The potential for using PIC chips in school control projects

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Abstract

Computers housed in a single IC package (programmable micro-controllers) have been manufactured since the eighties and are used in a variety of products including: remote controllers for TVs and car locks, washing machine and microwave programmers and communication devices. One popular range of programmable micro-controllers called PIC chips have been used by the Nottingham Trent University to explore their potential for Design and Technology education within secondary schools.

This paper discusses the rationale and development of electronic control education within the UK and outlines software and hardware developments using PIC chips, which could bring the use of computers embedded in individual projects within the reach of all schools.

PIC chip (Peripheral Interface Controllers - name registered by Microchip), programmable micro-controllers offer new challenges and opportunities for technology education. Industrial applications have demonstrated tantalising control versatility at low cost with minimal assembly and space requirements. What potential is there for using PIC chips in school projects?

This paper considers the rationale and development of electronic control within Design and Technology education in the UK and discusses the opportunities for using PIC chips in secondary schools.

Electronic control within D&T education

Electronic control has brought a valuable and stimulating dimension to the technology curriculum and must continue to reflect industrial progress both to maintain its curriculum credibility and to best prepare our children for the future. However, it is not sufficient for technology to merely exist in order for it gain a place in the curriculum. It must contribute to the education aims which for D&T education within the UK are concerned with developing capability through understanding everyday products, acquiring practical knowledge and skills and using those skills to design and make products. It must be in an appropriate form for children to use, cost effective resources must be available and teachers adequately trained. Can this be achieved in the current climate?

Electronic control became popular in UK education in the 80s. It offered relatively cheap resources consisting of various sensors and output devices. Signal processing involved logic switching, timing and counting. It became possible to model a range of sophisticated functions such as light, temperature and touch warning systems and vehicles which could navigate their way around obstacles.

The early work involved recognising and connecting components in given circuits and understanding system functions. Circuit wiring was time consuming and design opportunities were often limited by student's lack of understanding of circuit principles. Project work usually meant copying a standard circuit design and hoping it would work when soldered onto a board. Electronics education evolved into a systems approach where processing units were presented as modular building blocks, providing an electronic equivalent to construction kits. This offered a greater variety of functional units, increasing the design opportunities and reducing wiring time. Project work could present cost and complexity problems because it was relatively easy to create sophisticated systems requiring a multiplicity of components. Designs could also suffer from either being constrained or contrived to suit the limitations of individual system units.

Computers provided an alternative route to control. With a computer, control interface and appropriate software it was possible to connect sensors and output devices directly to the control interface. All the processing functions including logic decisions, timing, counting and memory were programmed and could be continuously tested and modified without having to handle a bank of electronic system units. Computers offered a software equivalent to electronic systems but with significant differences. They were expensive and bulky and could not be easily incorporated into a control model. The programming involved sequencing verbal commands which imposed constraints with some control functions. For example, it was extremely difficult to program for two or more functions to operate simultaneously.

The ideal compromise might consist of an inexpensive programmable controller which could be incorporated into a model and use a programming language which would offer the intuitive assembly of electronic systems but with the convenience and versatility of software. This vision gave the stimulus for the Nottingham Trent University (TNTU) developments.

TNTU developments

Investigations into industrial control systems revealed interesting parallels relating to control rationale. Industry's need for cost effective and flexible control systems had led to the development of Programmable Logic Controllers (PLCs). These had become increasingly important during the 80's offering an intermediate route lying between dedicated electronic systems and mainframe computers for the control of industrial machinery.

PLCs are programmable control units which are dedicated to individual machines (10). They can be programmed using a detachable programmer (figure 1).

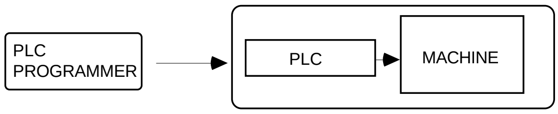

Figure 1: PLC System

A wiring diagram system used by electricians and called Ladder Logic was adapted as a control language (10) for PLCs to make programming readily accessible to electricians. An example of a simple ladder logic is program is shown in (figure 1). The output (007) is energised when two switches (030 and 031) are simultaneously operated.

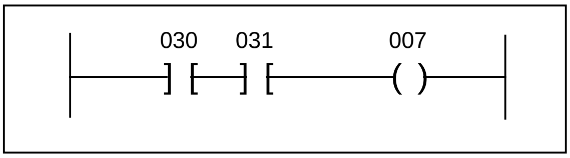

Figure 2: Ladder logic program

Separate control functions are represented by different rungs on the ladder but unlike programs such as LOGO or BASIC where one program line is completed before moving to the next, all the rungs are quickly scanned and any changes are implemented at the end of the scan. The system emulates parallel processing and requires a different approach to programming. Flow charts and the use of repeat loops are irrelevant, instead it is necessary to consider logic statements and appreciate that any changes will be acted on in real-time.

The PLC system was seen to offer a number of potential benefits for technology education and provided a focus for the developments.

Adapting the PLC approach for education

The PLC approach inspired two lines of development:

- a parallel programming language based on Ladder Logic.
- a programmable micro-controller which could be used independently from a computer.

This system would offer the following advantages:

- The programmable micro-controller could be attached to a model, freeing the desktop computer and allowing a greater degree of portability for the control model.
- Ladder Logic could offer a more user-friendly approach than verbal languages which might enable children to transfer design thinking more effectively across different control systems such as electronics and pneumatics.
- Ladder Logic would overcome the programming difficulties inherent with sequential languages such as LOGO and BASIC with situations which involve controlling two or more functions simultaneously.
- The system would offer experience of industrial programming systems.

Developing a Ladder Logic language

Work began on the control language and programmable micro-controller in 1987. The language called ICON was first published for the BBC computer in 1989 (11). Versions for IBM and Archimedes computers were released in 1996 (12). The principles of ladder logic were embodied in the manipulation of graphic symbols based on electronic functions which would be more relevant to students. The programming screen display is shown in figure 3.

ICON uses interconnected graphic symbols to represent logic statements. The user is presented with an on-screen programming page consisting of an ICON menu bar and left and right boundaries for the logic statement.

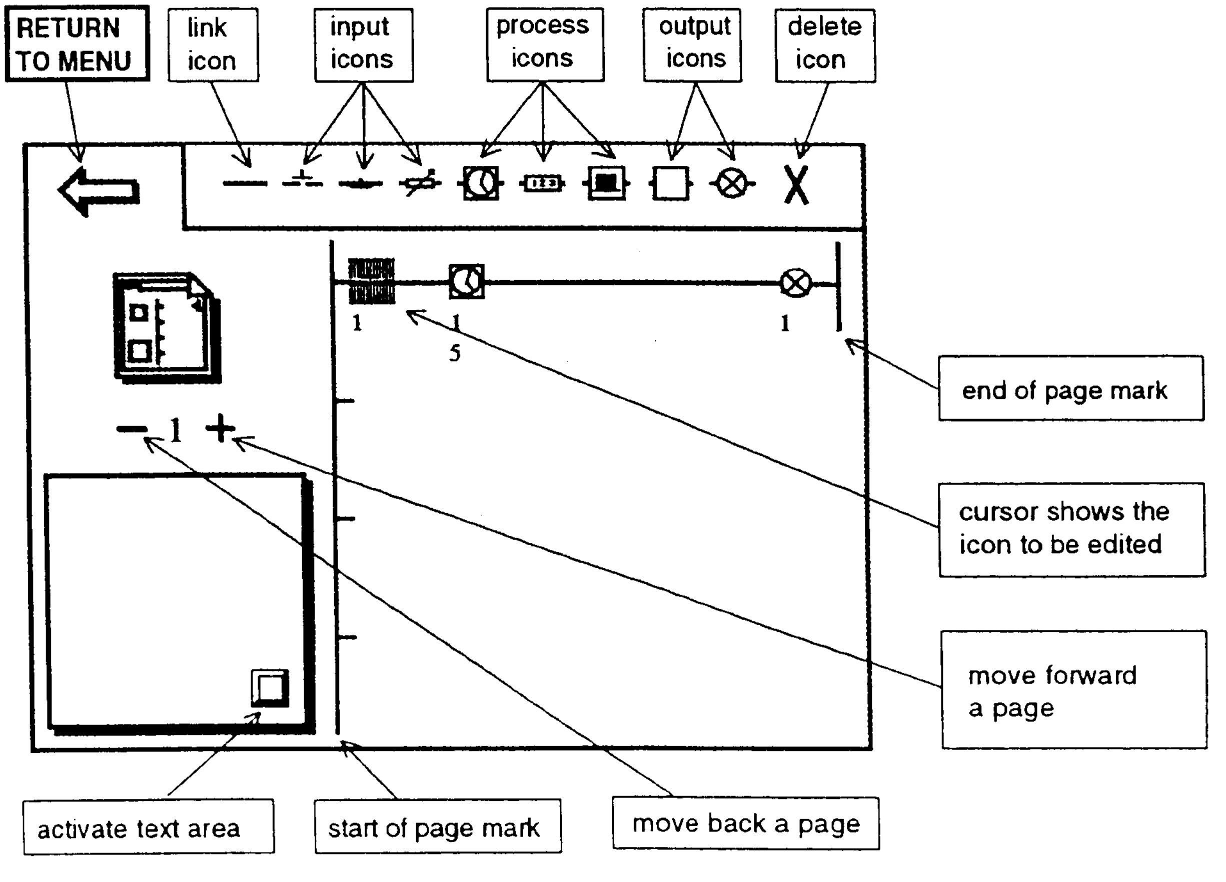

Figure 3 ICON screen display

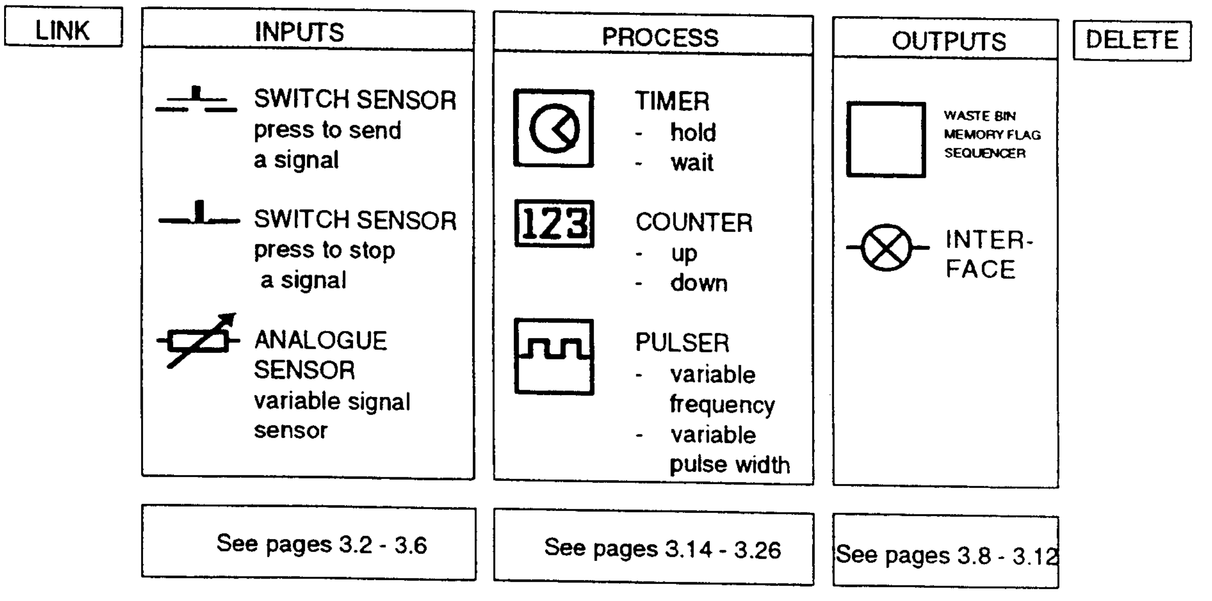

Figure 4 ICON function options

ICON programming involves selecting icons and assembling them to form a SENSE, PROCESS, OUTPUT statement working from left to right across the page. The functions offered are summarised in figure 4.

An example of a solution requiring a timer to come on for 30 seconds when a switch is operated is shown in figure 5 and compared with a typical LOGO solution figure 6.

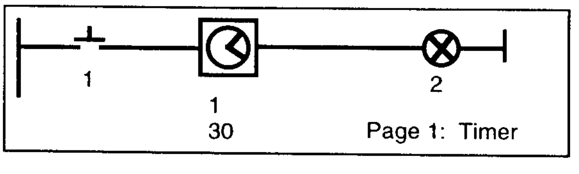

Figure 5 ICON timer program

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TO TIME
IF INPUTON? 1 [HOLD]
TIME

 TO HOLD
SWITCHON 1
WAIT 30
SWITCHOFF 1
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Figure 6: LOGO timer program

Programs which involve two or more independent functions are programmed with the independent functions appearing on separate pages. Each page therefore acts as a ladder rung in conventional ladder logic. The following program shows a solution for a model fairground which involves three rides. Each ride is operated by pressing a switch which activates a timer to hold the ride on for a set time figure 7.

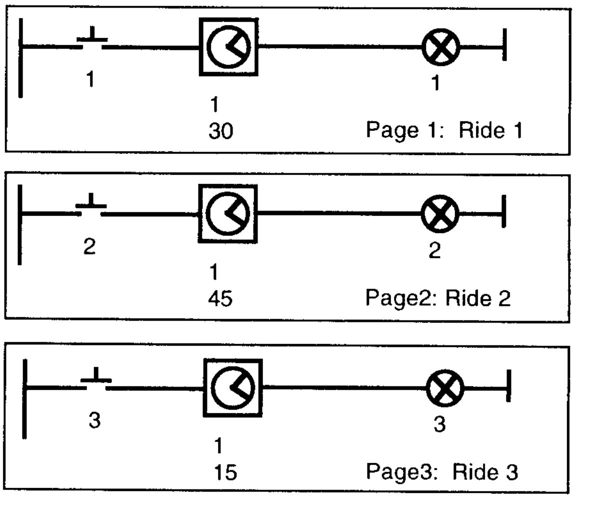


Figure 7: ICON solution for three fairground rides

The rides can be operated independently, in any order without any apparent pauses and using program structures which are logically straightforward. A further advantage is that different pupils could easily program their own ride on their own page within a single program to provide a group display. It would be extremely difficult to model this situation using a sequential language.

Developing a programmable micro-controller

Development of a programmable micro-controller based on standard computer technology, led to a commission from the National Education Centre for Education Technology and the unit was marketed as Sense and Control (1991). The unit is essentially a computer-in-a-box slightly larger than a video cassette and offers the equivalent of an industrial PLC. The data logging facilities incorporated in Sense & Control led to a more sophisticated design than needed for control applications and this was reflected in the selling price of almost £200. Sense and Control offered a programmable controller which could be installed in projects but the cost made it prohibitive for general school use.

PIC chip programmable micro-controllers

The introduction of integrated circuits (ICs) in the 1980s which offered a computer-in-a-chip, generated particular interest. In particular, the PIC chip range (peripheral interface controller - name registered by Microchip) with prices starting at £4 offered almost unbelievable potential. The challenge lies in developing a user-friendly programming interface which could be used with the limited memory allocations.

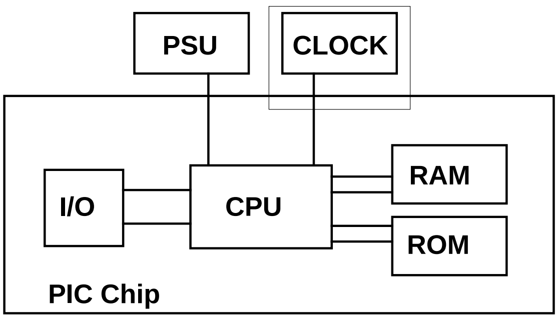


Figure 8: PIC chip system

A typical PIC chip system is shown in figure 8. and differs from computer processor ICs in that it has memory built into the chip. In addition to the chip, a power supply (and optional clock) are needed to form a complete computer system. Output drivers would also be needed to interface with control components.

Generally the higher the price the greater the facilities offered in terms of memory size and input / output facilities. They are electrically robust, having been designed for industrial applications, with a wide operating voltage range from 3.0 to 5.5V which makes them ideally suited to school use.

The Arizona Microchip range was selected for the development. The PIC 16C55, for example, offers 512 bytes of ROM, 24 bytes of RAM and 20 Input /Output lines. The cost of £4 suggests that a simple computer could be installed in a project for significantly less than £20. However, comparing the memory size with a BBC B computer (ROM 32 kbytes, RAM 32 kbytes) it can be seen that the programming options are severely restricted. Industrial applications make use of machine code programming but it would be neither practical in terms of curriculum time nor appropriate to teach this.

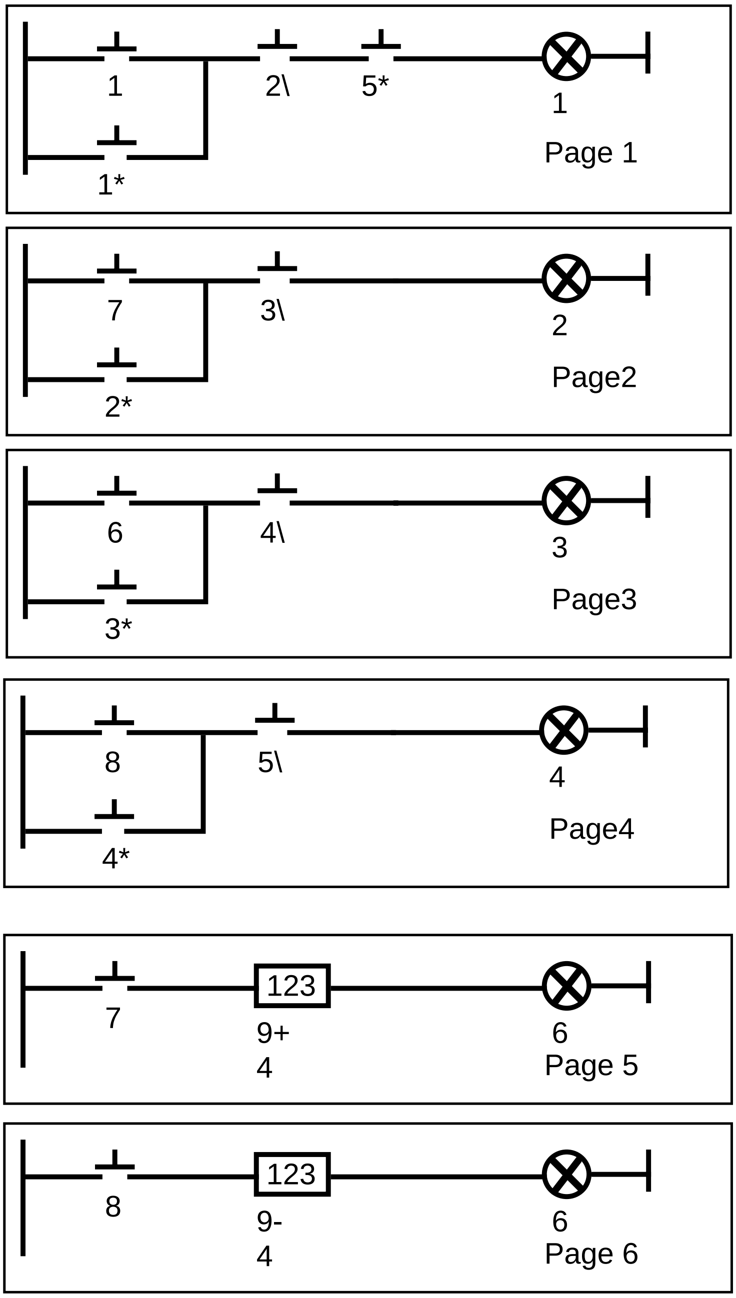
The challenge was to compile ICON programs so that they would run effectively with the limited memory available. The first working prototype was achieved in 1995 using a PIC 16C55 to control an automatic car park. It involved the use of 8 inputs and 6 outputs and occupied six pages of ICON program. The parts and costs for the electronic processing components including output drivers were approximately £10 which compared favourably with the costs for a discrete electronic solution.

The ICON program for the car park is shown in figure 9. Cars were monitored entering and leaving and a count was made so that cars could be prevented from entering the park when it was full. The system could handle cars entering and leaving at the same time.

The program represents a level of sophistication appropriate for GCSE. However, the process does challenge traditional programming techniques such as the use of flow diagrams, as programming assumes a completely different format which has more in common with electronic system design. A research program has been established to investigate the implications and learning opportunities for school use.

Inputs	
1	In button
2	In barrier - up switch
3	In barrier - down switch
4	Out barrier - up switch
5	Out barrier - down switch
6	Ticket out button
7	Car in sensor
8	Car out sensor

Outputs	
1	In barrier - motor up
2	In barrier - motor down
3	Out barrier - motor up
4	Out barrier - motor down
5	Spaces light
6	No spaces light



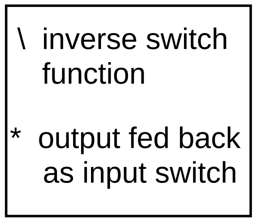


Figure 9: ICON solution for automatic car park

Education research programme

The education research programme is being conducted at both formal and informal levels. TNTU is funding a research student for a two year programme to investigate the impact of using the ICON control language on pupil's technological creativity. This work is being carried out in three secondary school's with pupils at KS3 and will report in September 1997.

At an informal level, ICON and PIC chips are being used for student project work on the Primary BEd and Secondary BEd courses. Observations indicate that students can handle independent programming involving inputs and outputs with functions including logic decisions, timing counting following a thirty minute introduction. The similarity to electronic system design coupled with the absence of linear programming techniques such as procedures and loops enable a rapid learning rate allowing students to devote more time to creative design.

One group of Primary Yr3 D&T specialists were involved in a 13 week programme which introduced a range of control systems including electrical electronic, pneumatic, and computer systems over a seven week period. The student's previous experience consisted of an introductory module in the first year. They were then required to develop a control system which incorporated position control and the use of at least two sensors and output devices.

Of the 15 students only four chose computer control using ICON. The remaining student's used electronic systems. The reasons for the choice of electronic systems included: more challenging, could be incorporated in the model and developed at home. One student with a physical disability used ICON because of difficulty in handling electronic components. She made a model greenhouse with an automatic watering, window opening and heating system. The other students chose ICON because of the sophistication of their control systems. One model involved a dragon teaching aid which gobbled coloured balls and displayed a count of the different colours. Another involved a robot arm which picked up eggs and placed them in their correct positions in an egg box. The other involved an attachment for a pushchair with rocking and sound effects to comfort a distressed child.

The PIC chip developments were carried out by students following the Secondary BEd course which involved advanced control teaching. The use of PIC chips was confined to exceptional students who were prepared to learn machine code programming in their own time. One project consisted of a simulated animal which would run away when shouted at or kicked, would move around avoiding obstacles and go to sleep when it was dark. Another project involved a telephone dialler for a disabled person which could be operated by a foot control and sound. Another student made a cricket ball throwing machine which used four motors to propel the balls each controlled by a PIC chip and using a fifth PIC chip as a master controller to enable different spin and velocity outputs.

The project examples illustrate the levels of sophistication and stimulating outcomes which can be achieved by students with appropriate experience and motivation. The aim for the ICON Project was to combine the ease of programming with ICON with the use of PIC chips to enable all students to gain access to exciting and challenging control systems.

Future developments

Work on the PIC chip development is still continuing. It is intended that PIC programs will be downloaded from ICON software and that the software will indicate the minimum PIC requirements to accommodate any particular program. A working system for schools would include a computer, ICON software, control interface and a chip programmer. A control program would be developed on the computer and when perfected programmed into a PIC chip. The chip with appropriate clock, input and driver circuitry would then be embedded in the project for totally independent control.

As this paper was being written news was announced of the launch of an 8 pin PIC chip with an expected retail price of £1.50? The situation is reminiscent of the introduction of the 555 timer in schools some 10 years ago. However, this chip is very different. Students will not simply solder an IC into a circuit designed by someone else. They will be able to create their own control system to meet specific requirements which they will embed in their own work. An AND gate or a pulser should prove easy for programmer and chip memory but more complex functions in a simple chip should also prove possible such as a system to control traffic lights. A robot animal which will move to avoid obstacles, will run and hide when shouted at and fall asleep when it is dark will demand a more powerful chip. ICON will tell the programmer the minimum chip specification for the program.

So what would a school need to put this system into use? A working system would include a computer (IBM or Archimedes) , ICON software, control interface and a chip programmer. A control program would be developed on the computer and when perfected programmed into a PIC chip. The chip with appropriate clock, input and driver circuitry would then be soldered onto a standard printed circuit board and embedded in the project for totally independent control.

The ICON / PIC system could bring programmable micro-controllers within the reach of all schools and replace the use of conventional electronic gates, flip-flops, timers, and counters to enable more challenging and creative outputs in our schools.

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