

MSP430 Teaching Materials

Chapter 15

Advanced Laboratories

RoboSapien powered by MSP430



Texas Instruments Incorporated
University of Beira Interior (PT)



Pedro Dinis Gaspar, António Espírito Santo, Bruno Ribeiro, Humberto Santos
University of Beira Interior, Electromechanical Engineering Department

Contents

- ❑ **RoboSapien powered by MSP430**
- ❑ **What is RoboSapien?**
- ❑ **How RoboSapien works?**
 - Analysis of the dynamics and kinematics of the robot
 - Analysis of all sensors, actuators and signal conditioning
- ❑ **MSP430 integration (PCB board and electronics)**
- ❑ **MSP430 C code programming**
- ❑ **Tests and development of new functionality**

RoboSapien powered by MSP430 (1/2)

□ **Robotics is being increasingly used as a vehicle for motivating students to learn:**

- Embedded systems;
- Artificial intelligence;
- Computer science;
- And even general science and engineering.

□ **Typically, laboratory classes for courses using robotics involve the construction and programming of simple robots, typically composed of:**

- Microcontroller;
- Sensors;
- Remote communication devices;
- DC or stepper motors;

mounted in all types of robot bodies.

RoboSapien powered by MSP430 (2/2)

- ❑ **The robotics topics involve both in mechanical and electronic engineering. Projects involve both hardware and software development, tailored to a specific application.**

- ❑ **This advanced laboratory takes a multidisciplinary approach and integrates together topics from different knowledge areas:**
 - Control systems, for the different control approaches;
 - Embedded systems based on the MSP430;
 - Instrumentation and measurements for the sensor signal conditioning and data acquisition;
 - C/C++ programming.

What is RoboSapien? (1/7)

- ❑ **The RoboSapien is a humanoid robot designed by Mark W. Tilden, marketed by WowWee () for the toy market;**
- ❑ **The RoboSapien measures approximately 34 cm in height and its weight is about 2.1 kg, including four mono (D) type batteries located in its feet;**



Copyright 2009 Texas Instruments
All Rights Reserved

What is RoboSapien? (2/7)

❑ Is preprogrammed for different motions and is controlled by an infra-red (IR) remote controller:

- Users can string together movement commands to form either macros or mini-programs (sets of instructions);
- Send a set of instructions to the RS by IR, and save it in on-board memory for later execution;
- Sensor-keyed instruction set, performing a specific set of actions in conjunction with a specific sensor system.

❑ RoboSapien is capable of:

- Walking motion;
- Grasping objects with either of its hands;
- Throwing grasped objects with mild force.

❑ It has a small loudspeaker unit, which can emit several different sounds.

What is RoboSapien? (3/7)

- ❑ **Some words of the Robot Tech Support, from WowWee Ltd.:**
- ❑ **“The RoboSapien is designed for modification. Here is the short hint list for the budding RS hacker.**
- ❑ **First off, we must warn you that completely replacing the RS brain should only be attempted by those with a lot of time, electronic skills, and programming ego.**
- ❑ **You don’t have to though — if you carefully remove the connectors and lift the RS motherboard, on the back you will find all inputs and outputs labeled, and right next to gold pads convenient for soldering wires...”**
- ❑ **in**

What is RoboSapien? (4/7)

- ❑ **This biomorphic robot was designed to be easily modified or hacked, the electronics inside the RS being easily accessed and clearly labelled;**
- ❑ **A growing community has devoted themselves to modify and add new functionalities to the robot:**
 - ❑
- ❑ **Some features have been added in order to provide new features to the RS:**

What is RoboSapien? (5/7)

☐ Microbi's RoboSapien mods:



☐ Active modifications: hand-beams, hand-LEDs,

☐ heartbeat, voice off, tunnel-beam, blue eyes.

☐ RoboSapien RF Sound Mod:

☐ ()

☐ RoboSapien Camera Mod:

☐ ()

☐ Active modifications: wireless camera,

☐ wireless radio, frequency audio and

☐ pc control.

What is RoboSapien? (6/7)

☐ **RoboSapienPets RoboSapien page:**



☐ **Active mods: SuperSapien microcontroller mod,
color and motion tracking CMUCam**

☐ **Mark C's Robosapien Hacking Site:**



☐ **Active mods: microcontrollers (PicMicro**

☐ **controllers, and Palm Pilot controllers for**

☐ **the Robosapien)**

What is RoboSapien? (7/7)

□ Robocup German Open 2005 tournament:

- 2 teams of 3 RSs each played the 1st soccer match for humanoid robots worldwide;
- Head replaced by a PDA, allowing a display of its environment using the camera;
- Information sent to a PC though the IR of the PDA.

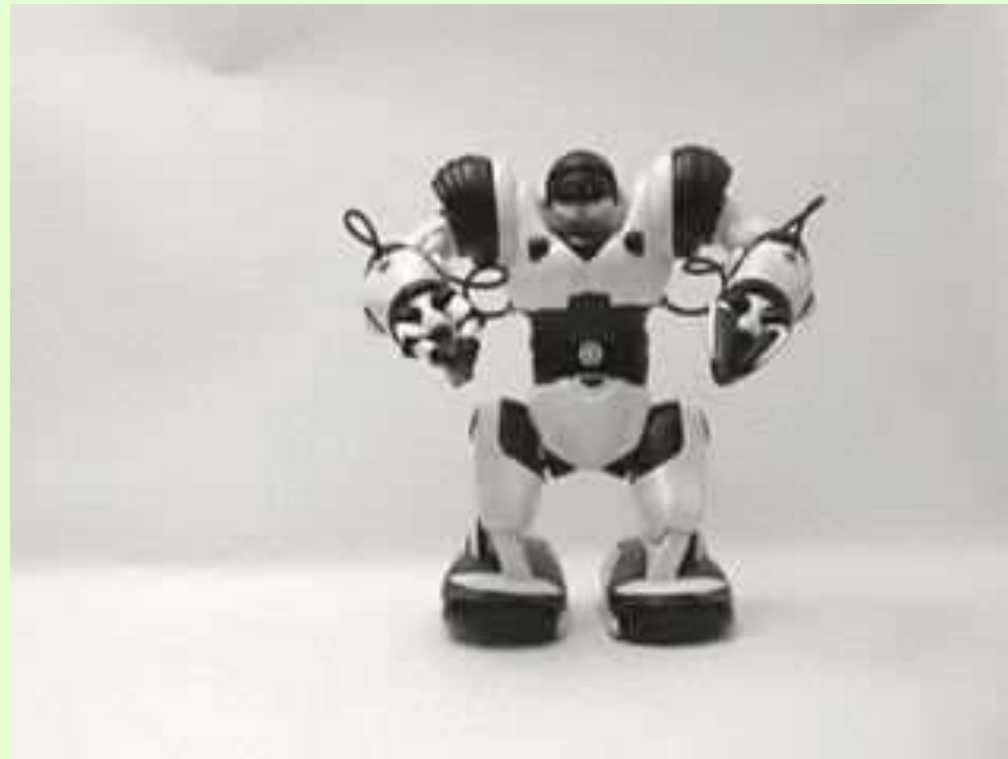


(Sven Behnke, Jurgen Muller, and Michael Schreib, „Playing Soccer with RoboSapien“, Proceedings of The 9th RoboCup International Symposium, Osaka, Japan, July 2005)

How RoboSapien works? (1/4)

Step 1: Analysis of the robot kinematics and dynamics

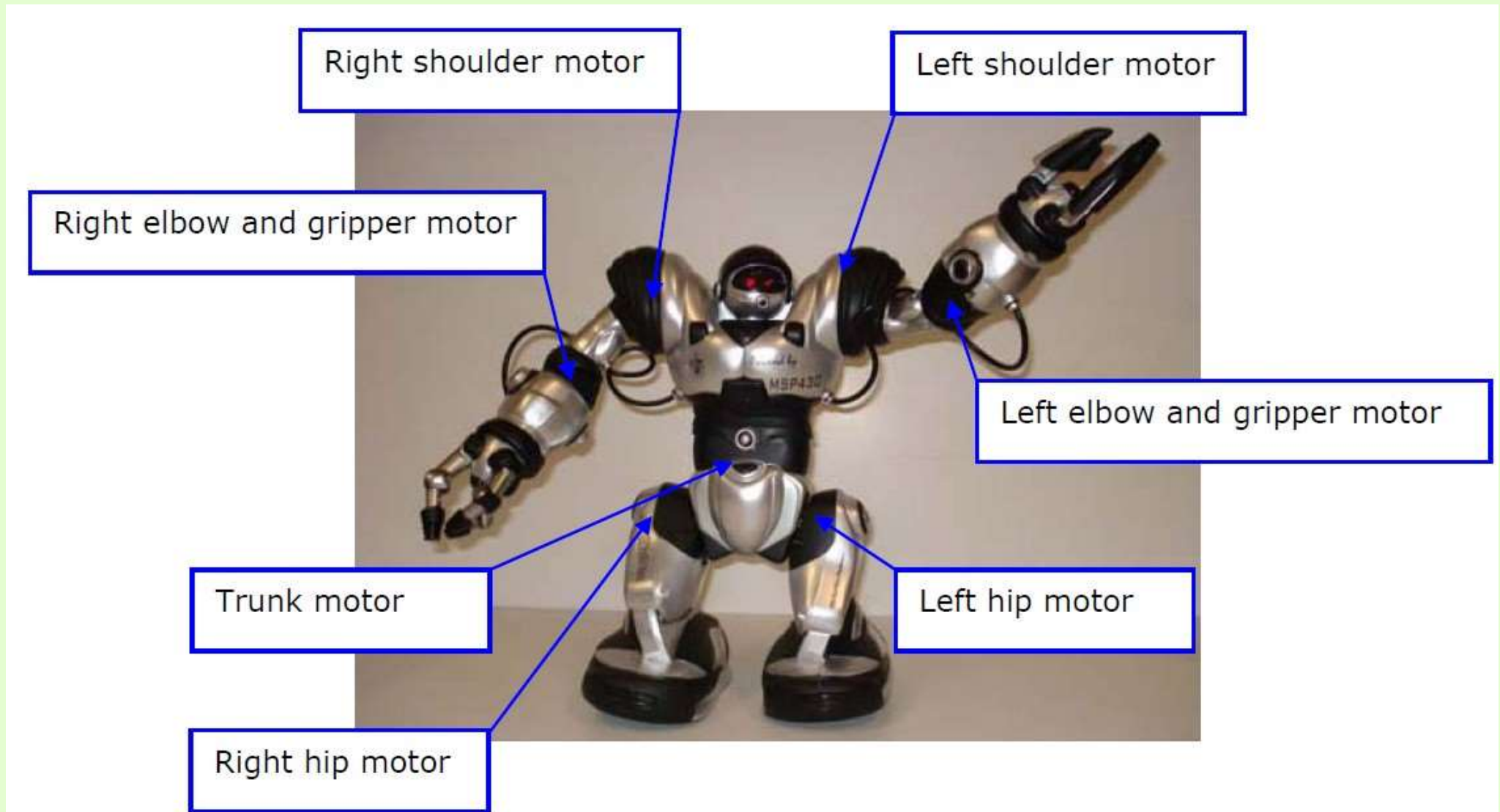
- ❑ **The first task consists in the analysis of the robot dynamics and kinematics (evaluation of the robot movements and its characteristics).**
- ❑ **This task requires testing the RS movements.**



How RoboSapien works? (2/4)

Step 1: Analysis of the robot kinematics and dynamics

❑ A. Analysis of the RS movements:



How RoboSapien works? (3/4)

Step 1: Analysis of the robot dynamics and kinematics

❑ A. Analysis of the RS movements:

- Dynamic walking pattern:
 - (1) The trunk motor tilts the upper body to the right. The centre of mass shifts over to the right foot. The left foot lifts from the ground;
 - (2) The hip motors move in opposite directions, resulting in a forward motion of the robot. As the upper body swings back, the left foot regains contact with the ground;
 - (3) Similar to (1). The trunk motor tilts the body to left;
 - (4) Similar to (2). Hip motors move in other direction.

How RoboSapien works? (4/4)

Step 1: Analysis of the robot dynamics and kinematics

❑ **B. Analysis of RS's remote control commands:**

- The RS's remote control unit has 21 different buttons;
- With the help of two shift buttons, 67 different robot-executable commands are available.



How RoboSapien works? (1/21)

Step 2: Actuators, sensors and signal conditioning analysis

- ❑ **The next task requires a dismantling procedure to allow detailed analysis of the:**
 - ❑ **Actuators (motors);**
 - ❑ **Regulation electronics;**
 - ❑ **Sensors and respective signal conditioning;**
 - ❑ **PCB included with the original robot.**

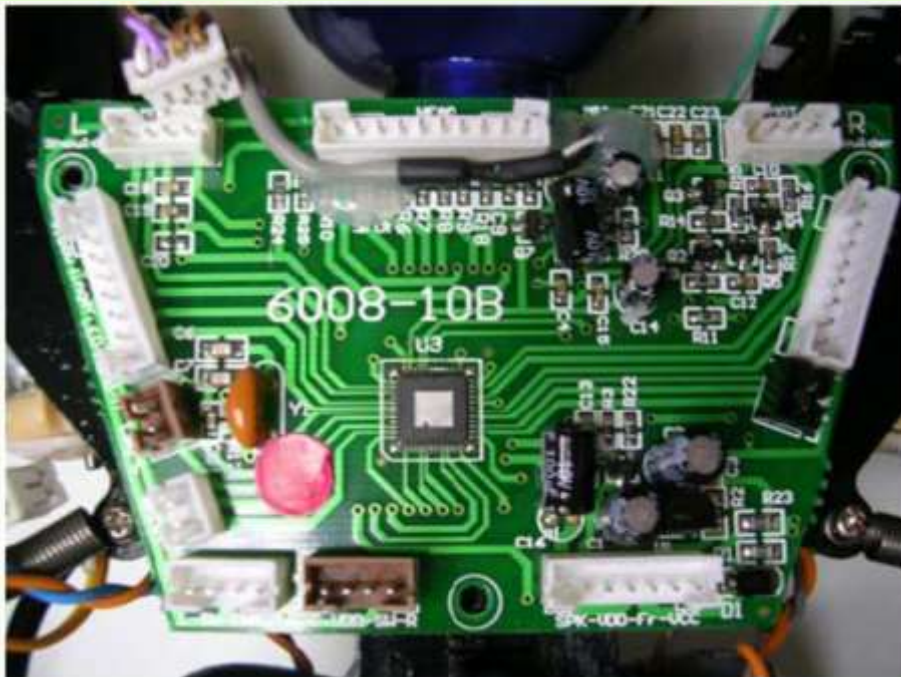
- ❑ **A procedure for dismantling the RS in order to give it additional features is detailed in:**

How RoboSapien works? (2/21)

Step 2: Actuators, sensors and signal conditioning analysis

□ **RS's PCB (Controller U2 and Motor Driver U3) is easily accessed and clearly labelled:**

- **M:** Motors;
- **P:** Input or output port;
- **VDD:** Raw battery voltage (fluctuates wildly);
- **Vcc:** Regulated voltage ($V_{cc} = 3.6 \text{ V}$);
- **Gnd:** Universal ground.



How RoboSapien works? (3/21)

Step 2: Actuators, sensors and signal conditioning analysis

□Tasks:

- List and investigate the functions of:
 - All the components and devices included on the PCB;
 - Actuators, sensors and output devices;
- Determine the mechanical and/or electrical characteristics of:
 - Controller U2;
 - Motor driver U3;
 - Power switch;
 - Motors: shoulder (2); elbow (2); hip (2) and trunk (1);
 - Foot touch sensors (4);
 - Finger touch sensors (2);
 - End course position switches (shoulders and elbows);
 - Sound sensor;
 - Eight LEDs (fingers (2) and eyes (6));
 - IR receiver and external IR remote control.

How RoboSapien works? (4/21)

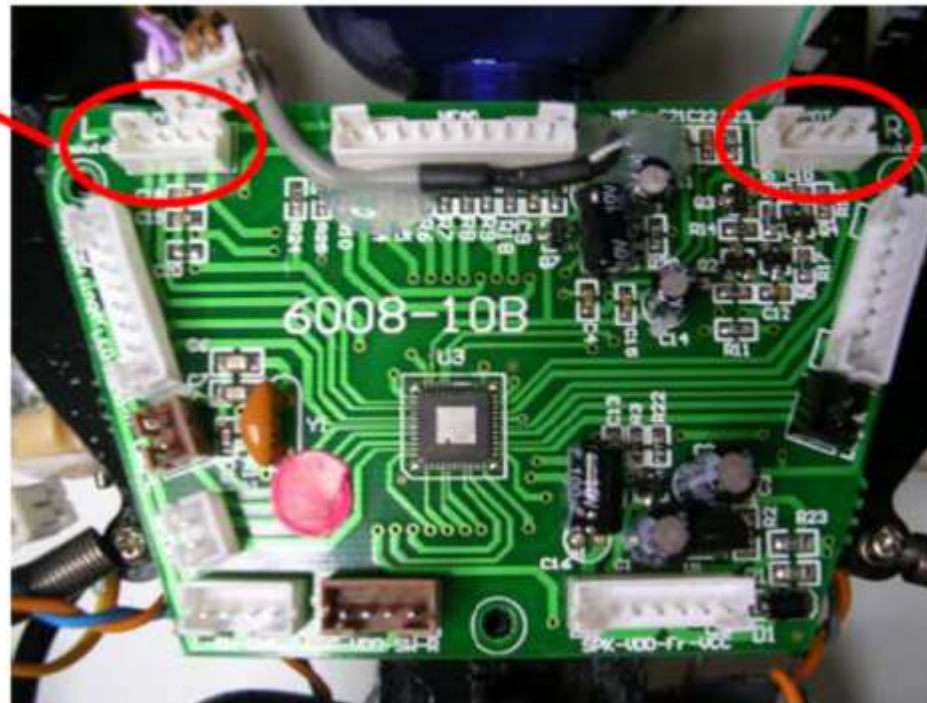
Step 2: Actuators, sensors and signal conditioning analysis

❑ A. Motor controller (U2) connections:

- Details of the connections to the motors of the U2 controller.
- **Shoulder motors:**

Left shoulder motor
M2- M2+ Vcc P1.3

Right shoulder motor
P1.6 Vcc M4- M4+

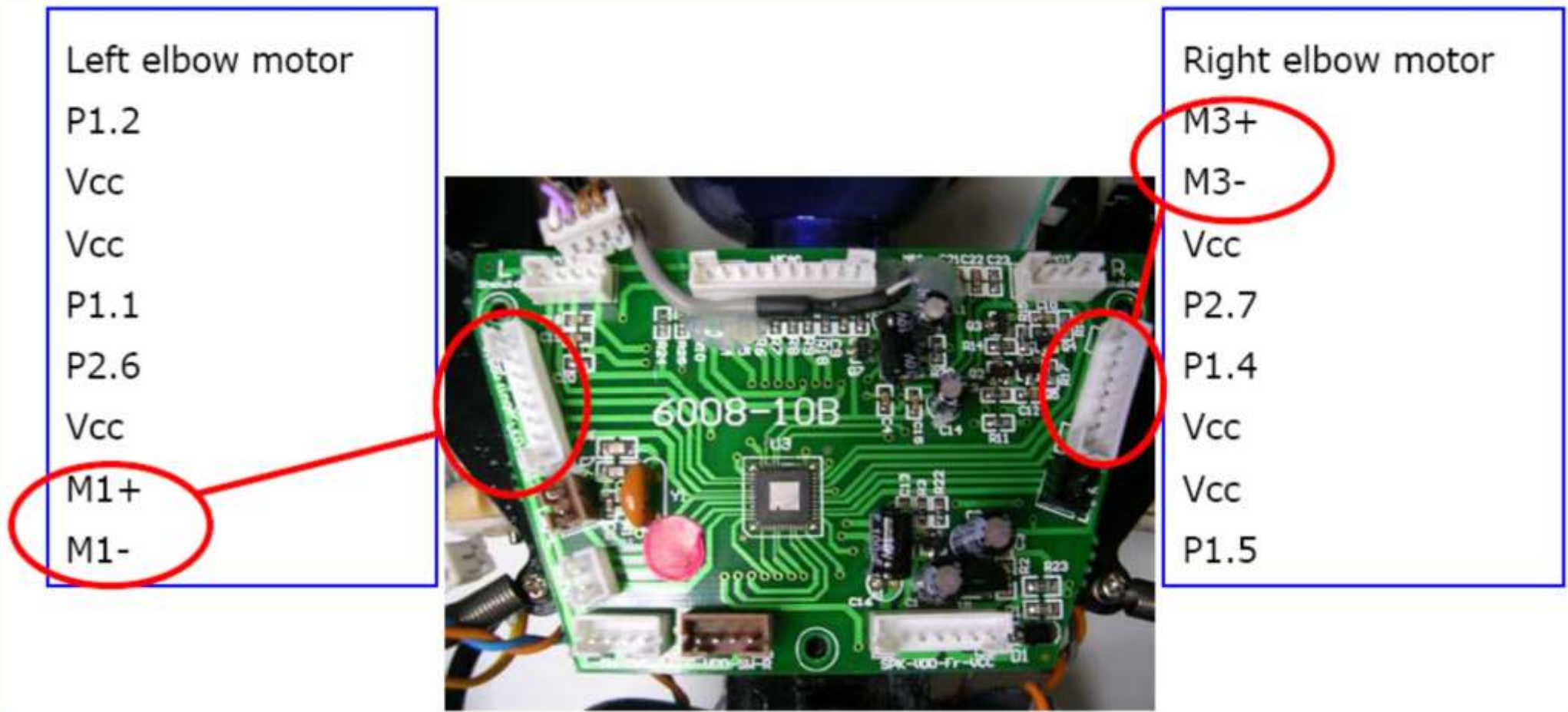


How RoboSapien works? (5/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ A. Motor controller (U2) connections:

- Details of the connections to the motors of the U2 controller.
- **Elbow motors:**

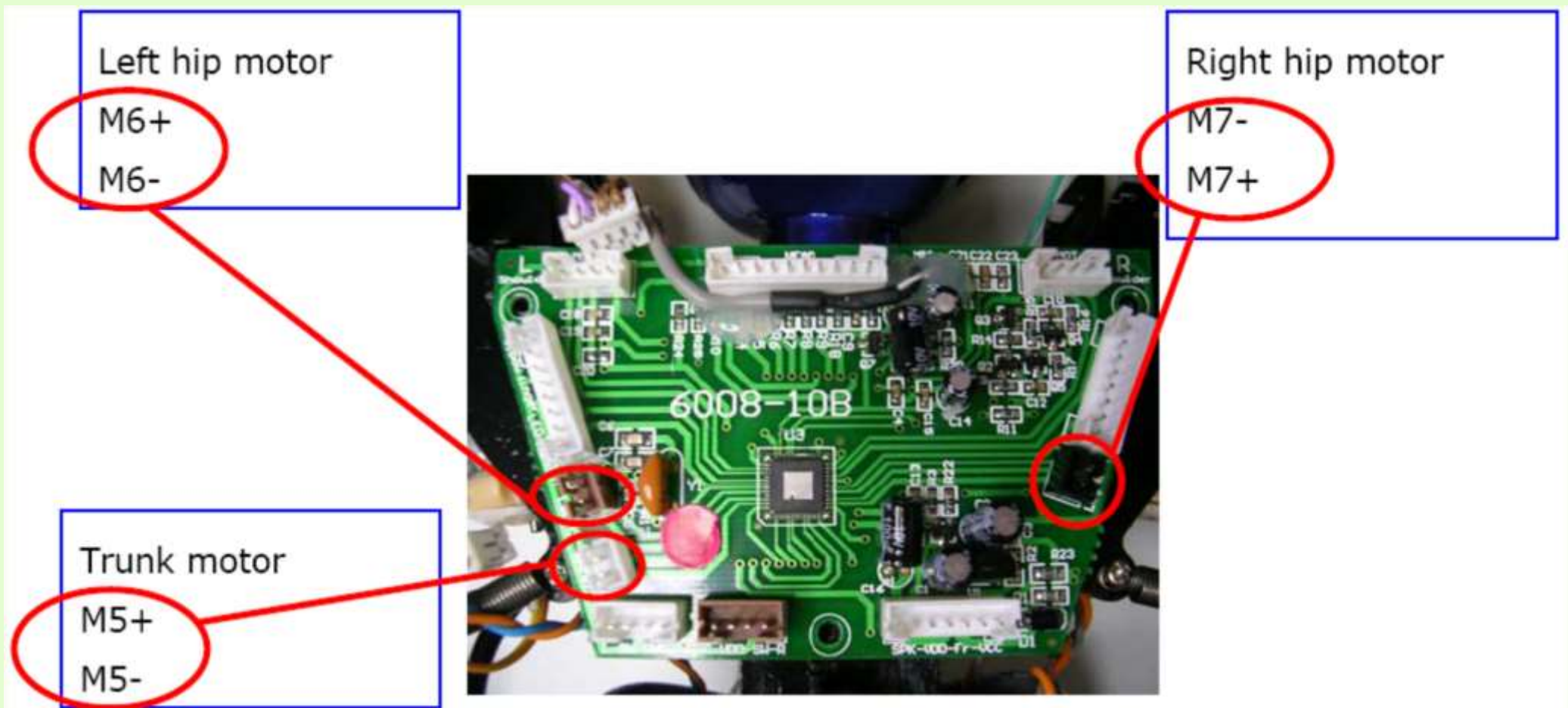


How RoboSapien works? (6/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ A. Motor controller (U2) connections:

- Details of the connections to the motors of the U2 controller.
- **Hip and trunk motors:**



How RoboSapien works? (7/21)

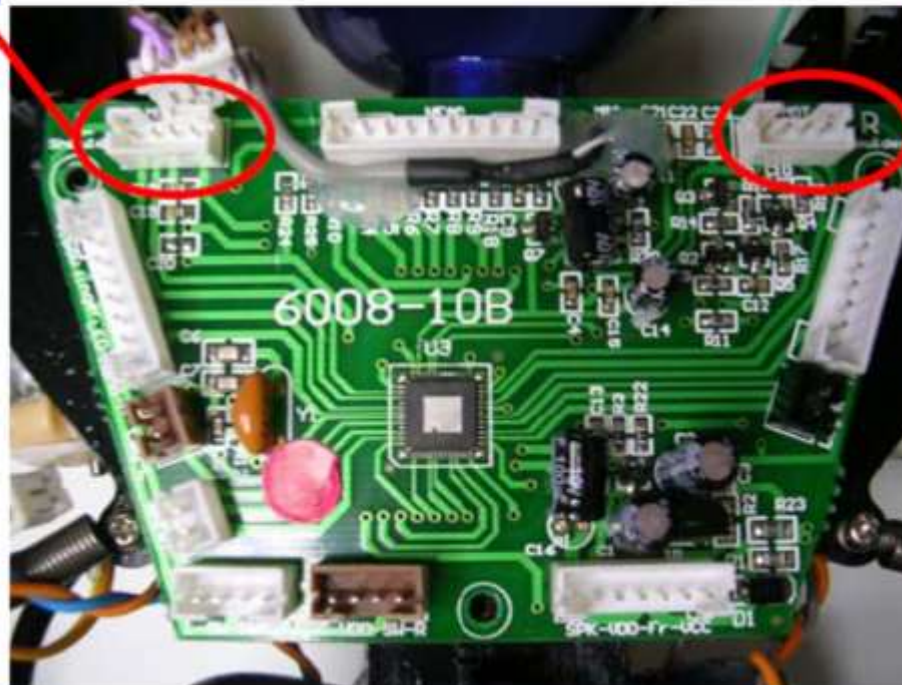
Step 2: Actuators, sensors and signal conditioning analysis

□ B. Position switches and touch sensor connections:

- Details of the connections to the switches of the U2 controller.
- **Shoulder position switches:**

Left shoulder switch
M2- M2+ Vcc P1.3

Right shoulder switch
P1.6 Vcc M4- M4+

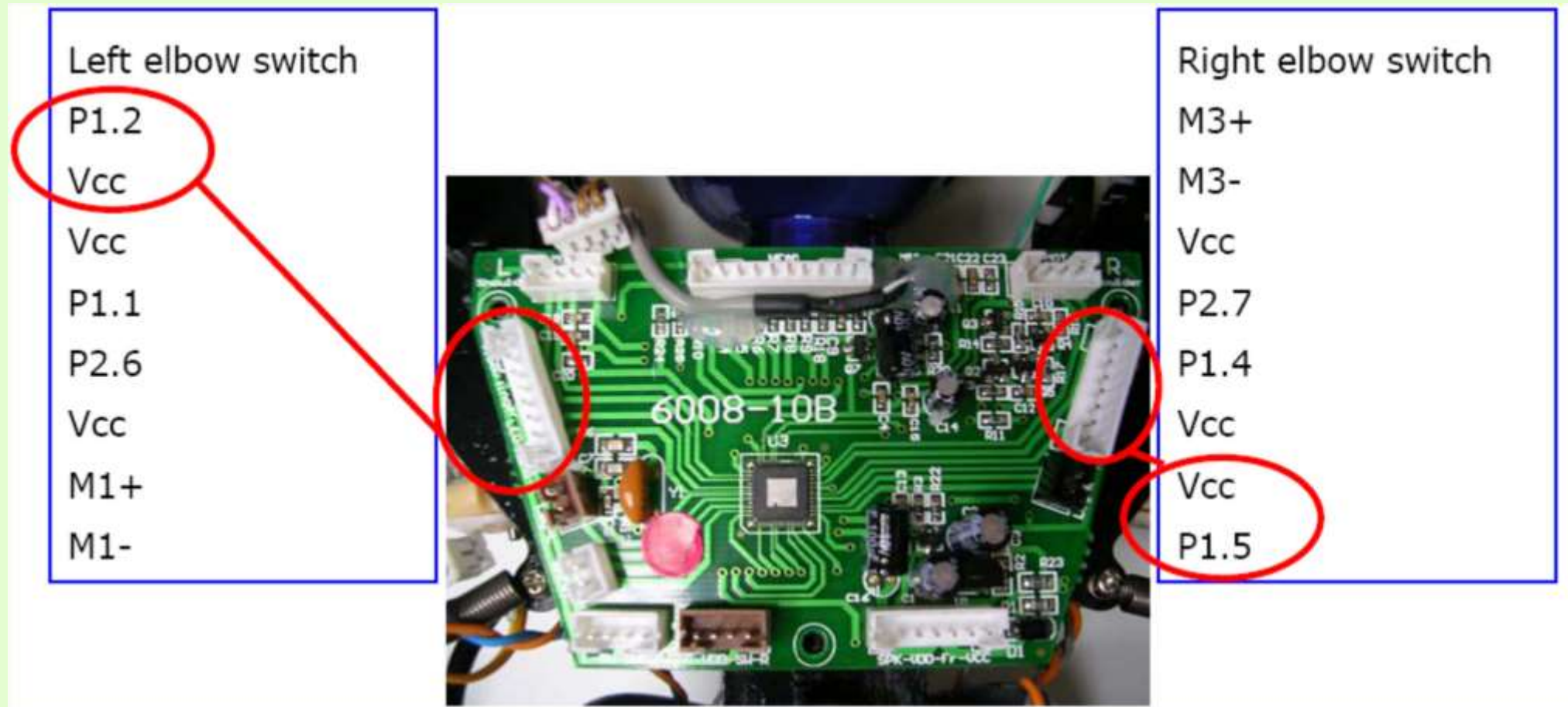


How RoboSapien works? (8/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ B. Position switches and touch sensor connections:

- Details of the connections to the switches of the U2 controller.
- **Elbow position switches:**



How RoboSapien works? (9/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ B. Position switches and touch sensor connections:

- Details of the connections to the switches of the U2 controller.
- **Finger touch sensors:**

Left finger sensor

P1.2

Vcc

Vcc

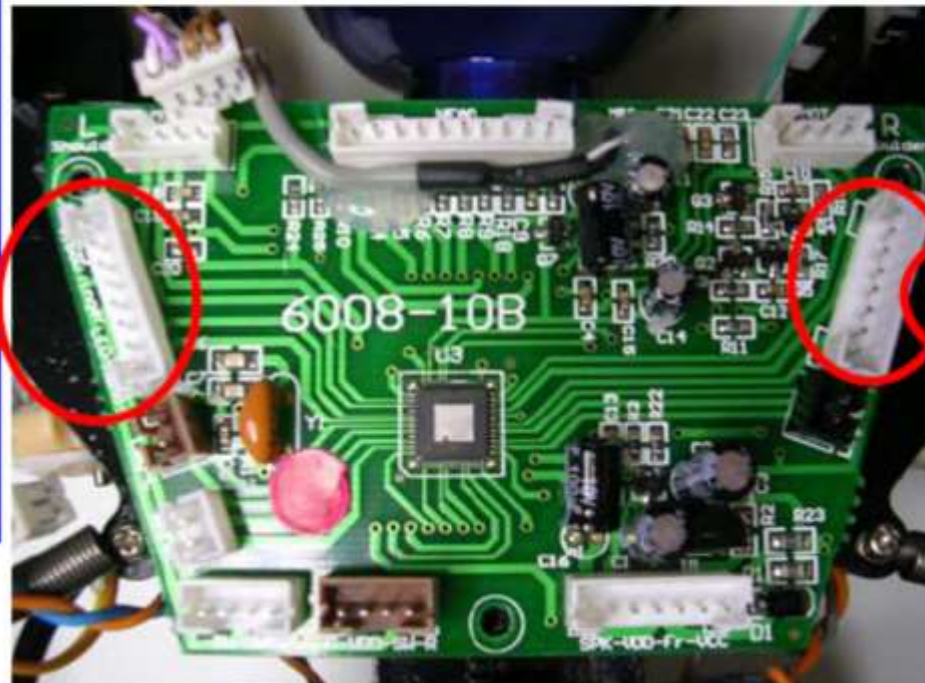
P1.1

P2.6

Vcc

M1+

M1-



Right finger sensor

M3+

M3-

Vcc

P2.7

P1.4

Vcc

Vcc

P1.5

How RoboSapien works? (10/21)

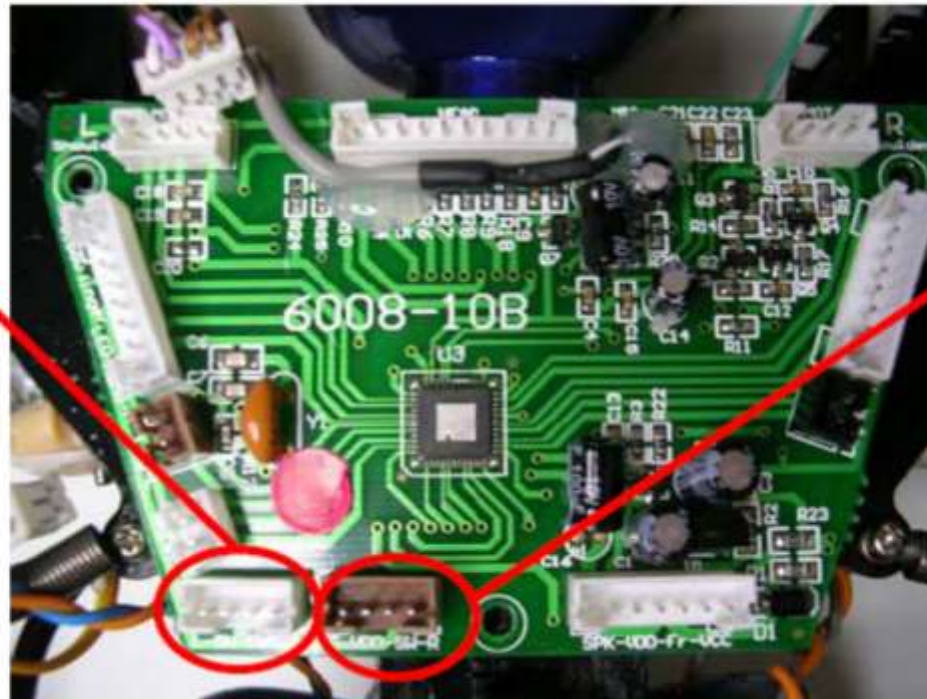
Step 2: Actuators, sensors and signal conditioning analysis

❑ B. Position switches and touch sensor connections:

- Details of the connections to the switches of the U2 controller.
- Feet touch sensors:

Left foot sensor
P1.1 Vcc Gnd Vcc

Right foot sensor
Vcc VDD Vcc P1.4



How RoboSapien works? (11/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ C. LEDs connections:

- Details of the connections to the LED of the U2 controller.
- **Finger LED connections:**

Left finger LED

P1.2

Vcc

Vcc

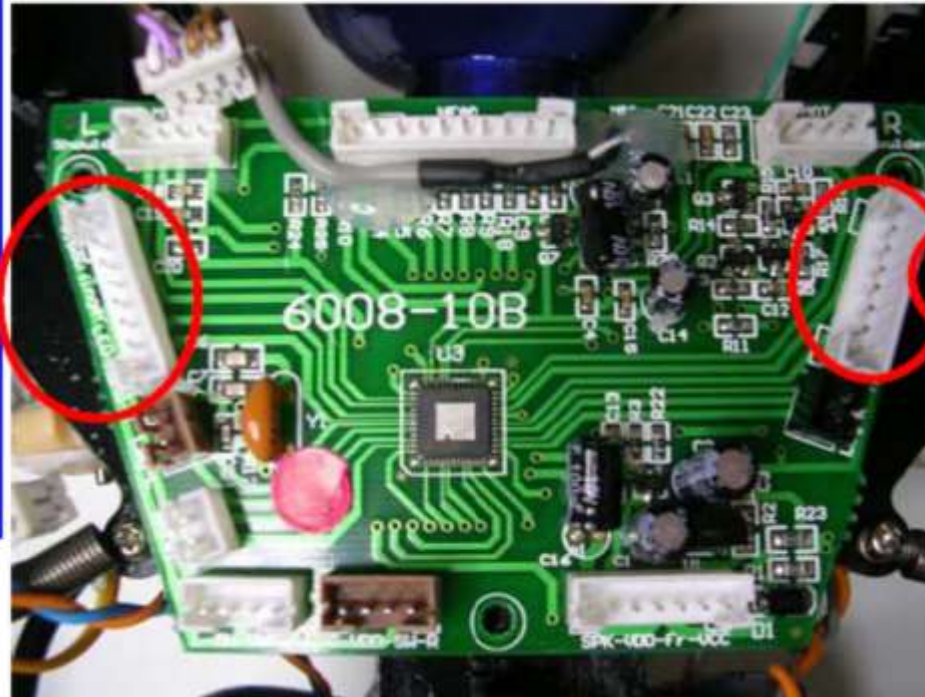
P1.1

P2.6

Vcc

M1+

M1-



Right finger LED

M3+

M3-

Vcc

P2.7

P1.4

Vcc

Vcc

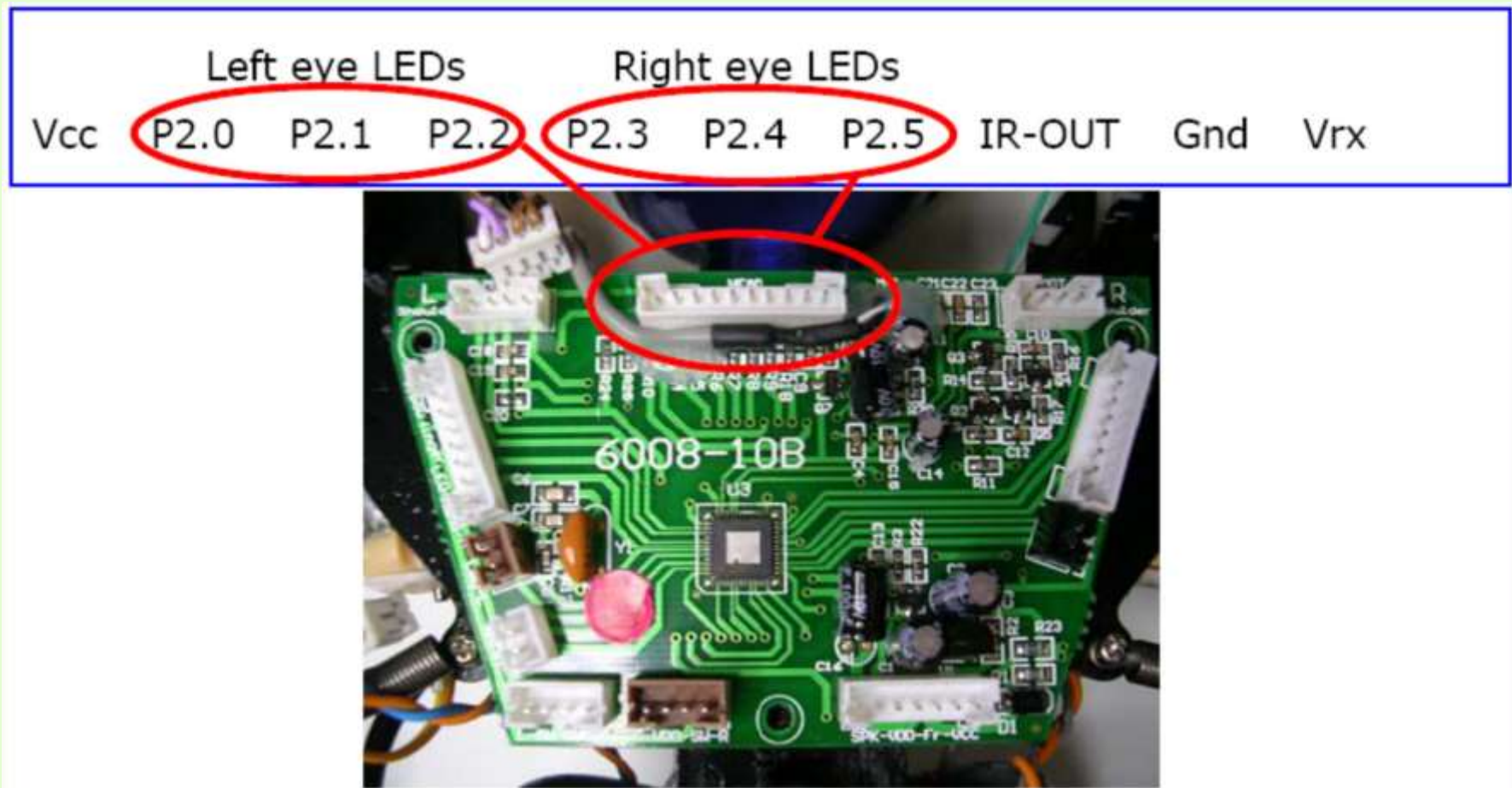
P1.5

How RoboSapien works? (12/21)

Step 2: Actuators, sensors and signal conditioning analysis

□ C. LEDs connections:

- Details of the connections to the LED of the U2 controller.
- **Eye LED connections:**

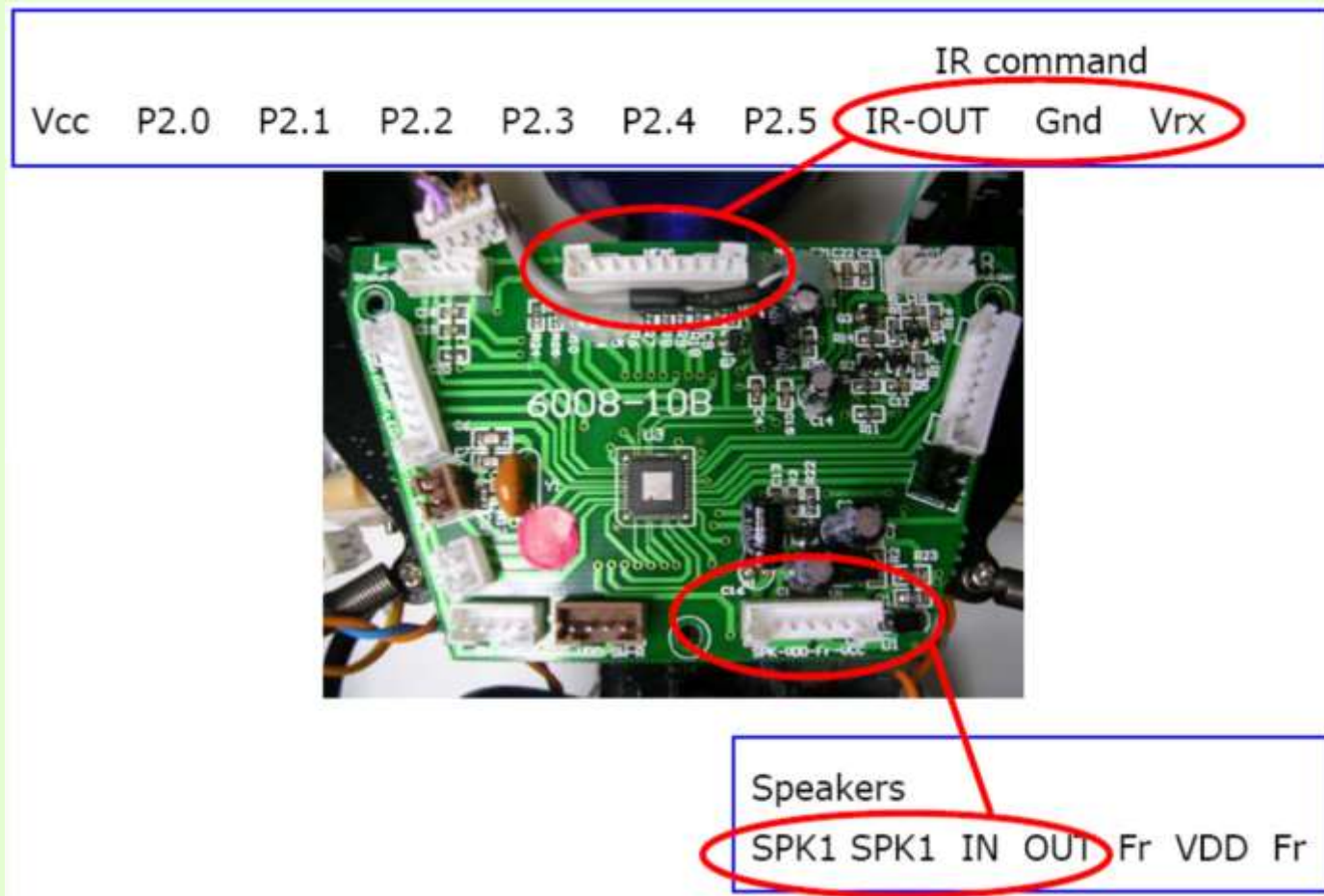


How RoboSapien works? (13/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ D. Command and power connections:

- Details of the command and power connections.
- **Command and power connections:**



How RoboSapien works? (14/21)

Step 2: Actuators, sensors and signal conditioning analysis

□ E. Acquisition and analysis of digital port signals:

- Continue with the analysis of the digital signals acquired from the ports on the PCB;
- Evaluate the original microcontroller control output ports when the robot performs a specific command function;
- Define the time sequence of the active/inactive motor in each specific movement;
- Procedure:
 - List the active/inactive time of each motor:
 - Single movement (single motor);
 - Combined movements (more than one motor).

How RoboSapien works? (15/21)

Step 2: Actuators, sensors and signal conditioning analysis

□ E. Acquisition and analysis of digital port signals:

- **Task:**
- Use an oscilloscope to acquire the signals used for single movements;
- If available, use a logic analyzer to acquire the signals used for the combined movements signals;
- Connect probes to the output port pins.



Copyright 2009 Texas Instruments
All Rights Reserved

How RoboSapien works? (16/21)

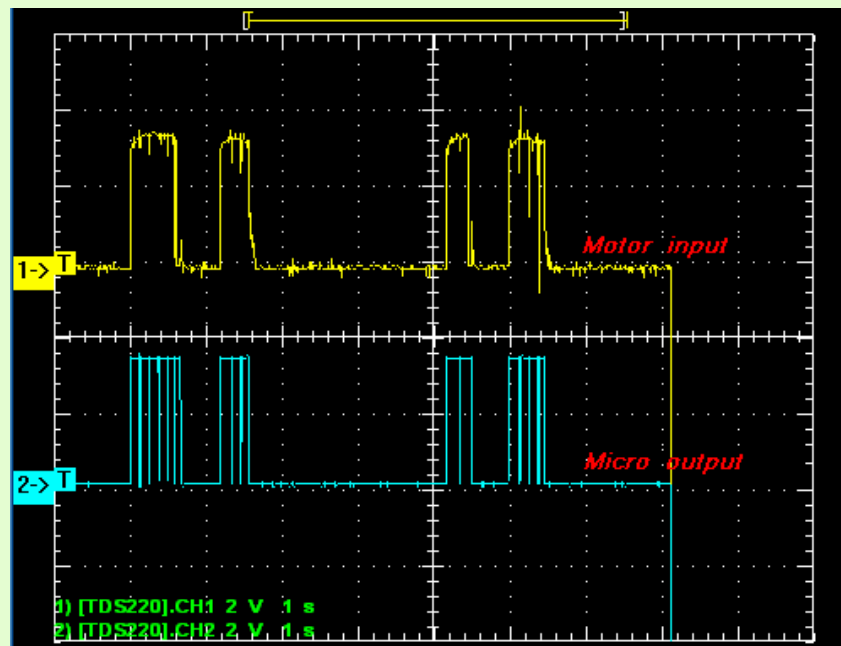
Step 2: Actuators, sensors and signal conditioning analysis

□ E. Acquisition and analysis of digital port signals:

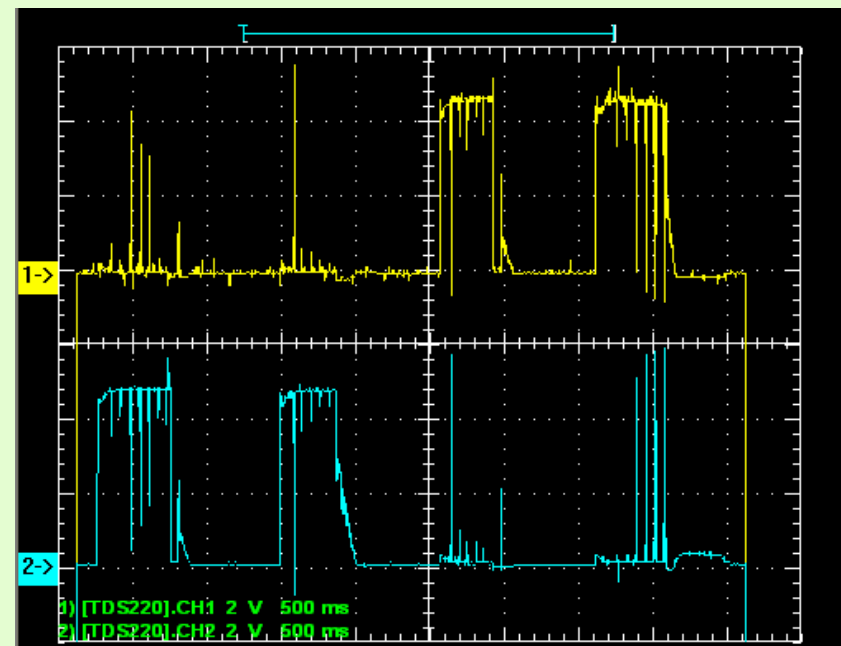
▪ Single motor signal analysis:

- Compare the output signal from the original microcontroller and the signal that the motor receives.

• Examples:



(a) Output signal vs. motor input signal.



(b) Left elbow movement from the inside to outside and vice-versa.

How RoboSapien works? (18/21)

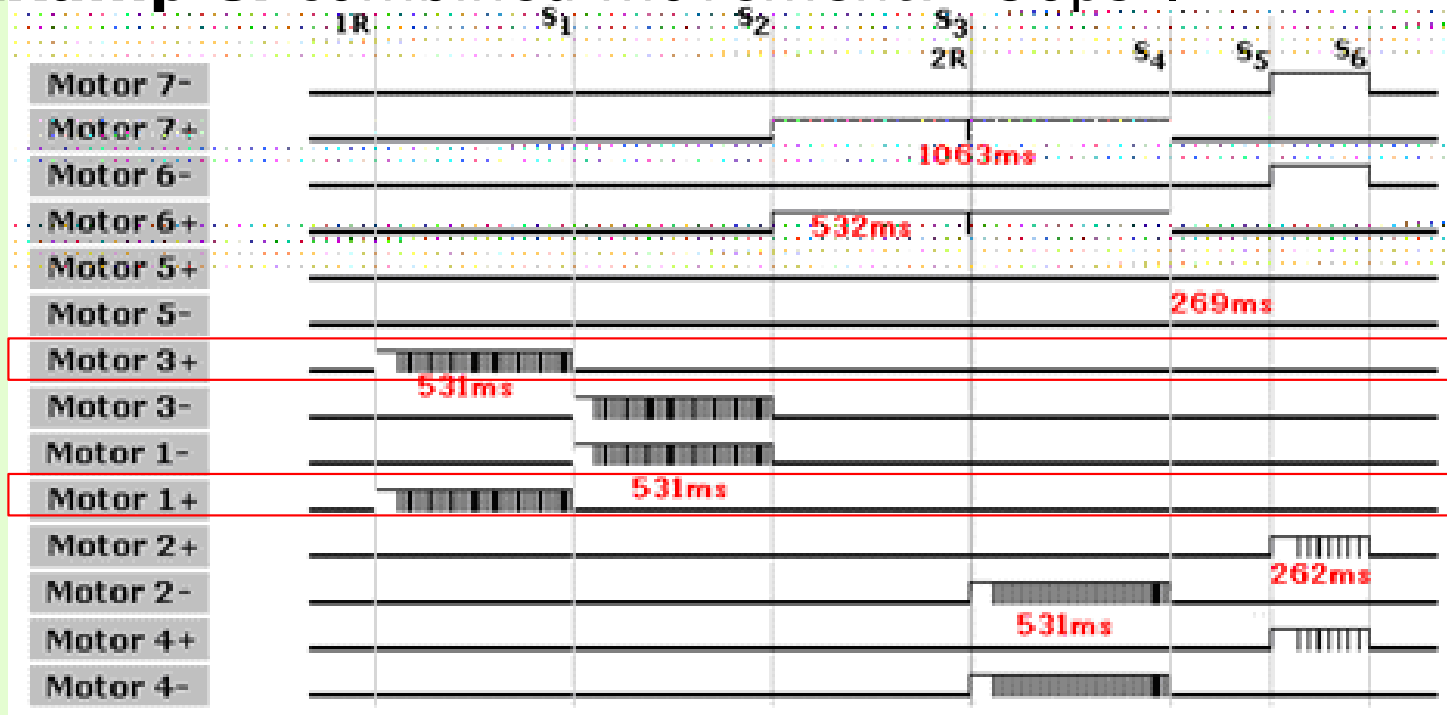
Step 2: Actuators, sensors and signal conditioning analysis

□ E. Acquisition and analysis of digital port signals:

▪ Analysis of signals for combined actions:

- Connect probes to the original microcontroller ports to measure the digital signals with a logic analyzer.

• **Example:** combined movement: “Oops”.



How RoboSapien works? (19/21)

Step 2: Actuators, sensors and signal conditioning analysis

□ F. Analysis of the eyes pattern:

- Evaluate the eye pattern (6 LEDs – P2.0 to P2.5) depending on the command that is executed:

Commands	Eye pattern	Commands	Eye pattern
Awake		Angry	
Down right		Startled	
Down left		Sleep	
Look up		Off	
Confused		Wink	
Look down		Program mode	
Up right		Program right reflex	
Up left		Program left reflex	
Listen		Program sonix reflex	
Listen			

How RoboSapien works? (20/21)

Step 2: Actuators, sensors and signal conditioning analysis

❑ **G. Analysis of the IR commands:**

- Using a logic analyser, determine the IR command digital value (port IR-OUT) for each movement command of the remote controller.

- **Serial communication specifications:**
 - Direct serial input to the IR-OUT pin (active low signals, 1200 bps);

 - Timing based on 1/1200 second clock (~ 0.833 msec)
Signal is normally high (idle, no IR);

 - Data bits: for each of the 8 data bits, space encoded signal depending on the bit values (Sends the most significant data bit first). (Carrier is 39.2 kHz);

How RoboSapien works? (21/21)

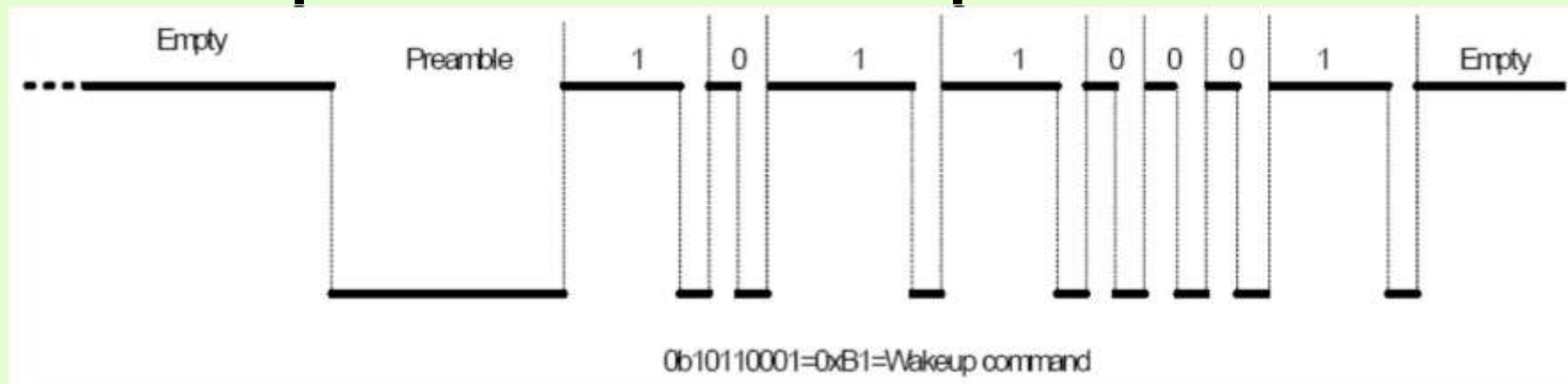
Step 2: Actuators, sensors and signal conditioning analysis

□ G. Analysis of the IR commands:

▪ Serial communication specifications:

- Preamble: signal goes low for 8/1200 sec;
- data bit = 0: signal goes high for 1/1200 sec, and low for 1/1200 sec;
- data bit = 1: signal goes high for 4/1200 sec, and low for 1/1200 sec;

- **Example:** Command “Wake Up”: 0xB1.



以上内容仅为本文档的试下载部分，为可阅读页数的一半内容。如要下载或阅读全文，请访问：<https://d.book118.com/807115011106006035>