ENGAGING ELECTRONICS PROJECTS FOR DESIGN STUDENTS THROUGH OPEN DESIGN APPROACHES

Ross John Robert MACLACHLAN
Department of Design Manufacture and Engineering Management, University of Strathclyde

ABSTRACT
Product design students typically undertake multidisciplinary curricula studying components of both mechanical and electrical engineering to complement studio and project based learning of design practice. Where electrical concepts are less likely to be integrated with design classes, it is understandable that many design students view stand alone electrical modules as a secondary concern, often adopting a strategic or surface learning approach. Furthermore, where these classes are taught outside of the design department, it can be difficult to relate fundamental concepts to the rest of the product design curriculum. Electrical concepts represent major enabling technologies, and therefore there is a need to deliver the subject in a way that provides students with an opportunity to adopt a deep learning approach to fundamental concepts, and to connect the relevance of these concepts to product design. This paper presents an ‘open design’ project approach to engage first year product design students with electrical concepts. The project required student teams to build and test a wireless audio loudspeaker product. Student teams were supported to develop three product modules (FM transmitter, audio amplifier and loudspeaker) concurrently, and then integrate these into a singular product. Each module comprises a circuit where fundamental electrical components form the central functionality of the product. The practical experience of designing circuit layouts, constructing the circuits, ‘hacking’, researching electrical concepts and working as a team to produce a cohesive product are valuable and transferable learning experiences.

Keywords: Open design, electrical concepts, product design education

1 INTRODUCTION

In 2009, the author undertook development of ‘Electrical Concepts’ course content as a component of a 1st year undergraduate module entitled ‘Technology Concepts’. The module was developed specifically for BSc Sports Engineering (SE) and Product Design and Innovation (PDI) students, serving as an introduction to mechanical and electrical engineering. It replaces individual modules, previously taught out with the department with the aim of relating the fundamental principles of electrical and mechanical engineering specifically to the discipline of Product Design.

1.1 Electrical Concepts

The electrical concepts module has 3 key learning outcomes as part of the curriculum:

1. Apply fundamental electrical principles
2. Solve problems of basic science, particularly when applied to everyday products
3. Appreciate the relationship between principles underlying mechanical and electrical energy transfers

The potentially unique aspects of these objectives appear to lie in the ‘application’ to ‘everyday products’. Within the department there is a shared understanding that in achieving this particular objective, product design student interest and motivation would be strengthened, with learning that is transferrable to parallel and subsequent project based design curriculum supported.

The topic selection for the syllabus is conventional: DC and AC circuits, Ohm’s Law, resistivity, resistances in series and parallel, electrical energy and power, DC and AC electric motors. A brief introduction to digital electronics has also subsequently been added.

1.2 1st year Engineering Education

Even in pure electrical and electronic curriculum, there has been considerable discussion highlighting that traditional curriculum is no longer engaging current students [1].

With respect to design engineering education, traditional engineering science curriculum has been criticised or rejected for some time [2]. Concepts of mechanical and electrical engineering are significant parts of the product designer's knowledge base. In particular, electrical concepts appear to hold threshold concepts which 1st year students find particularly difficult to attain, perhaps as physical product features are not often obviously linked to fundamental circuit laws and components.

Tsividis [1] identifies 3 considerations in developing first year electrical engineering courses:

1. today's students have less 'patience' in linking theory to practice.
2. the computer age students are abstracted further from the relevance of fundamentals and circuit laws from the circuit 'tinkerers' of earlier times.
3. ensuring that the "first course" is tied to the rest of curriculum.

Considerations 1 and 2 could be addressed by encouraging more of the 'tinkering' experience that may have been traditionally expected of engineering course entrants into the 1st year. Point 2 could be further addressed by familiar product functionality to demonstrate fundamental concepts. This could heighten the interest of early career design students and enable them to integrate these ideas to critical issues, such as society and the environment, being concurrently explored in other areas of the design curriculum. A top-down product and systems approach to early electrical concepts curriculum also seems to address all these points [3].

2 OPEN DESIGN

There are numerous examples of 'collective invention' and free information sharing in engineering and innovation [4] preceding the similar and more recently popularised concept of 'Open Source' software development. However, it has been in the software field that the idea of sharing design data with others for free use, adaption and distribution (within license terms) has been formalised. These open licenses encourage and support collaborative development communities and are central to a number of examples of successful software products, such as the Linux kernel. The popular phrase 'Open Source' is now often assigned to any non-proprietary or community approach to the development of any product type (for example Open Source Car [5]).

The phrases 'open source hardware' or 'open design' are commonly used to describe open non-software product development. 'Mass Collaboration' [6] is another commonly used phrase describing a general community based development approach, most easily exemplified in software and initiatives such as Wikipedia, but including engineering product development [7]. In the context of this paper, Open Design is considered the most descriptive title as we are not operating on a mass and distributed scale (class of 40) but are basing project work on openly shared design ideas and aiming to contribute further developments to the communities that provided the initial information.

2.1 Open Design Projects as Situated Learning Environments

The idea of participant learning within community product development has been identified as a 'major motivational force' for participation and a key area for further research [8], [9]. Ye and Kishida [9] suggest that such projects could provide learning opportunities within higher education where linking theory with practice in commercial scenarios is not always obtainable. These projects situate the learner; knowledge is not de-coupled from practice. They propose that Lave and Wegner's [10] Legitimate Peripheral Participation (LPP) model is useful in describing the community situated learning process. The novice or newcomer is increasingly 'legitimised' as a practitioner, starting at community's periphery, through following community norms and eventually contributing to and developing the product.

Adapting the 'open source' project model for education is perhaps most easily done in software disciplines where large scale projects exist [11]. In terms of engineering education it is suggested that to view engineering discipline itself as an 'epistemic community' [12] of practitioners, and the student as the newcomer who must become 'legitimised' in that community, is a useful analogy. As open design projects offer opportunities for learning in this way, it is proposed that synthesis of such a project within engineering education offers opportunities for enhanced student motivation and learning.

2.2 Hacking in Technology Disciplines

Another aspect explaining participant motivation in open design development is ‘hacker culture’ or ‘hacker ethic’[13]. The definition of a hacker is someone who likes to build things and solve problems, operating in any technology discipline [14]. The act of hardware hacking is defined as ‘modifying a product to do something it was never intended to do’, and along with reverse engineering, is proposed as an important facet of any technology professionals development [15].

The concept seems to have parallels with the ‘tinkerer’ student that Tsividis [1] reminisces of, and also with Tyre and von Hippel’s [16] concept of ‘learning through doing’. It could be argued that it is this very ethic that should be acquired in becoming a professional designer.

2.3 Electronics as a Candidate for Open Design Approaches

Despite advances in affordable and ‘open’ rapid prototyping technology [17], desktop fabrication has not yet reached a level of ubiquity that would allow physical product designs to be shared and built on the same mass scale as software. For analogue and digital electronics, many circuit schematics are in the public domain and therefore easily shared and prototyped using available and affordable tools; open approaches to the development of the functional aspects of electrical products are common place. In particular, audio electronics has a long history of hacker culture, DIY spirit and community development.

3 THE PROJECT

It was essential that the product choice for a suitable project should ensure that key curriculum topics were explored, but also provide flexibility for students to make their own design decisions and encourage exploration and creativity.

The core attributes for a suitable product area for the practical project were that:

1. The product functionality be closely linked to fundamental electrical concepts
2. The product functionality be of perceived use and interest to the participants
3. On completion, the project should provide a sense of achievement that was perhaps unexpected

Successful 1st year student engagement in electrical concepts within design curricula has previously been reported through projects based around audio electronics [18]. Furthermore, as most students appreciate music, of some description, a project focused on audio reproduction was considered to have a level of familiarity and appeal to a majority of students in the class.

3.1 Wireless Loudspeaker Project

The initial product idea of a loudspeaker design project was inspired by Jose Pino’s [19] Styrofoam plate loudspeaker, shown in Figure 1(a) It is a relatively crude representation, but surprisingly impressive in its demonstration of the loudspeaker concept and in its audio reproduction performance. A polystyrene plate forms the diaphragm supported by a suspension mechanism of folded business cards. The motor of the loudspeaker is composed of a copper wire coil attached to the plate and a strong permanent magnet. When an amplified audio signal (music) is fed through the copper coil, a magnetic field is generated that varies with the music signal which is either attracted to or repelled by the permanent magnet. This vibrates the plate surface to generate music. Other loudspeaker driver projects gave ideas for further development options [20].

To create a modular product architecture with some independence between modules, which is critical for products that are developed by communities [7], the plate loudspeaker became a ‘core module’ of a wireless loudspeaker system where wireless transmission of music is provided by Open Thing’s Niftymitter FM Transmitter [21] shown in figure 1. (b). Audio amplification was provided by a semiconductor based amplifier module.

(a) (b)

Figure 1. (a) Jose Pino's Styrofoam plate loudspeaker and (b) Open Thing's Niftymitter

3.2 The Brief

The project brief was to design, build and test a wireless loudspeaker system. Students arranged themselves into groups of 6, and into 3 pairs with the team, with each pair working on one of 3 core product modules. The pairs then reformed as a group of 6 to combine the modules as a singular product. To do this they were required to 'hack' a bought miniature radio, design and build an additional power supply module, create product housings and decide on placement of user control buttons and switches. Figure 2 provides an overview of the complete product architecture.

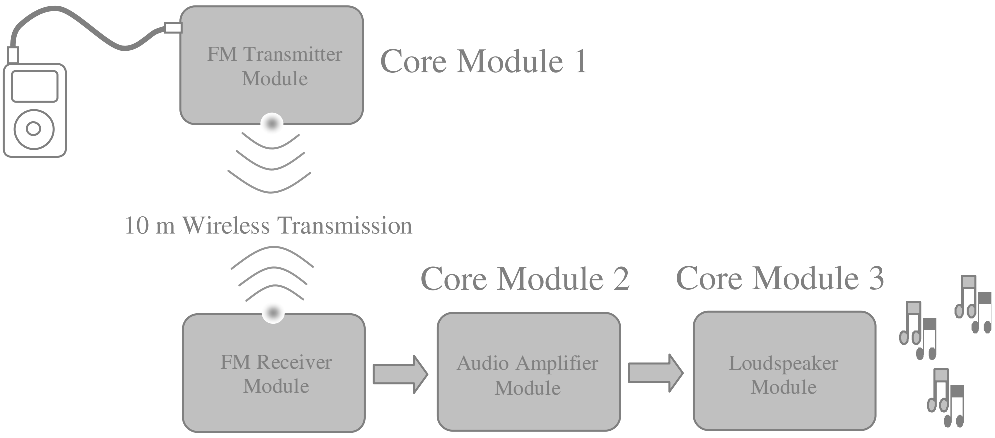

Figure 2. Wireless Speaker Product Architecture

The project was carried out over 4, 2 hour long, lab sessions with technician support. Additional information on equipment setup and basic procedure were distributed as necessary. The final product was submitted along with a group report detailing design, build, testing and costing of each module. The brief also required that research be carried out on the operation and applications of major circuit components in each module.

4 RESULTS

Each team was able to confirm the functionality and reliable operation of each module independently before integrating all modules together in single product architecture. All teams produced a working product which was able to play back music transmitted from the opposite side of the lab.

Figure 3 shows an example of a finished **transmitter module**. Functionality is provided by a simple battery powered circuit to which an audio source, such as an mp3 player, can be connected. It wirelessly transmits the audio as an FM radio signal that can be picked up by any FM radio receiver within at least a 10 m radius. A single transistor forms part of an Inductor and capacitor oscillator (Clapp), and acts to amplify the audio signal for transmission. Students are given a circuit schematic, components and tools, and are asked to design, assemble and test (bandwidth of) the circuit on stripboard as shown in figure 3 (a). As well as the circuit board layout, the team designed a housing exemplified in figures 3 (b) and (c). The frequency response of the transmitter was measured and plotted in spreadsheet.

Figure 3. (a) transmitter strip board layout designed by student team; (b) and (c) enclosure for transmitter provides user access to battery and audio plugs.

Loudspeaker module prototypes were constructed in a similar way to Jose Pino's example in figure 1(a). Flat plates, bowls, cups and other light and stiff forms identified by students were tested using a frequency generator connected to the prototype and measured using a sound pressure level (SPL) meter. Measurements of each prototype were plotted on the same graph axes for comparison. Figure 4 (a) and (b) shows development of the speaker prototype to be housed in an enclosure which further contributed to the acoustic amplification of bass frequencies.

Figure 4. (a) completed product with speaker mounted in box (b) speaker voice coil and magnet configuration (c) amplifier wiring and switch mounting.

The enclosure also provided space to house the amplifier (figure 4 (c)), which was wired to a 'hacked' radio receiver (figure 5 (a)). The teams also had to construct a voltage regulator module which allowed the amplifier and radio receiver modules to be powered by the same battery and switched on and off together as shown in figure 5 (b). The team also had to consider positioning of user controls to allow control of the product as shown in figure 5 (c).

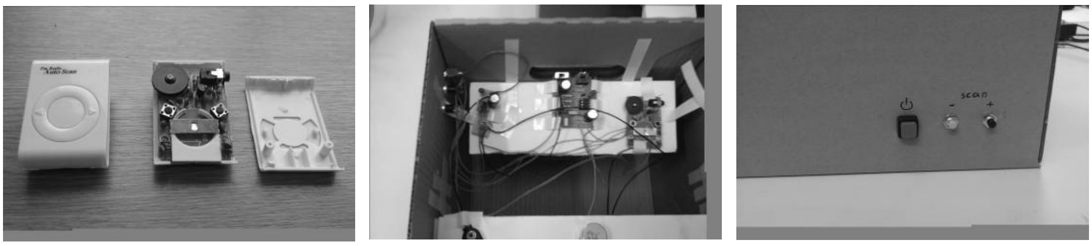

Figure 5. (a) miniature radio to be hacked (b) amplifier, radio receiver integrated with same power supply (c) arrangement of product interface.

5 CONCLUSIONS AND FURTHER WORK

The project detailed has not yet been established as a 'mass' collaborative project. However, students are aware that the source of the module ideas has come from community contributions, and that their work will be submitted to the growing 'Open Thing' project. This should foster community with future student cohorts and with any other interested 'hackers'. In this sense the project will be evolutionary; another key characteristic of open design approaches [7]. The product and development tasks will annually evolve from a repository of work.

The project also follows an open design approach in terms of its modular product architecture. Students voiced preference for the modules on which they wished to work, following a similar model for participation as open source software projects.

It is considered that where electrical concepts are embedded with practical skills experience and within a familiar and appealing product genre, the concepts are more likely to be transferrable to other projects (for example final year design project prototyping).

In this first implementation, students have engaged with the project, understood the links between fundamental concepts and product functionality and benefitted from gaining knowledge embedded with practical skills experience. It is intended that the impact of this approach will be formerly evaluated in future cohorts using survey instruments analogous to the Force Concept Inventory [22], [23].

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