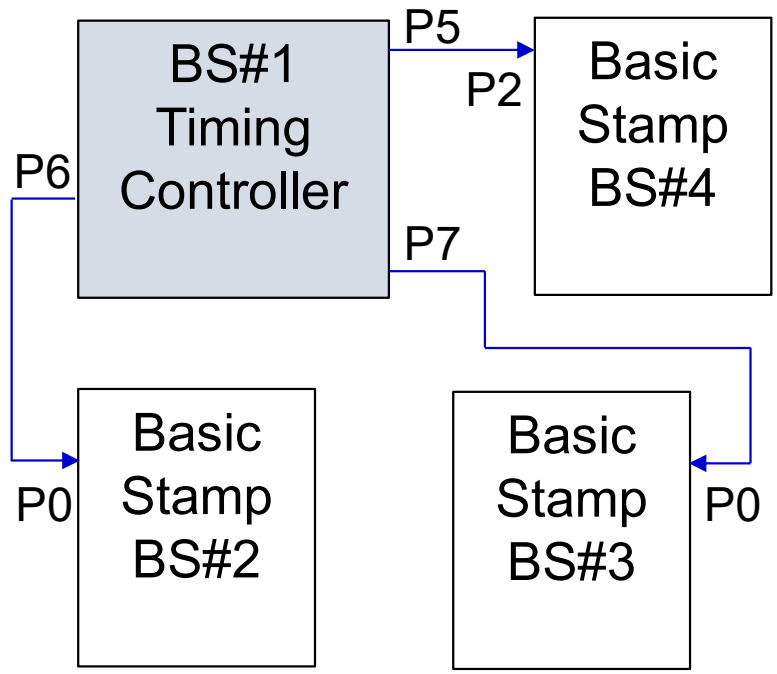
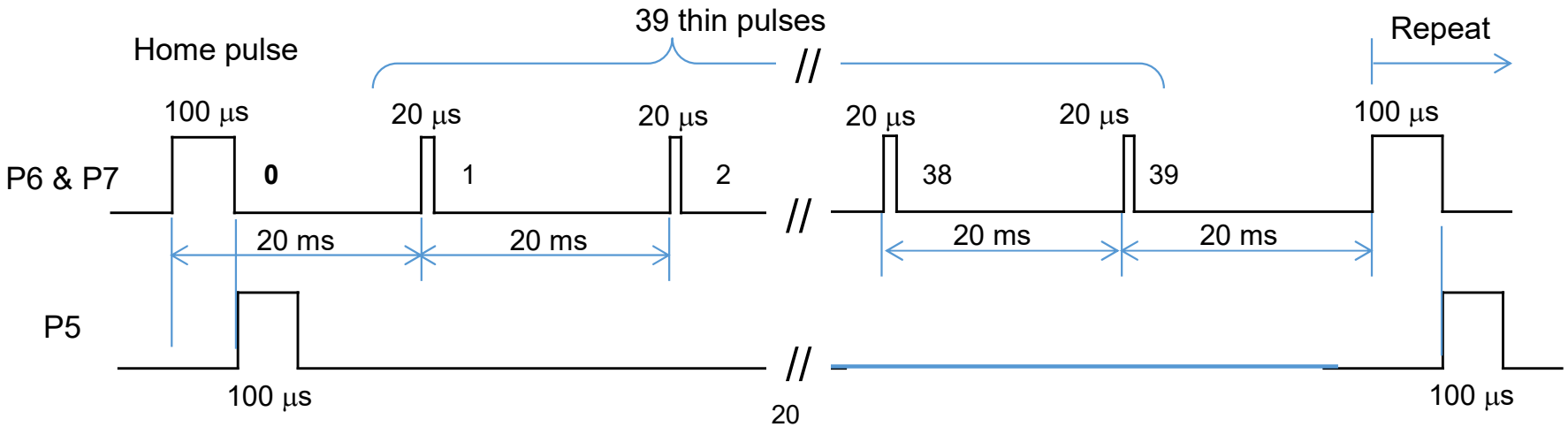
BASIC STAMP #1: TIMING CONTROLLER

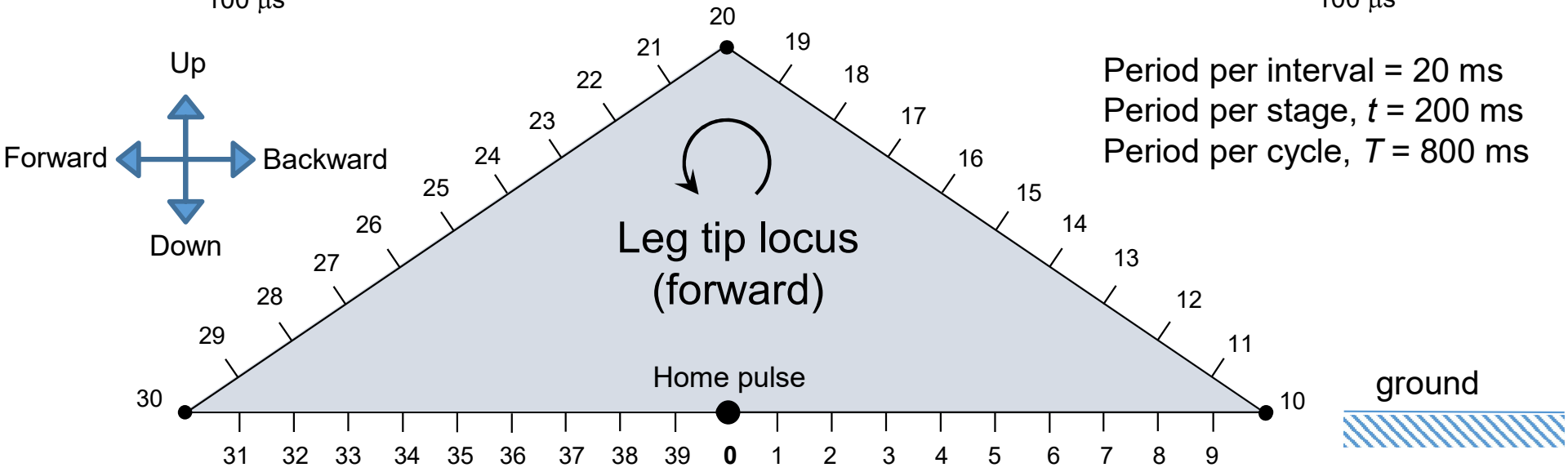
– To send timing pulses to all other Basic Stamps to synchronize the movement of the legs:

- Home pulse (100μs) + 39 thin pulses (20μs) at intervals of 20 ms over a period of 800 ms
- Update frequency = 50 Hz



BASIC STAMP #1: TIMING CONTROLLER



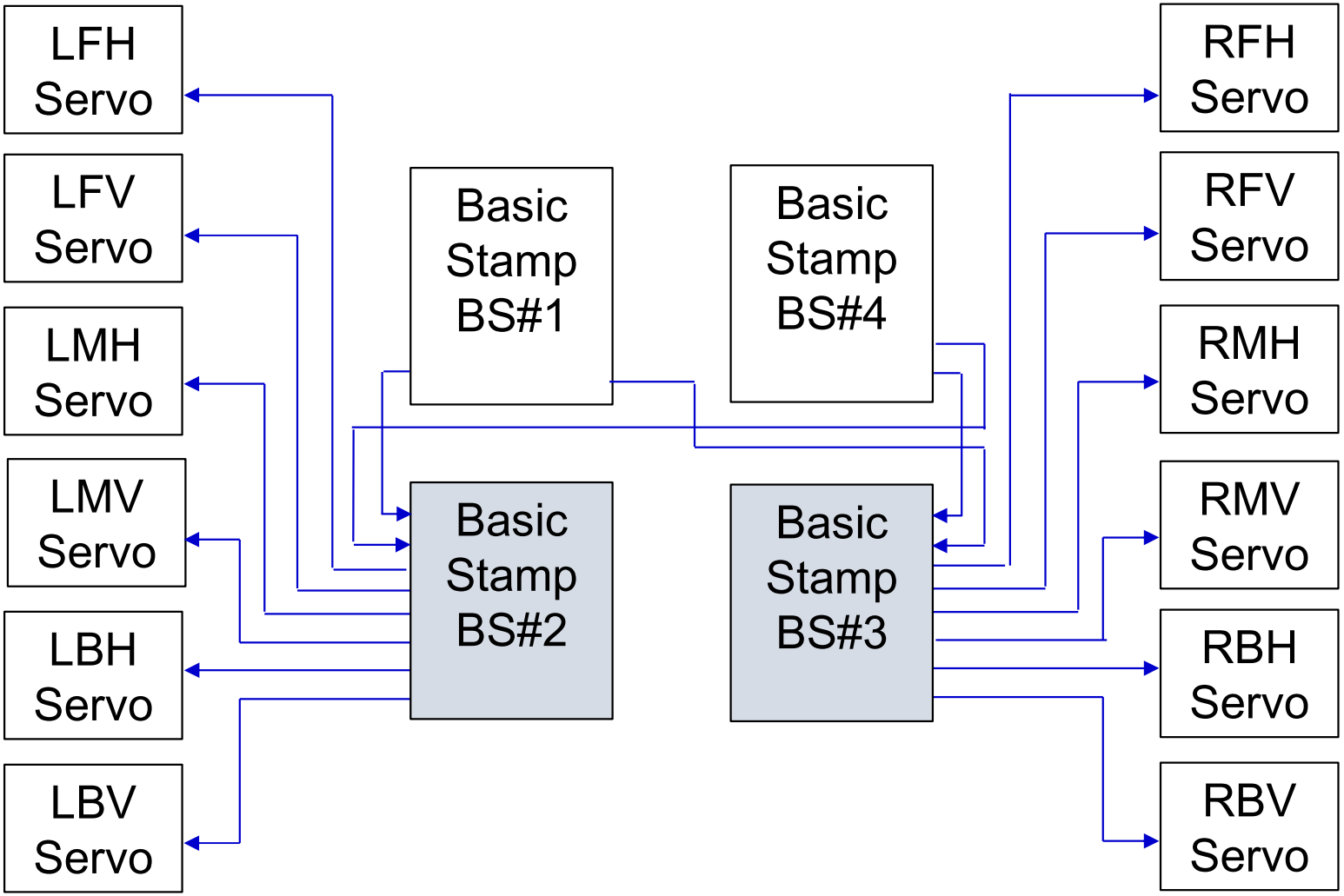


STEP 5: PROGRAMMING

BS#2 & #3: L & R LEG CONTROLLERS

– Control 6 servos each (P2-7)

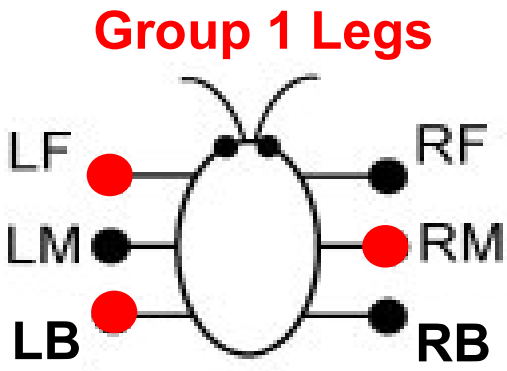
– Receives timing from BS#1 (P0) & direction from BS#4 (P1)

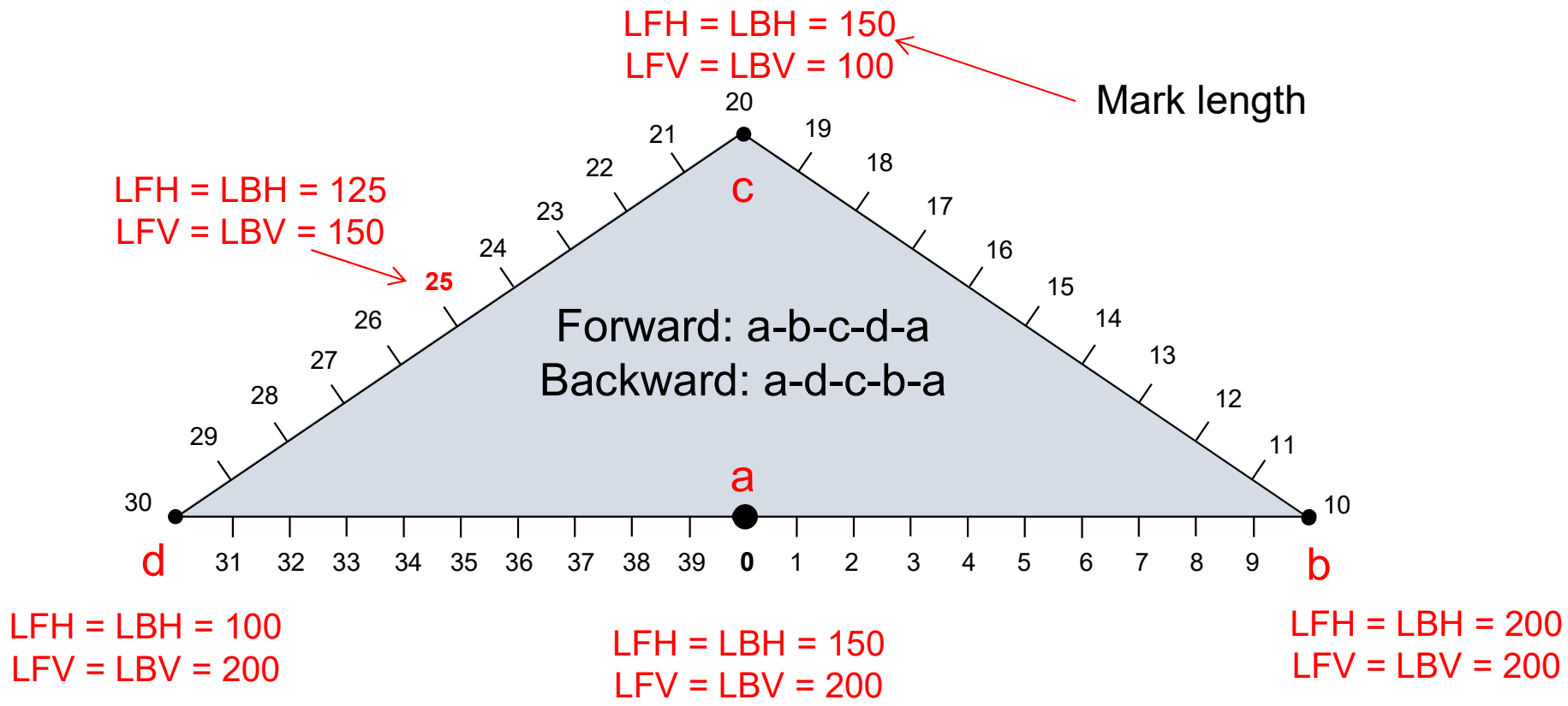


STEP 5: PROGRAMMING

BASIC STAMP #2 & #3:

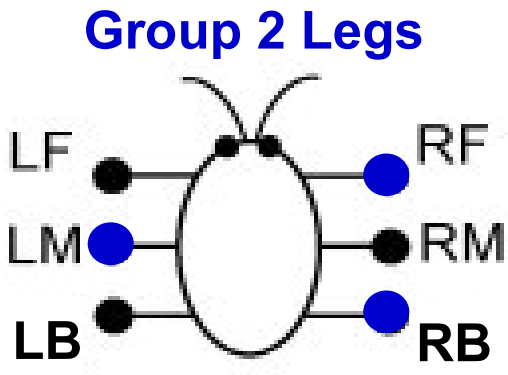
- *Left* & Right Legs Controllers

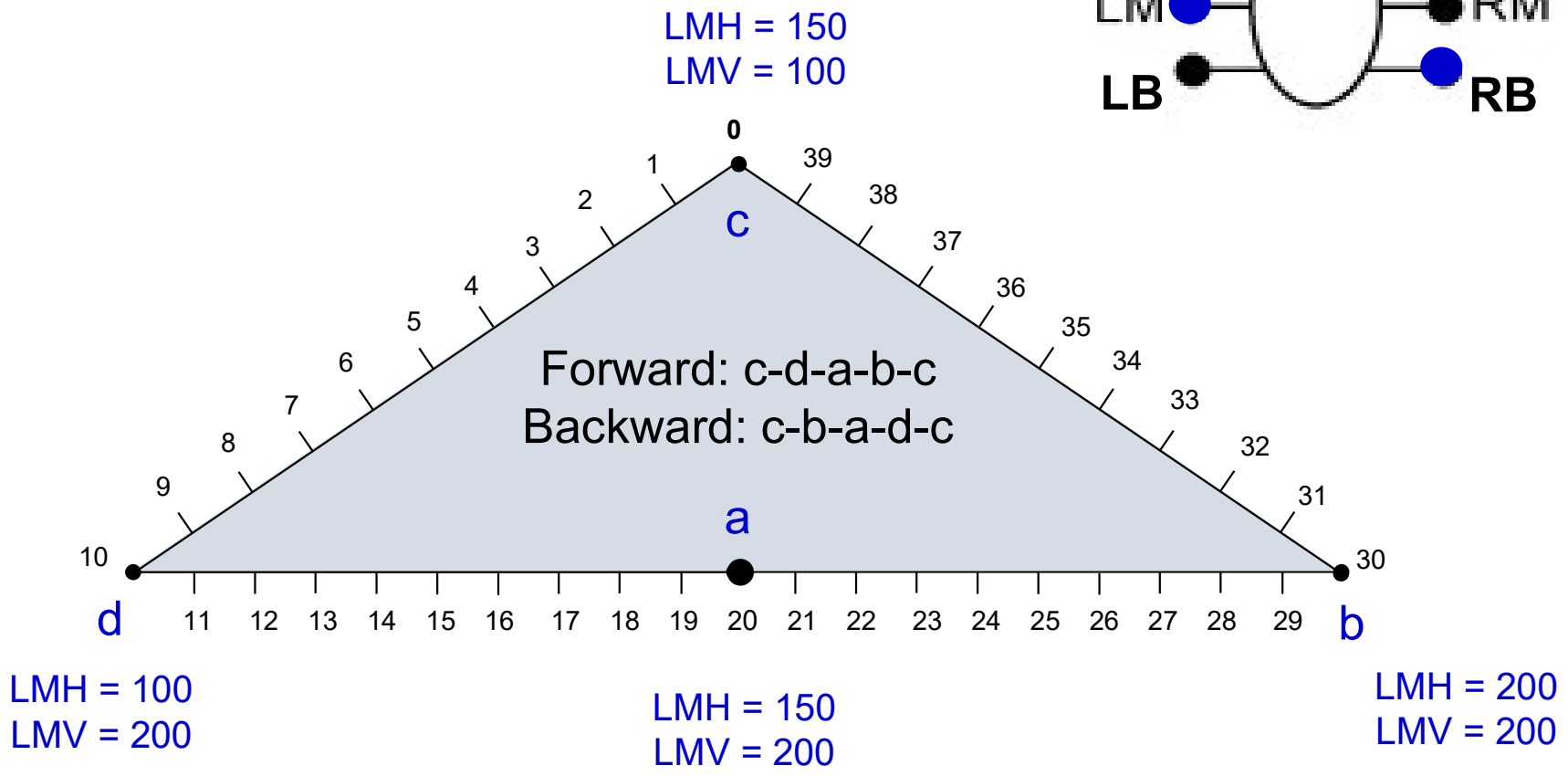




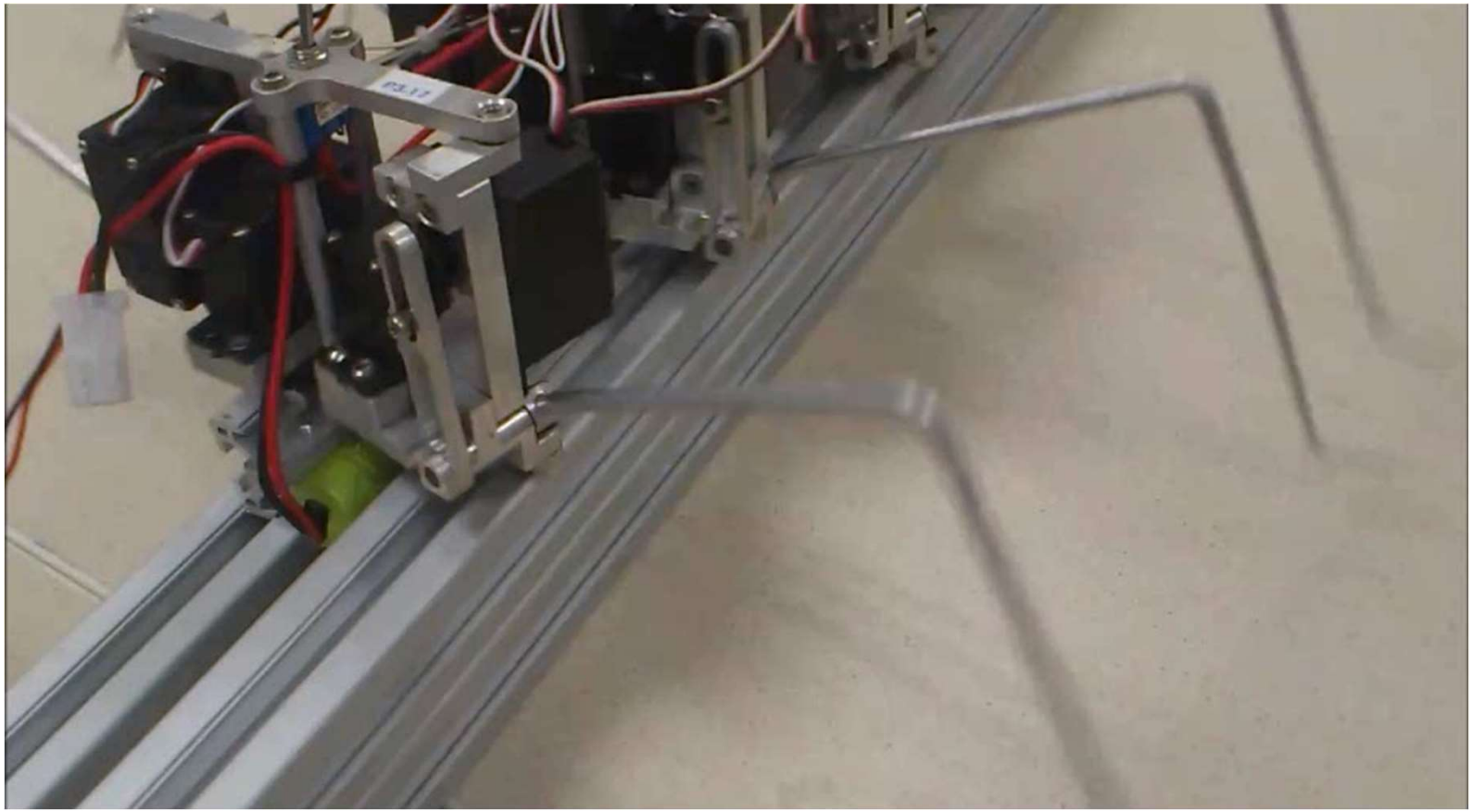
BASIC STAMP #2 & #3: *LEFT* & RIGHT LEGS CONTROLLERS

- Movement of Group 2 Legs is 180° phase offset from Group 1





TRIPOD GAIT



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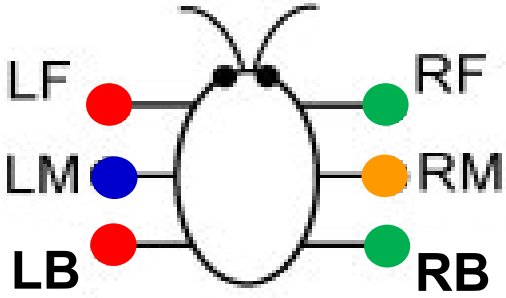
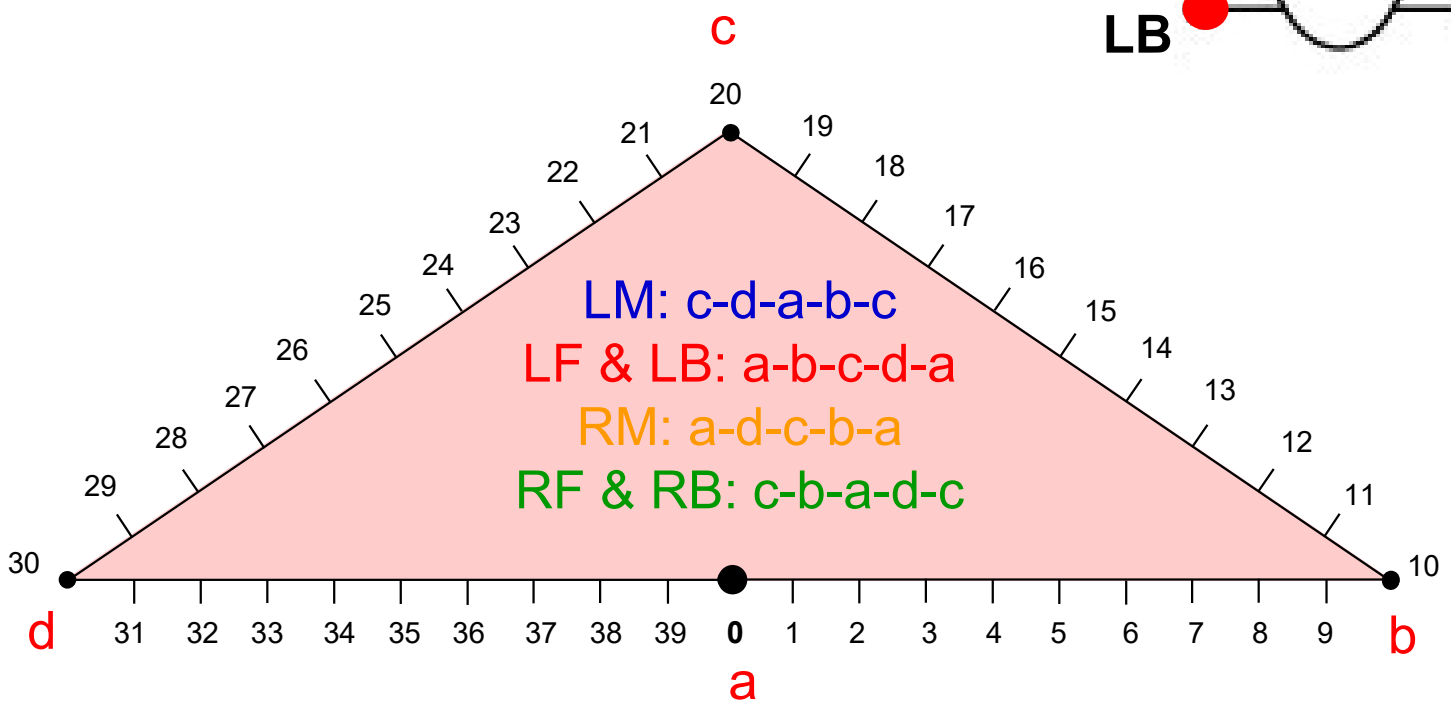
STEP 5: PROGRAMMING

BASIC STAMP #2 & #3: LEFT & RIGHT LEGS CONTROLLERS - ROTATE RIGHT:

- Left legs forward
- Right legs backward

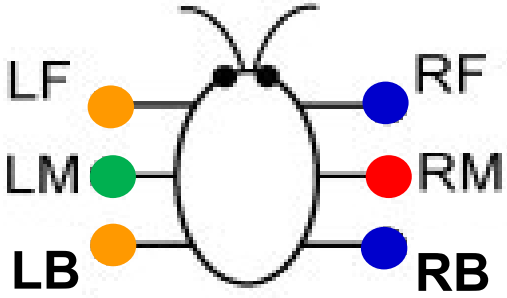


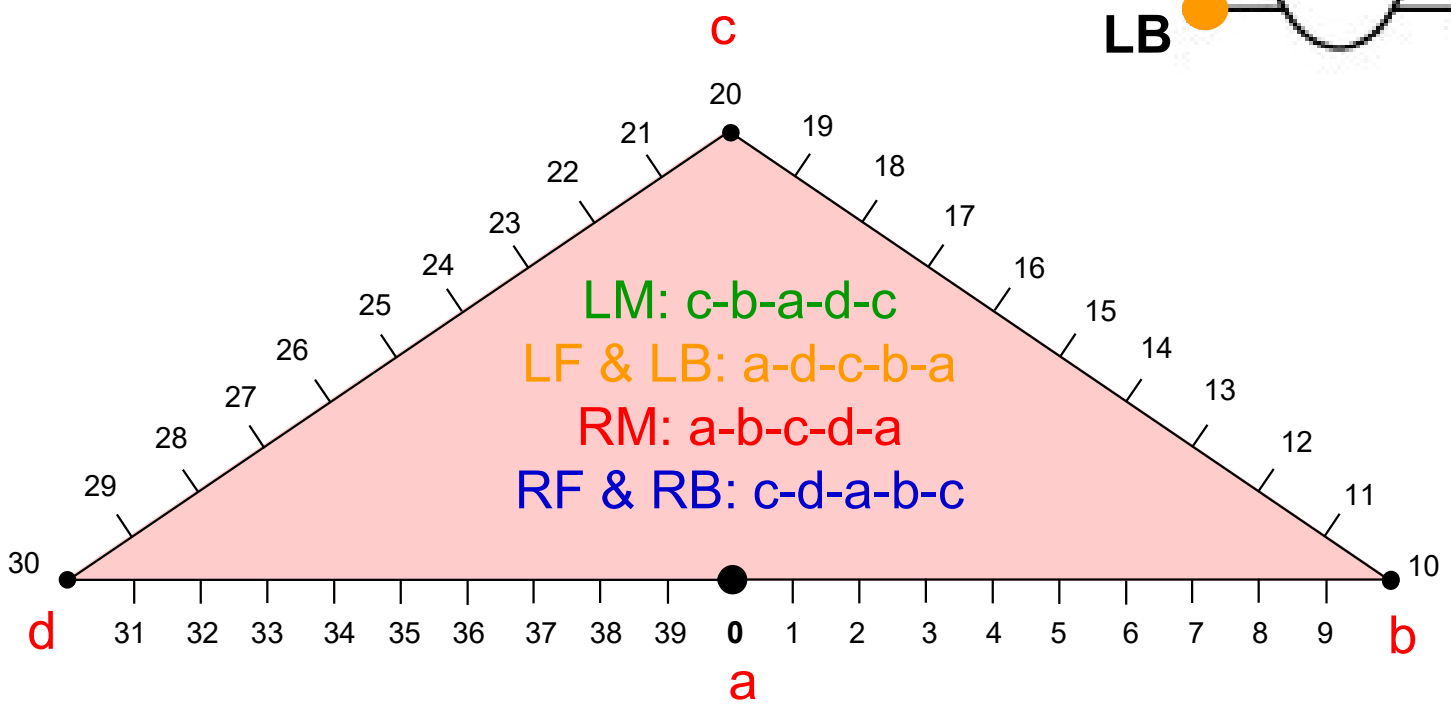


STEP 5: PROGRAMMING

BASIC STAMP #2 & #3: LEFT & RIGHT LEGS CONTROLLERS - ROTATE LEFT:

- Left legs backward
- Right legs forward

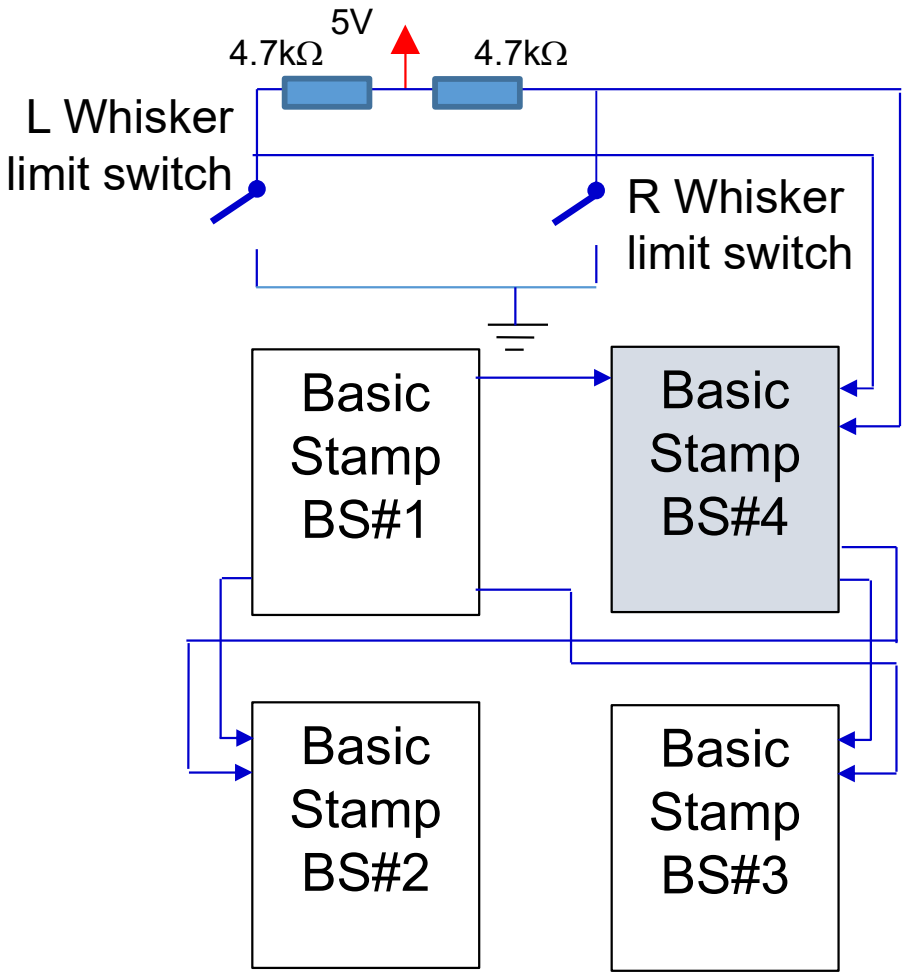




STEP 5: PROGRAMMING

BASIC STAMP #4: REFLEX CONTROLLER

- BS#4 receives a LOW (0) when Left & Right Whisker limit switches are closed
- BS#4 sends signals to P0 & P1 of BS#2 & BS#3 respectively to control forward / backward directions:
  - LOW(0)–backward; HIGH(1)-forward
  - P0=0 & P1=1: Rotate Right
  - P0=1 & P0=0: Rotate Left



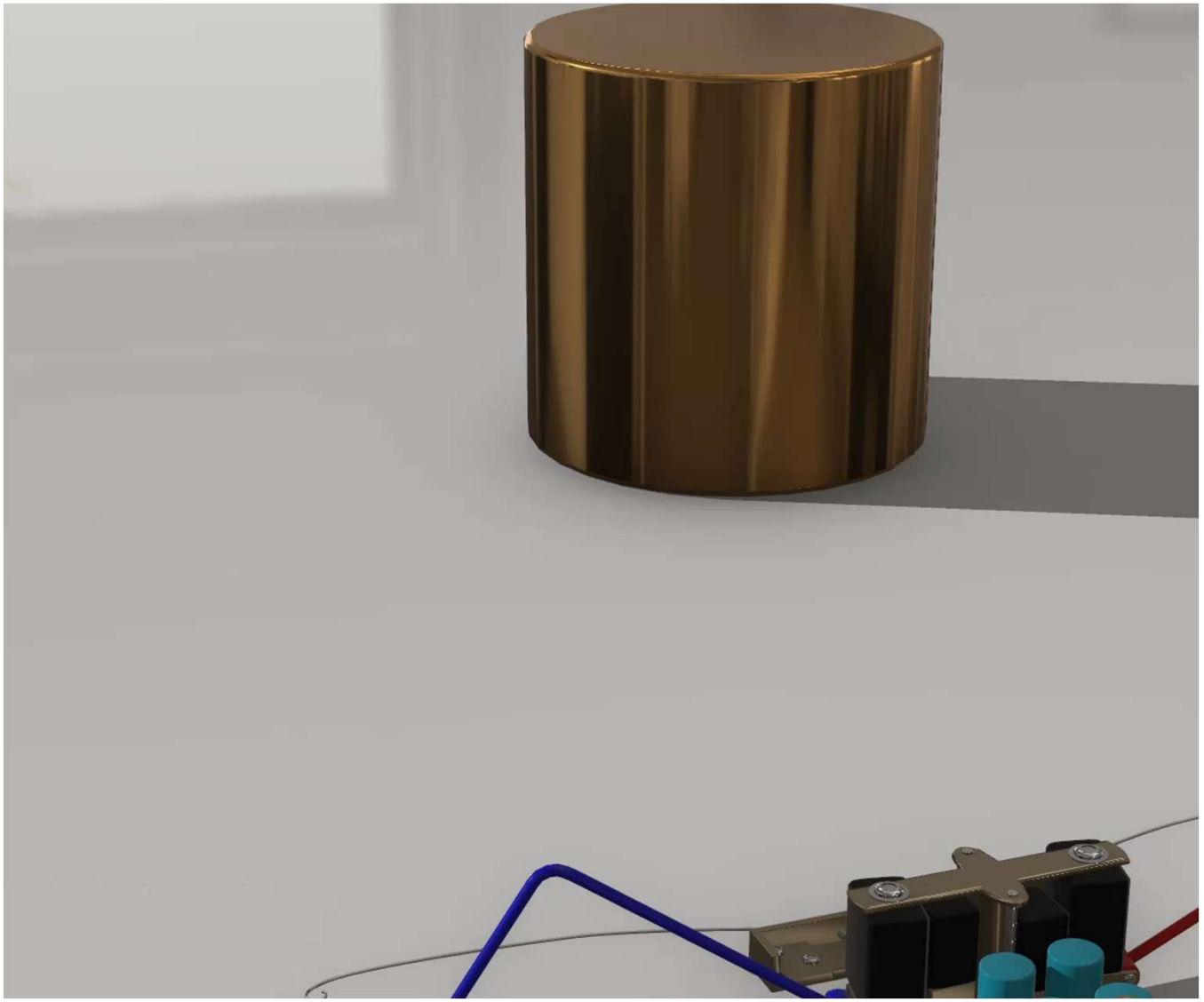
STEP 5: PROGRAMMING

BASIC STAMP #4: REFLEX CONTROLLER

– Obstacle avoidance strategy:

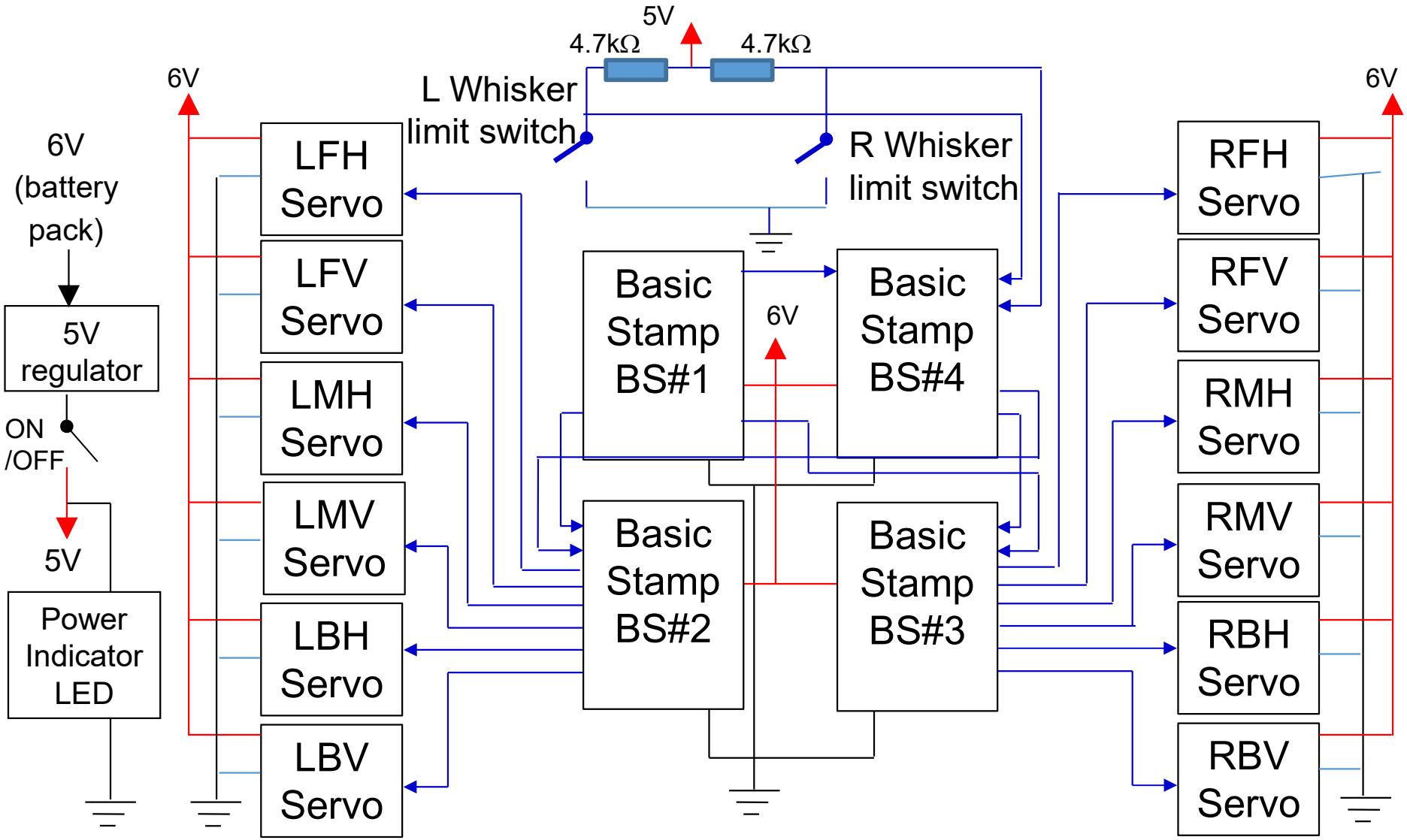
- If Right Whisker limit switch activated
  - Go backward (P0 = P1 = 0) for 3 cycles (BS#2 & BS#3 receive Home pulse 3 times)
  - Rotate left (P0 = 1, P1 = 0) for 2 cycles
  - Go forward (P0 = P1 = 1)
- If Left Whisker limit switch activated
  - Go backward (P0 = P1 = 0) for 3 cycles
  - Rotate right (P0 = 0, P1 = 1) for 2 cycles
  - Go forward (P0 = P1 = 1)

OBSTACLE AVOIDANCE

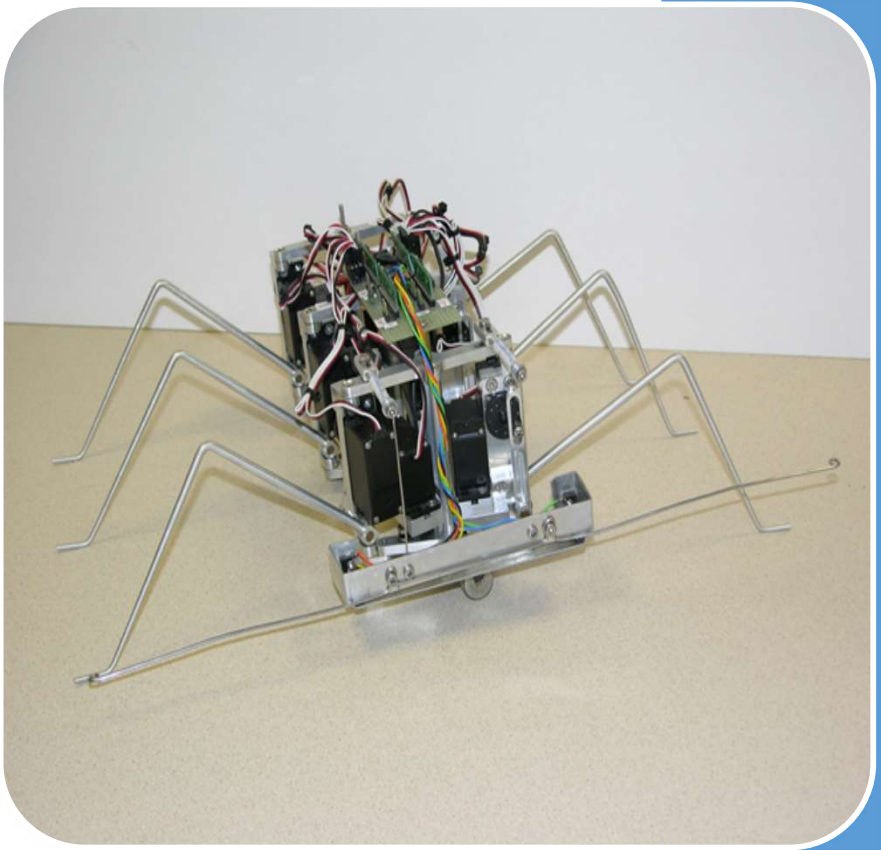


Click this image to play animation

A COMPLETE BLOCK DIAGRAM



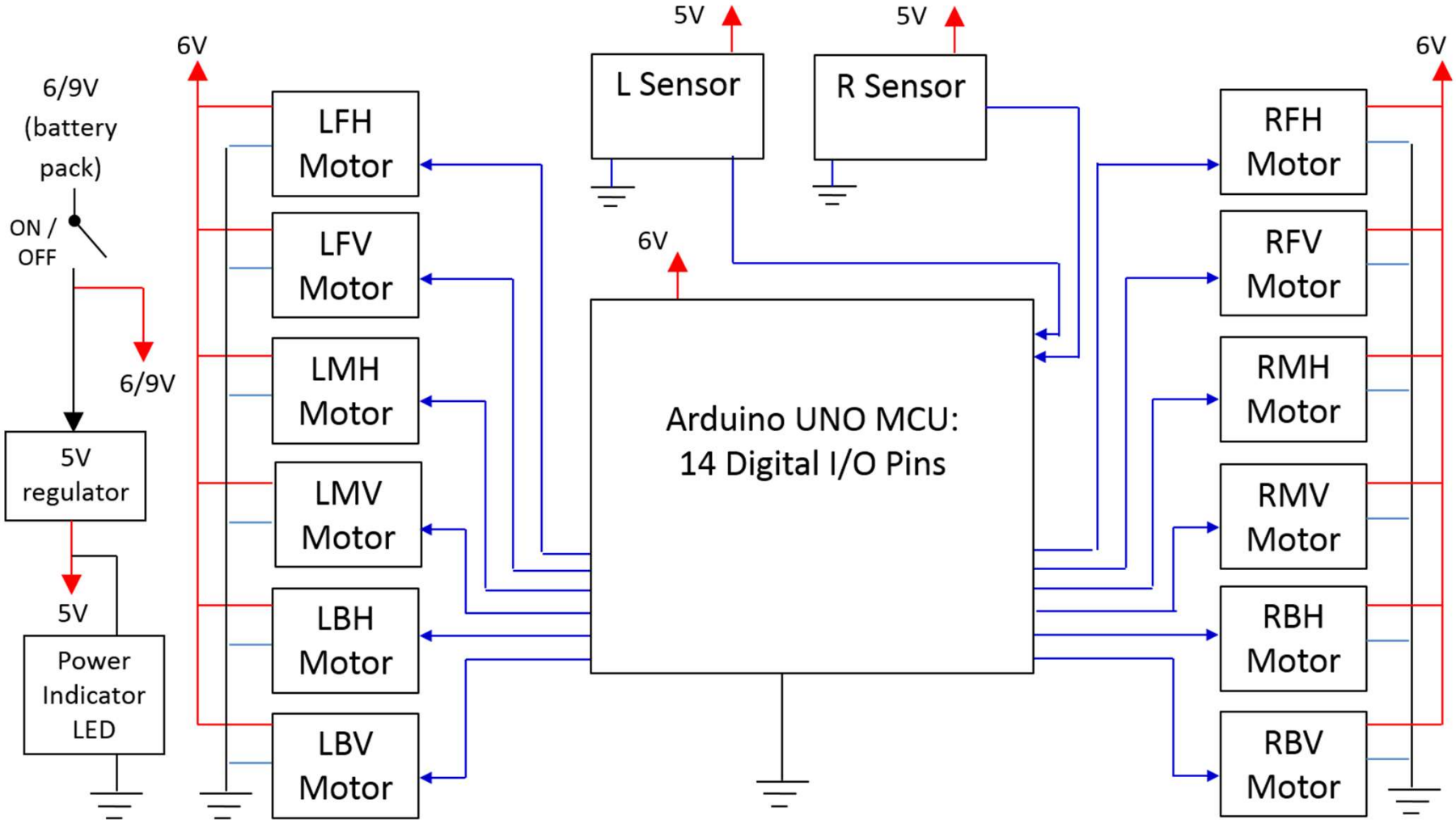
REDESIGN THE CONTROL ARCHITECTURE WITH ARDUINO UNO MCU



How many pieces of Arduino UNO MCU would be needed for this application?

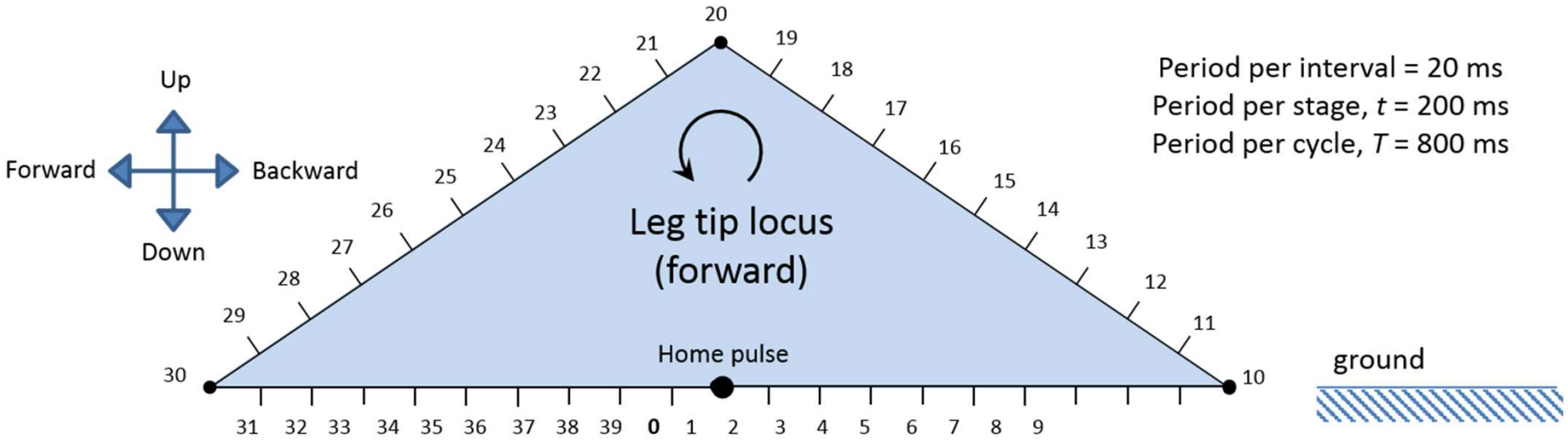
- 1
- 2
- 3
- 4

FUNCTIONAL BLOCK DIAGRAM



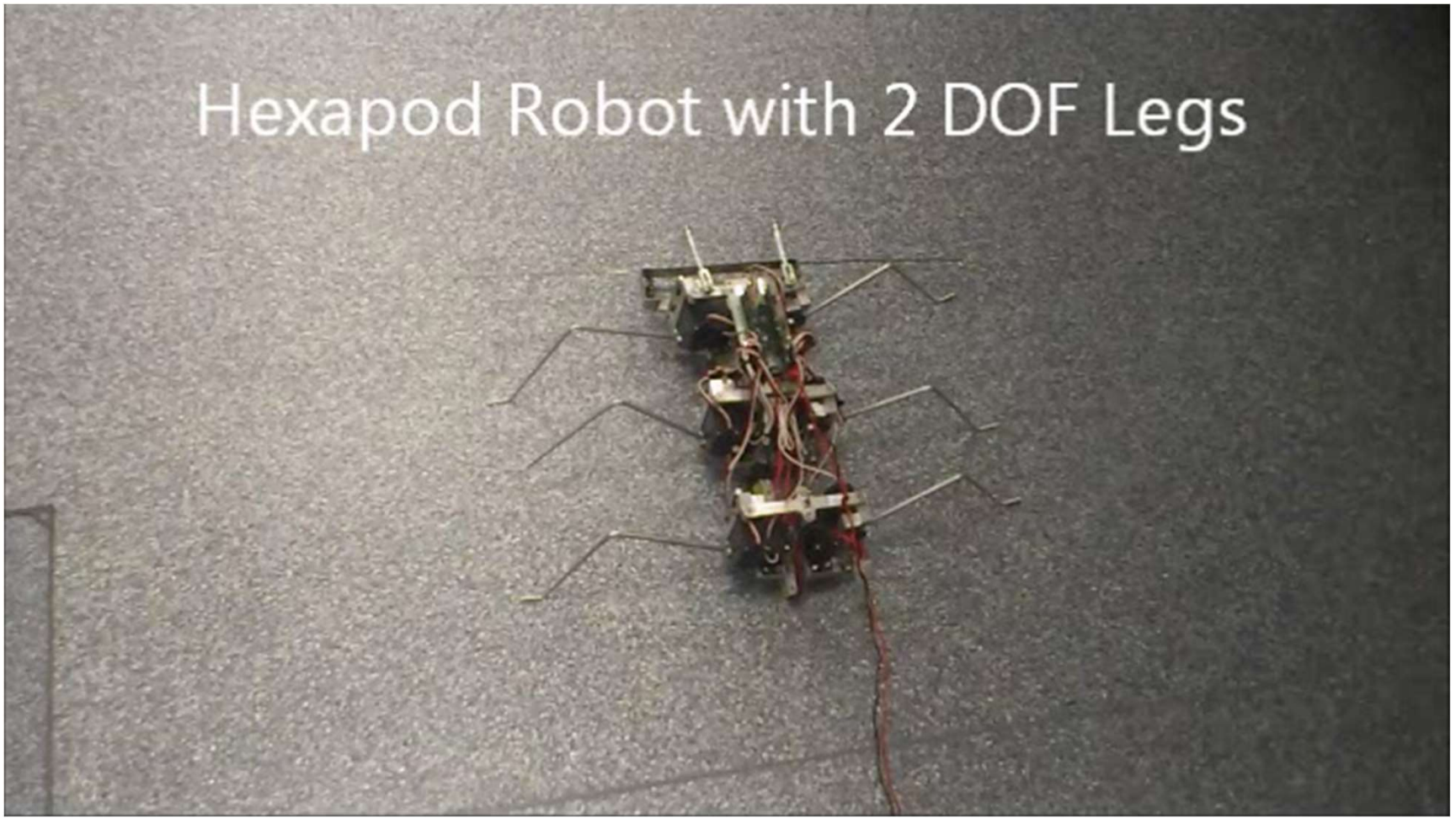
PROGRAMMING

- Timing Controller Basic Stamp to be replaced with internal timer to trigger movement every 20 ms



- Just 1 MCU to control the left & right legs, i.e. the MCU has total knowledge of all its components, which enables more sophisticated control strategy

HEXAPOD ROBOT WITH 2 DOF LEGS



Click this image to play video

SUMMARY: MECHATRONICS SYSTEMS DESIGN

1. Understand the task, define the problem
2. Sketch a functional block diagram
3. Decide & select mechatronics components (type, number, communication protocol, etc.) :
   - Digital control architecture
   - Sensors & input interfacing
   - Actuators & output interfacing
   - Display
4. Construct hardware prototype
5. Programme software / firmware