The Scope of Computer Control within Technology

Mike Bostock

Computer control offers a productive medium for making progress in the study of systems within Technology. In this review Mike Bostock explains where control fits within the Technology orders, why it is important for design and technology, and what new opportunities for systems work are made possible through the use of this medium.

Computer control is a relatively new experience for pupils in schools. Over the last few years it has appeared within the Information Technology Capability strand of National Curriculum Technology where it sits in the Attainment Targets alongside turtle graphics and data logging. It is also implicit within the Programmes of Study for Design and Technology where it provides an important medium for systems work when used alongside other resources.

Computer control work in Design and Technology can contribute to the design-and-make cycle by providing a facility for developing the function of something a pupil will make. A computer control program can provide the logic that will cause a device to function so as to perform a task. Without some form of control pupils will have made an *artefact*. With computer control pupils will have made a *system*.

Where do we find computer control in Technology?

The IT Capability Attainment Targets for the Measurement and Control strand include the following:

5b. understand that a computer can control devices by a series of commands, and appreciate the need for precision in framing commands.

6b. understand that a device can be made to respond to data from sensors

8c. be able to construct a device which responds to data from sensors; be able to explain how they have made use of feedback when implementing a system incorporating monitoring and control.

The sensible home for this work, which spans Key Stages 3 and 4, would be Design and Technology, for although sensors can be associated with data logging work in Science, the ability to respond functionally to sensors is the province of systems work in Technology.

The revisions of National Curriculum Technology, and in particular the Orders for Design and Technology, have described systems work to different degrees of detail as a progressive set of practical experiences within Design and Technology schemes of work. One of the most detailed documents on this was the 1992 proposed orders for the Programmes of Study for Control Systems and Energy. Recent revisions have slimmed down some of the references although the concepts and their position in relation to levels would remain implicit within any scheme of work which covered control systems.

Table 1 lists in the first column, 'References to Systems', the key words from the statements in the Programmes of Study from the 1992 proposed orders. The next column, 'System concepts' pulls from this list some of the corresponding systems concepts that may be associated with these key words.

The third column, 'Resources', uses the examples of components or equipment either mentioned specifically, or implied. If we look down this column we see a list of key resources which a school would need in order to cover systems work generally across Key Stages 3 and 4.

The method of control (electronic, gate, microprocessor, computer) is implied in part within this list of resources but in practice we could substitute one approach or other at different times, depending on the learning outcomes that we would wish for the activity.

The last column, headed 'Computer control', provides keywords for a computer control interpretation relating either to the system references or to the associated system concept. As such this suggests that the choice for using a computer for control could be made at many points during a Design and Technology course.

Choosing different approaches to control

In practice, it would be valuable to be able to choose particular approaches to control at different times over Key Stages 3 and 4, selecting between using electronic circuits, logic gates, microprocessor boards, or computer control. In practice, when we select a particular approach we will be promoting different educational outcomes.

If we use a component approach we might do so in the context of teaching about transistors, resistors and capacitors, and the skills associated with making printed circuits. If we use logic boards, we might be focusing on developing system skills — the ability to rapidly assemble a circuit that can solve a problem, for example using two inputs and a logic gate. To use a microprocessor board is to

References to systems	System concepts	Resources	Computer control
Level 3			
simple mechanisms		hinge, wheel, axle	
switches		switches	programmed switching
electrical circuits		lamp, buzzer, motor	control appliances
Level 4			
subsystems	subsystems	levers, gears, pulleys	control of movement
		electrical components	
Level 5			
command sequences	sequences	computer program	command sequences
mechanical components		links, cranks, gears	
switches	switching	tilt, toggle, reed switch	decision making
Level 6			
input process output	input process output		process control
interconnection of systems	system integration		integrated control
sensors	analog sensors	light, moisture, temp.	analog sensing
digital logic circuits		electronic circuits	
pneumatic/hydraulic movement	binary numbers	pneumatics/hydraulics	pneumatic control
control devices		valves	
electronic circuits	electronic switching	electronic components	
prototyping	prototyping		control programs - building and testing
Level 7			
open/closed loop systems	open/closed loop		decision-making programs
feedback	feedback		
relays		relays	computer switching
movement			
basic pneumatic systems		pneumatics	pneumatic control
integrated circuits		integrated circuits	
logic gates	logic gates	logic boards	
Level 8			
sensitivity and lag	sensitivity and lag		processing logic
test equipment		multimeter	
calculation			mathematical processing
pneumatics		valves, cylinders	pneumatic control
integrated circuits	integrated circuits		
latching	latching	latch	programmed latching
Level 9			
stability	stability		programmed stability
computer control		computer, program	computer control
microelectronics control		microelectronics	
pneumatics			pneumatic control
pulse generator		pulse circuits	
Level 10			
comparison of system types	choice of system		computer control
new technologies			
optimising performance	optimisation		developing algorithms
automatic systems	automatic systems		programmed applications

Table 1: The contribution of computer control to design and technology (based on the Programmes of Study for Control Systems and Energy (1992 proposed orders)

emphasise the use of binary codes and sequencing that lies at the heart of work with computers. To use a computer is to promote the high level design and testing of the logic that can govern the function of a system.

Why is computer control an important medium?

When working with a computer it is possible to use a high-level computer control application working with an interface to allow control programs, or *algorithms*, to be developed from the computer. This can be accomplished with relative ease, particularly when one is working within a window environment and using a mouse. In this situation one can 'design' command sequences and select switching patterns by clicking on buttons portrayed on the computer screen. Programs developed in this way can be tested and improved more rapidly than one could do with a *hard-wired* electronic system.

A computer in effect provides a graphical surface over an electronic circuit whose function can be made almost infinitely flexible. The function of the system can be changed by changing what is on the screen rather than rearranging the electronic components as we would need to do in a lower-level system.

Working with a computer is a *black-box* approach to systems work. It reduces the need to understand how electronic circuits are made and promotes productivity in designing, building and testing control algorithms. Because of its accessibility, computer control can be used with very young children, where the approach used is similar to writing sentences, or at more advanced levels with the brightest secondary school students where, for example, *interrupt-driven* programs may need to be developed in order to control systems which will operate in response to signals from many sensors operating at the same time.

Computer control remains an optional medium to use from Level 3 work through to Level 10 work where it can contribute to the learning about systems concepts. At Level 3 computer control is useful because it makes systems ideas like sequencing, sensing and movement accessible in a practical sense to young learners, whereas alternative approaches may introduce barriers such as constructional requirements, that can detract from these goals. At the highest levels computer control will be important because it provides a medium whereby complex systems can be made to operate with a level of function that would be difficult to achieve using lower-level microelectronic approaches.

When computer control is used alongside the use of microelectronics there is scope for moving between working at a high level so as to develop an understanding about what systems can do, to moving to a lower level in order to develop an understanding about how they do it.

The level of sophistication of the control program that can be created using a computer is one important reason for using a computer. For it will be possible to support advanced systems work where students could create a program sufficiently developed to enable a system containing several sensors and actuators to perform a meaningful task. Such activities help to promote the subject of Technology as relevant to the experiences pupils will have of technology in the modern world, where programmed systems make a major contribution.

Choosing computers for control also reflects the techniques used for software development in real system applications. This can include the logic needed for traffic control to the engine management systems now commonly used in cars. Modern software development would typically use a high-level control program for the ease of development of the control logic for the target system. Once the software has been tested, it will be *compiled* into the low-level code used by a microprocessor in what will become a dedicated control system. In the classroom this last stage has not traditionally been followed although there are now control programs which can compile programs into microprocessor code, and there are also interface boxes containing a microprocessor able to run the program independent of the computer that created it.

In an educational context, one of the most important reasons for using computer control as a medium is that it promotes the process of design when making and testing systems. This is because control programs can incorporate graphical techniques for assembling command sequences, and for expressing the flow of control, which are shared with other programs used for drawing or designing. Furthermore, high level control software can produce print-outs that can clearly present and communicate the logical flow that describes the function of a system. Overall this is an appropriate approach for a design and technology department because their interest is to encourage design skills, not to produce computer programmers.

Outcomes of computer control work

The educational outcomes of work with computer control will include the following:

Conceptual skills

- the ability to analyse a system problem, breaking it into stages that represent separate tasks.
- the ability to design sequences and control structures that make up a control program.
- the ability to think and make decisions at a systems level of operation.

Practical skills

- the ability to link together the separate parts of the system, i.e. the sensors and actuators through an interface to the commands represented on the screen.
- the ability to operate the control program effectively using the mouse and keyboard.
- the ability to adapt and develop all parts of the system (program, sensors and actuators, mechanical and structural elements) so as to optimise its function.

Understanding

- an understanding of how software algorithms control the function of modern systems in our society.
- an understanding of how algorithms that represent the flow of logic in a system are built from software subsystems containing sequences and decision-making units.
- an understanding of the relationship between high-level commands and the low-level operations like switching or sensing that take place when a system operates.

Products

The physical product from a computer control activity will be a print-out of the computer program. This will provide a visual description of the algorithm, or *logic pathways* that govern the function of the system. An algorithm is a true product and as important an outcome as the system that is built, although it will be a structure built from information rather than from physical materials. If students also use a spreadsheet or a desk-top publishing program then these will also provide *information products* when printed out.

What will be controlled?

The first decisions that will be made when setting up a facility for supporting work involving computer control and systems will be in obtaining an appropriate number of computers with the correct ports, a set of control boxes to go with them, and some computer control software.

The next step will be to consider the sort of systems activities that pupils should experience over Key Stages 3 and 4 and to identify what other materials will be required at each stage. It is clear from the Design and Technology Programmes of Study quoted that a hierarchy of components and sub-systems will be needed.

In regard to this, a department might determine what aspects of systems work will involve consumables, and what aspects will use components able to be recycled. Clearly, most work with pneumatics will not be consumable — pupils ought not to take away the compressor! In this case the system that is built could be photographed and the materials re-used. Similarly with computer control work, the computer and interface will stay at school. Kits like FischerTechnik, LEGO or Meccano will also fall into the non-consumable category and, despite the relatively high initial costs of these materials, being reusable they are cost-effective in practice.

However, a problem with kits at Key Stage 3 is that when the next class comes in we will need the materials again, so in this case it will be difficult to build systems that are intended to be developed over several weeks.

There is however a place for kits that doesn't have the requirement for disassembly at the end of each lesson. That is to make a set of models offering a good computer control problem and to keep them made as something to be controlled, adding superglue to some parts if necessary to ensure they stay assembled. Although this may not sound like good Design and Technology, if we acknowledge that the goals for a control task need not always include making skills then this will be a perfectly acceptable approach when balanced against all of the activities over a key stage.

Final Products or Prototypes?

Another difference between work involving systems as opposed to artefacts is that we need be less concerned with what is made looking like a 'final product'. Work involving artefacts lends itself to encouraging the skills of making, and to product realisation. There is plenty of scope over the key stages to achieve both these outcomes without it needing to be a high priority for systems work.

The opportunity offered by systems work is the important technique of *prototyping*. This allows systems ideas to be put together rapidly and to be tested and revised in the light of that testing. This approach can promote a rapid understanding of systems, and of the requirement for all elements (mechanical, structural, logical) to operate together successfully. In practice the system may only be representational, or as skeletal as is required to test its function. After all, the goal of good systems work will be to develop its function, not necessarily to develop its appearance.

Once a functioning system has been prototyped, decisions may then be made as to how far towards the 'completed' system one should then go. This will depend partly upon the time available, but more importantly, whether there are new educational goals to be gained through this choice. Sometimes there will be, but on occasions a working prototype may mark the conclusion of a piece of work.

Project themes for computer control work

With the means to resource the designing and making of systems comes a range of new possibilities or themes that can stimulate good Technology work using this medium. These activities will typically involve mechanised devices, simple or more complex, often with movement or function, and designed to serve a specific purpose or solve a defined problem. Within these themes there is scope for covering many essential systems concepts and encourage choices over the materials or control system that will be appropriate. No system should be off limits to study. Where a very large system is chosen, a scale model could be studied, but pupils will need to be clear about how scaling up might highlight differences between the real system and the model.

One of the most versatile starting points for exploration of the problem, or for the first

Project Themes	System examples
Fairgrounds	Burglar alarms
Helping the disabled and the elderly	Washing machines
Energy	Lighthouses
Measurement	Thermostats
Environmental control	Fairground machines
Automation in manufacturing	Grading machines
Security systems	Combination lock
Inventions and gadgets	Three floor lift
Monitoring animal behaviour	Environmental control systems
Robots	Conveyor belt sorter/counter
Automatic vehicles	Robot manipulators
Quality testing systems	Solar drive mechanism
Automated shopping	Optical card reader
Penny-in-the-Slot machines	Cash point machine
Vending and dispensing machines	Chocolate bar machine
Exploration in inhospitable areas	Automatic barriers and doors
Remotely-controlled devices	Level crossing
Telechirs	Cable car
Machines and Medicines	Robot welding/spraying machines
Sport and Leisure	Buggy studies
Space Travel	— sensing the environment
Agricultural machines and devices	— measuring distance
The Theatre	— finding a light source
Kitchen machines and devices	— detecting and retrieving objects
Intelligent machines	— avoiding objects
Gardening aids	**Scientific studies**
Bridges and cable cars	speed of a model car
Traffic control	acceleration due to gravity
Dynamic sculptures	thermostatic control
A better mousetrap	simulation of an iris
Point-of-Sale systems	a car flasher system
The automated home	an automatic greenhouse
	an electronic thermometer
	rate of heat flow in materials

Table 2: Design and Technology Systems Applications

experiences of testing a prototype, will be to use computer control as the medium for trying out ideas before defining more clearly the functional steps and the necessary system requirements. Having developed an initial understanding of the parameters and variables of the system, decisions can then be made as to how best to proceed.

Table 2 lists, in the first column, some possible project themes. Each item could give rise to a range of possible approaches where new system ideas could be explored. For example, 'Penny in the slot machines' could give rise to an exploration of Victorian mechanical theme machines (haunted house, creepy graveyard, etc.) leading to a project which might seek to develop a similar device which could represent themes more suitable to modern times.

The second column lists some examples of systems that could form more of a basis for study or development. In many cases they could be studied at first hand by locating real examples of the system. It is possible that information could also be discovered about many of these examples to help identify the system characteristics: input, process, output, details of the mechanisms, tasks to be carried out, operating conditions, etc.

The scope for good design and technology work involving computer control is very great and the high-level approaches which allow system function to be explored complement other approaches which focus on how a system works and how a system is made. Computer control, by encouraging a systems approach to design and technology, can also help develop high-order thinking skills in pupils which can complement the designing and making skills associated with more established work in this subject.

Summary

Some points to bear in mind when considering computer control as a medium for systems work might include the following:

- Computer control can encourage work at the highest, or 'systems' level.
- Computer control can provide an accessible medium which can provide practical experiences of many systems concepts.
- The graphical medium of the computer screen can promote the process of design and can aid presentation and communication of the logical flow that describes the function of a system.
- Computer control can allow complex systems to be designed, made and tested.
- Computer control makes it possible to study systems relevant to the technological world in which we live.
- Computer control offers an approach to the development of systems similar to that found in industries specialising in the manufacture of systems.