ES2C6 – Electro-mechanical System Design

Self-balancing Robot Project (WMG)

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Design Project Aim

The aim of this project is to design a low cost self-balancing robot (SBR). Much of the theory needed to do this will be covered in the lectures for this module, specifically DC motors, electro-mechanical energy conversion (H-bridge circuits), sensors (IMU), closed loop feedback control, block diagrams, PID controllers and stability.

Design Project Objectives

- To demonstrate electro-mechanical energy conversion in DC motors.
- To demonstrate closed loop control and feedback using an IMU sensor.
- To demonstrate power electronic circuits for driving two DC motors.
- To demonstrate the theoretical and practical aspects of the design and a suitable test plan.
- To undertake an open ended design project which includes programming.

You are to design, build, program and test a self-balancing robot (SBR). The following requirements must be met:

1. You complete all necessary Engineering Build Space General Risk Assessment and Core Rules forms. (See Project Management & Safety on page 2)
2. The robot balances on just two wheels for at least 10 seconds on a variety of surfaces.
3. The fully assembled robot fits into the storage box provided but the wheels can be removed for storage. The internal dimensions of the storage box are: 105×170×295mm.
4. The robot can be safely deployed i.e. bits don't fall off nor become disconnected when in motion.

Components

Your group will be provided with the following components:

- ×2 4TRONIX MOTOR GEARBOX with JST connector + motor mount (printed in PLA)
- ×2 4TRONIX 65mm Yellow Wheel
- ×1 Arduino Leonardo
- ×1 SBR4A motor Shield PCB for Arduino Leonardo
- ×1 IMU NANO SHOE PCB with Arduino Nano and IMU GY521
- ×2 USB cables: ×1 Micro USB adapter and ×1 USB extension cable
- ×2 Switches (Red and Green)
- ×1 Rechargeable Battery and charger
- 20x20 Aluminium extruded section, T-nuts and brackets
- Electronic components: resistors, capacitors, potentiometer, header pins etc.
- Allen key and POZI Screwdriver
- 18 Compartment Box and project storage box
- Selection of M3 and M4 Nuts and Bolts
- Tie wraps
- Breadboard jumper wires (various colours)

The total group budget is £200. The above default list of components was purchased from this budget to save you time and effort. The **remaining discretionary budget for each team is £70**. Additional components should be ordered from official University of Warwick vendors (preferable

Rapid Electronics or RS Components). It is recommended that additional components be ordered before the start of week 7 however we cannot guarantee that they will arrive in time.

Note:

- All components for your project remain the property of WMG. You are to submit your hardware with your design portfolio. It is expected that tools and items such as batteries, chargers, USB cables Arduinos, boxes etc. will be reused on future years. It is also anticipated that some robots will be used for outreach and recruitment activities after completion. So please adopt child-appropriate names/designs for the robots.
- Please be careful in your handling and testing of the components. In the event of accidental damage, there are a ***very limited*** number of spare components available from the supplied list. Please see the instructor if you need a replacement. It is suggested that SBR's are tested on the floor where they will not fall off tables etc.

Timetable

There are 10 scheduled lab sessions from weeks 4 to 9. The final presentation and submission are in week 10. Most lab sessions will be self-directed with the project instructors and some lab demonstrators available for advice and feedback. Lab 1 includes a directed component where your team will be assigned your prescribed hardware. Labs are not all in Engineering's build Space so manufacture of parts must be completed by the end of week 8.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Design project Briefing			1-hour design project briefing							
Design project lab hours		Students are notified of design project		2 design hours in ES_EBS1.3 & 1.1	2 design hours in ES_EBS1.3 & 1.1	4 design hours: Mon in ES_EBS1.3 & 1.1, Thurs in A2.06	4 design hours in ES_EBS1.3 & 1.1	4 design hours in ES_EBS1.3 & 1.1	4 design hours in A0.08	0.5 hour Submission, presentation and Assessment

Project Management & Safety

It is expected that your group will distribute tasks among its members according to your skills and interests. Nevertheless, it is expected that everyone will contribute to the overall design process. **Every individual team member must keep a logbook which is provided** with dated records of your ideas, progress, and how your contribution integrates with the rest of the group. In addition, you should document how your team manages both project risks and health and safety risks. The logbooks should be brought to every lab session and they will be handed in with your completed robot at the end of the presentation and checked by staff.

As most sessions are in the Engineering Build Space there are updated versions of the General Risk Assessment and Core Rules. All users (staff and students) will need to read and electronically sign the updated forms at the following link in order to continue or begin using the Build Space (this should only take 5-10 minutes):
https://warwick.ac.uk/fac/sci/eng/facilities/buildspace/build_space_access/

Anyone who has not signed the forms will not be able to use the space for any activities, which includes timetabled teaching activities.

A recommended project timeline is as follows:

- **Prior to start: Complete Build Space General Risk Assessment and Core Rules forms online**. (See previous.)
- **Week 4: Hardware and team orientation**. Identify the major design decisions to be made and the selection criteria that will guide them. Identify risks to the project and to health and safety and how they will be managed throughout the project. Assign task leads: background research, mechanical design and CAD work, electronic design, manufacture of mechanical components and electronic circuit boards, assembly, programming and testing and overall project management. Post seminar work should show development of design concepts towards an outline physical embodiment of the SBR along with ideas on control of the SBR and its motors. One or two individuals to manufacture and test the Leonardo motor Shield in electronics workshop. Bring logbooks showing this progress to the following seminar.
- **Week 5:** C**oncept finalisation and bill of materials finalisation.** Develop, discuss, and scrutinize potential designs and control methods according to the selection criteria. Choose a final design and decide on the materials and hardware needed. Preliminary testing with the prescribed hardware. Complete the Leonardo motor Shield circuit board manufacture and testing. Post seminar work should focus on design refinement and detailed design of robot chassis and parts for manufacture. Additionally work on the design of motor control, and research on SBR control theory, sub-assembly testing and programming. Bring logbooks showing this progress along with final bill of materials, design drawings of chassis and motor mounts, to the following seminar.
- **Week 6 (2 sessions): Choose a final design to manufacture.** Develop and implement a robust testing plan. Order components as needed. Design and order parts to be manufactured either by 3D-printing or laser cutting. All designs will need some fabrication and assembly! Bring part/completed sub-assemblies to following seminar.
- **Weeks 7-8 (2 sessions per week): Implement the chosen design and engage in regular testing.** The design should be completely manufactured without any further consultation. Circuit boards should be fully tested. Software drafted for testing and a final component and overall test plan drafted. Draft content for the design portfolio. Compile a final bill of materials and draft assembly and component drawings in CAD. Illustrate report with exploded views and drawings of assembly. Draft and check the wiring diagram for the Leonardo motor Shield. Bring drafts and logbooks to following seminars.
- **Week 9 (2 sessions): Complete the design implementation.** Write the design portfolio (see design portfolio guidance on Moodle). Prepare for the final presentation and demonstration. Final SBR programming testing and update test plan results! Look after your robots and film them working!
- **Week 10: Submit the design portfolio.** Practice and do the final presentation and demonstration. The whole team should have an input on the design portfolio to insure all details are correct and present. These are not tasks for just one team member, particularly if they have not been involved in other aspects of the project.