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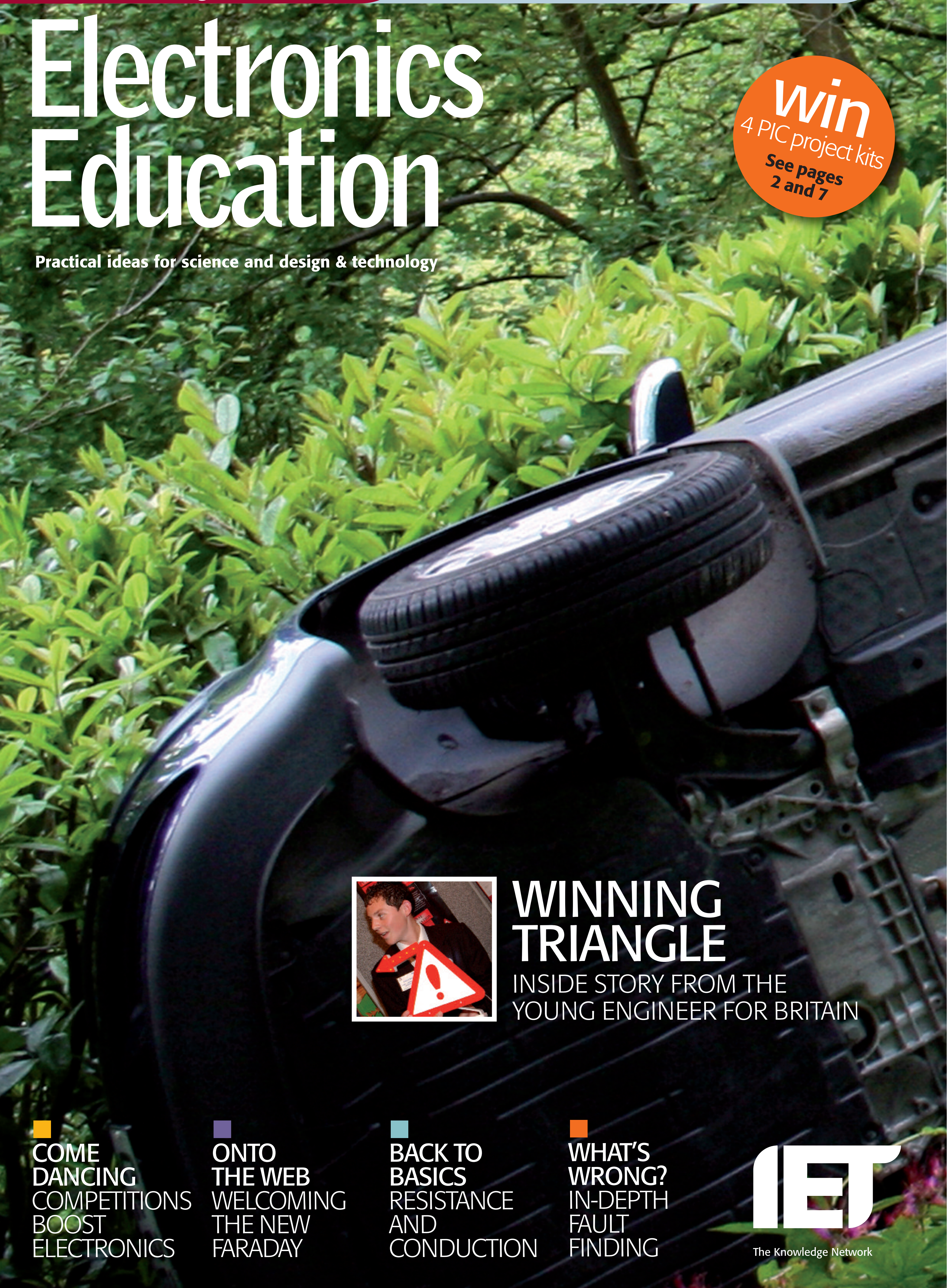


Electronics Education

Practical ideas for science and design & technology

win
4 PIC project kits
See pages 2 and 7

WINNING TRIANGLE
INSIDE STORY FROM THE YOUNG ENGINEER FOR BRITAIN

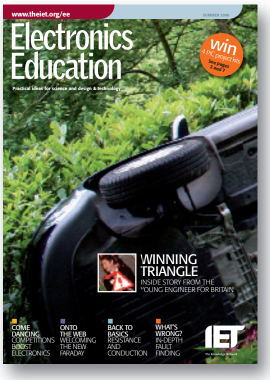
COME DANCING
COMPETITIONS BOOST ELECTRONICS

ONTO THE WEB
WELCOMING THE NEW FARADAY

BACK TO BASICS
RESISTANCE AND CONDUCTION

WHAT'S WRONG?
IN-DEPTH FAULT FINDING

IET
The Knowledge Network



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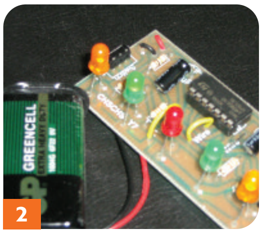
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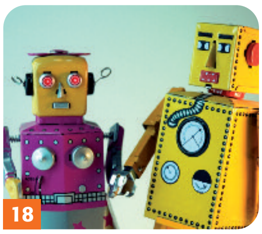
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editorial and advertising office
Electronics Education, The IET, Michael Faraday House, Six Hills Way, Stevenage, Herts SG1 2AY, United Kingdom
+44(0) 1438 313311
Facsimile: +44(0) 1438 765526
Email: roger.dettmer@theiet.org
subscription enquiries and orders
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agenda

Brave new world

NEXT SEPTEMBER sees the introduction of a new secondary school curriculum in England, along with the new Diplomas. An article in the Spring issue of *Electronics Education* provided a useful primer on the Diplomas – however, as a non-teacher, my knowledge of the new curriculum is distinctly hazy. I've been mugging up with the help of the QCA website, and the promisingly entitled 'The new secondary curriculum – what has changed and why?' Obviously, there are dangers in trying to paraphrase a complete document in a single sentence, but a reasonable summary of what's intended would seem to include greater freedom for teachers, through a less prescriptive curriculum; focusing on the "key concepts and the big ideas" that underpin subjects, and, using these key concepts and big ideas, to identify "cross-curricular links", leading to the design of less subject-bound teaching programmes that will "meet individual needs and engage all learners".

The words sound great, but what will they mean in practice? Opinion among the teachers seems divided between cautious optimism and world-weary cynicism. The optimists enthuse about the 'golden opportunity' for different teaching disciplines, especially D&T, science and maths, to work together. For example, using a textile project to look at the ethical implications of the materials being used, the science of fabric manipulation, fashion design, testing for wear, and the ethics of the sweatshop.

In the opposing camp, the cynics question whether anything very much is going to change, citing the inertia inherent in the school system, the pressure of assessment, and resistance from traditional maths and science departments.

In *Electronics Education* we'll be aligning ourselves firmly with the optimists. The IET's educational remit is basically to encourage all forms of school-based teaching that equip pupils to study engineering at university.

This embraces the whole of the STEM area, along with support to electronics teaching within D&T – the traditional role of Electronics Education.

Roger Dettmer
Editor

In future, alongside our long-running electronics-D&T articles, we will be publishing articles reflecting the cross-department teaching of the new curriculum. As always, the intention will be to provide practical, confidence-building articles for the working teacher.

We've a few ideas for prospective articles, but we'd like more. So, if you've a story to tell, or you've strong opinions on the new curriculum, or the parallel development of the new Diplomas, get in touch. And remember, with each issue there's a feedback prize to be won. This time it's four kits designed to enable your pupils to program a PICAXE chip to play their own compositions on a glockenspiel (see page 7 for details). A better example of cross-curriculum teaching it would be hard to imagine.

tribute

Frank Muraca, National Coordinator for the Technology Enhancement Programme and a long-serving member of the Electronics Education editorial advisory panel, died in January of this year. Three panel members, **Philip Hargrave**, **Peter Branson** and **Bridget Elton**, remember a delightful colleague who played a seminal role in shaping modern D&T teaching.

A one-off

FOR MANY years Frank Muraca was a member of the editorial panel of *Electronics Education*, an IET resource for teachers, and helped to make my role as Chair a delight. I vividly recall many marvellous occasions when he would produce 'something exciting' from his briefcase or pocket, and inspire us all with ways in which it could be used in an educational setting. I also loved his stories, and remember him recounting how he inadvertently went the wrong way down a one way street somewhere in Italy, only, when challenged, to got away with it by faking a complete ignorance of Italian.

His enthusiastic but light-hearted manner of jumping in with clever ideas helped ensure the success of many a meeting. The way he described the challenges he faced as a result of his treatment was inspirational. His medication had the unfortunate side-effect of making him see double, and I can picture him now, fully participating in one of our meetings with one eye closed because he was struggling to coordinate the inputs from his two eyes. At another meeting he regaled us with the story of how he had been inspired to think through the design of a basic but effective ECG device while was being monitored in hospital. It almost belies belief. But that was Frank, a one-off, who will be greatly missed.

Philip Hargrave

I can't remember when I first met Frank Muraca – he seems always to have been there – but one of my earliest recollections is of him holding forth on a course about "what it is now possible to do". He brought from his box of goodies a plethora of gizmos and gadgets and proceeded to solve a host of technological problems. He expanded colleagues' horizons about what it was possible to do and achieve, and he was often at the forefront in developing those new products to keep pushing the boundaries of possibility.

Frank was always a delight to be with and to work with. He was full of amusing anecdotes which would be told enthusiastically – he would have made the ideal after dinner speaker. We would often meet at the IET editorial panel meetings, where we discussed the latest editions of *Electronics Education* and Frank would always be informative, make critical comments and be generous in his praise of other colleagues' work.

His energy and enthusiasm for D&T knew no bounds. He was the consummate salesman for the subject and for TEP products! He had a lovely sense of humour and sparkle in his eye. We will all miss him greatly.

Peter Branson

I met Frank when we were both on the editorial board of *Electronics Education*. By the time I joined the board, he was already ill, but he came to meetings when he could. He invariably had some gadget or project with him, the latest in his seemingly inexhaustible supply of good ideas for teaching D&T. His sense of humour, his enthusiasm and above all his innovative thinking were an inspiration. He is a great loss to D&T teaching.

Bridget Elton

■ **More tributes to Frank can be found at www.cliffeco.com/InMemoriam/FrankMuraca.html**

'Team Pulse also won the 'fastest car' award clocking a time of 1.064 seconds, just shy of the world record'

PRIZES

Plymouth school crowned F1 in Schools World Champions

Team Pulse and Bernie Ecclestone

TEAM PULSE from Devonport High School for Boys, Plymouth, are 2008 F1 in Schools World Champions, winning the Bernie Ecclestone Trophy. After 12 months of intense competition from over 7 million students, the team members, John Ware, 16, Samuel Wood, 15, Andrew Lees, 16 and Thomas Simpson, 17, battled their way through regional and national finals to reach the World Championships, held in Kuala Lumpur, Malaysia from 18th to 20th March.

Team Pulse also won the 'Fastest Car' award clocking a time of 1.064 seconds, just shy of the world record set by Team Fuga of Northern Ireland last year at 1.020 seconds. Several of the teams blamed the slower times on the humid conditions which increased the moisture in the air, and in some cases added weight to the miniature cars.

"When we were at school, we did manage to get under one second," said the team's graphic designer, Thomas Simpson. "I think the conditions here in Malaysia played their part but it means the challenge is still there for teams to break the one second barrier."

As part of their prize, Team Pulse attended the Malaysian Grand Prix at the Sepang International Circuit, where they had access to the prestigious Formula 1 paddock, rubbing shoulders with the likes of Lewis Hamilton, Kimi Raikkonen and Fernando Alonso, as well as enjoying a tour of the pits and garages.

ROADSHOW

BAE roadshow wining heart and minds for engineering

BAE SYSTEMS has launched the third of its annual roadshows, using actors and simple props to take engineering directly into classrooms. From its start at Kirkham Grammar School in Lancashire, this year's show will visit another 110 schools and play to 10,000 more children. Over the past two years, the roadshow has visited over 355 schools and performed in front of 43,000 children.

The latest roadshow aims to gets young people excited about working in engineering by using innovative techniques including theatre and interactive workshops. It centres on a new piece of theatre called 'Scrapheap Charlie'. The audience is invited into the world of a young inventor who builds vehicles from recycled scrap in a hidden den. The performance is followed by workshops in which young people explore what it means to be an engineer and how they might pursue a career in the field.

Encouragingly, there's evidence that the message is getting through. Research figures released by BAE Systems show that, following its last roadshow for schools, 61 per cent of children questioned said they would actively consider a career in engineering. This contrasts with a recent survey by the Engineering and Technology Board that reported only one in 20 16-19 year olds feel 'well-informed' about the subject and another survey by OCR Exam Board reporting that just 7 per cent of 13-16 year olds think science/engineering is 'cool'.

More information about the Roadshow can be found at www.baesystemseducation programme.com.

A GUIDE FOR AUTHORS

Electronics Education welcomes contributions, especially from teachers. If you have something to say that you think could be of value and interest to teachers of electronics, then why not turn it into an article?

Full-length articles, up to around 2,000 words, could describe a school case study, the introduction of a major new product, new approaches to teaching, and changes in the curriculum. Shorter articles, perhaps just a few hundred words in length, could focus on hints for teachers: how to get difficult ideas across; how to make sure a tricky piece of kit always works. In addition, we'd welcome news items about events and activities likely to inform and encourage teachers. Or perhaps you've got some strongly held opinions you'd like to share with your fellow teachers. If you can turn this into 600-700 words of lively coherent copy, then there's a good chance we'd be happy to publish it as an opinion piece. Alternatively, you might just like to send a letter to the editor.

The process of turning an initial idea into a published article can be protracted and difficult, but aspiring contributors will, where necessary, receive detailed help and advice. We can advise on the suitability of topics, suggest how an idea could be structured into a successful article, and, if appropriate, provide detailed editing of copy to ensure a clear and readable end result.

If you'd like to discuss any potential ideas, please contact the editor at roger.dettmer@theiet.org

'As a starting point, I reviewed the different problems faced by a driver breaking down on the roadside at night'

safer on the road

Patrick Burns, a pupil at Abbey Christian Brothers' Grammar School, Newry, Northern Ireland, describes how he transformed the capabilities of the breakdown warning triangle to win the title Young Engineer for Britain

WARNING TRIANGLES play an important part in motoring. In countries like Spain and France it is illegal to drive a vehicle without having a standard reflective warning triangle. They can be an important aid to road safety, but they could do more.

Picture someone driving along a dark country road without any street lights, when, suddenly, they get a flat tyre. They get out and place their reflective warning triangle beside their car. They're now more likely to be seen by other cars, but their immediate need is to change the tyre, and how will they see to do that? They might have a torch, but if they're on their own, who will hold it while they change the tyre?

Also, when people are intent on their work, they tend to block out everything that's going on around them. Spare tyres are often fixed to the underside of a car, and the potential dangers involved in accessing these tyres in the dark are obvious. Protruding legs may not be seen by approaching drivers, and, in extreme cases, fatalities can occur. My project was designed for just this situation.

THE BUILD

My dad's a firefighter, and I came up with the idea of a car hazard warning system after he'd told me stories of people being hit by cars on the roadside at night. I then had to begin my research on what type of project I could do to help reduce this hazard.

As a starting point, I reviewed the different problems faced by a driver breaking down on the roadside at night. In particular, I wanted to give the driver an easy-to-use light, to warn approaching drivers that a car had broken down, and to warn the driver of the broken-down car that other cars were approaching.

I began by trying out different shapes: a flashing arrow on its own, a cone with a rotatable arrow on the top, a reflective circular stop sign, and, eventually, after many prototypes, I came up with the final design. This is based on the standard warning symbol, which approaching drivers will be immediately familiar with, but incorporates a number of additional features,which, I believe, will do a lot to improve safety in the event of a roadside breakdown in the dark. ▶

'Crucially, in contrast to the standard warning symbol, my warning triangle is powered using a car cigarette lighter'

◀ Crucially, in contrast to the standard warning symbol, my warning triangle is powered using a car's cigarette lighter. It can run on voltages between 6V and 12V. This means the triangle can be used to provide a working light for the stranded driver, and lights can be built into the triangle, making it easier to see.

The working light, comprising a set of high-intensity white LEDs, is fitted on the back of the triangle. It can be rotated into the desired position for working, and can be folded away for easy storage. Flashing red LEDs are also built into the arrow attached to the top of the triangle. This arrow is intended to give approaching drivers an indication of the position of the stranded car, so that they can take evasive action.

To help warn the stranded driver – who could well be preoccupied with changing a tyre – that a car is approaching, I added a light-sensing circuit to give an audible warning when the triangle is illuminated by a car's headlights. There's also a sensor to detect the vibrations of an approaching vehicle, which, again, triggers an audible warning.

YOUNG ENGINEER FOR BRITAIN

I entered my project in the Northern Ireland Sentinus competition, and on winning this, I gained entry into the Young Engineer for Britain competition 2007. This turned out to be a really great experience.

When, last September, I arrived in the Royal Naval Hall in Greenwich for the National Final I was really looking forward to the competition and couldn't wait to test my knowledge of my project. On the second day, the judging began, with the judges asked me some really gruelling questions. I didn't feel very confident about some of my answers, but I had done my best. I must have done reasonably well, because I won £250 for myself, £250 for my school, and a nice glass trophy.

In the evening we went to the dinner in the Painted Hall at Greenwich, where the bigger prizes were given out. The guest of honour was RAF Wing Commander Andy Green, who holds multiple land-speed records, and it really was an honour to meet him.

When the awards were being announced, I was very tired, and just didn't want to be there. I just wanted it all to be over, so I could go home and sleep.

That all changed a few moments later, when Kate Bellingham announced: "And the winner of the Young Engineer of Great Britain 2007 is ... Patrick Burns". I woke up from my silent slumber when I heard my name announced, but I was thinking there must be another Patrick Burns in the competition.

I looked up to the screen where it said my name and school, and I jumped out of my seat. I found it hard to control myself, and was very tempted to run up onto the stage . But I managed to fight this urge, and was elated when I collected my trophy and was informed I would also be getting £1,500 for myself and £1,250 for my school.

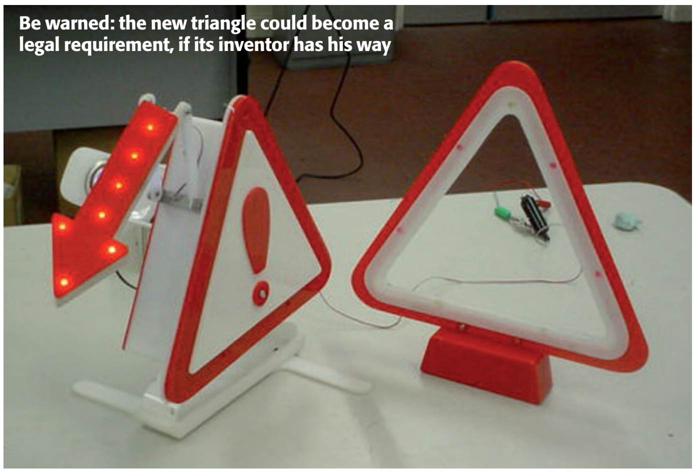
The next morning I had to talk to some journalists about my project, but the fact that I had won the Young Engineer 2007 still hadn't sunk in. It was a long day and on the way to the airport my lack of sleep the night before really hit me. When I got home, my family threw a small congratulations party for me. It was definitely the best experience of my life to date.

COMPETITORS AND RESEARCH

The only other competitor to my project is the standard, reflective warning triangle that is a legal requirement in your car in many European countries. It costs roughly £6 to buy new, and doesn't provide much protection to the user. Obviously it's better than nothing but it's not very good value for money. My technologically-advanced model, which I call the Automatic Hazard System, cost me roughly £12 to make, and could be produced for a fraction of this, if manufactured in volume. It could be sold for around £10, and I believe that because it will make drivers safer, would be well worth it. My hope for the future would be that my triangle would be the new legal requirement in European countries, rather than the standard reflective triangle.

THE FUTURE

My project is nearing the end of its patent process, and, although I've yet to find someone interested in producing my triangle commercially, I feel the future is bright for the Automatic Hazard System. I am still coming up with new ideas to improve the project, such as a wireless link between the detachable triangle and the stationary triangle, or devising a light sequence that indicates that the approaching car is moving closer to the triangle. ■


Be warned: the new triangle could become a legal requirement, if its inventor has his way

Give us your feedback on *Electronics Education* and you could win four kits to enable your pupils to program a PICAXE chip to play their own compositions on a glockenspiel. **Clive Seager** describes a highly innovative approach to cross-curriculum teaching.

feedback

contact

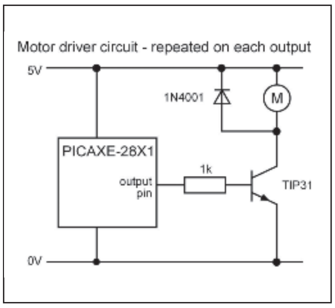
Send any feedback to the editor, Electronics Education, IET, Michael Faraday House, Six Hills Way, Stevenage, Herts SG1 2AY, or by email to roger.dettmer@theiet.org including your address
For feedback intended for publication as letters to the editor, the IET reserves the right to use submissions in any other format

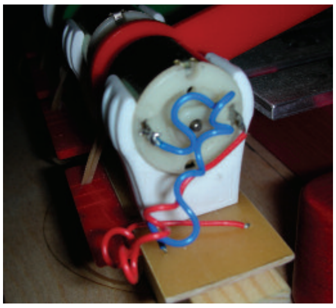
VIVA TECHNO-MUSICOLOGY!

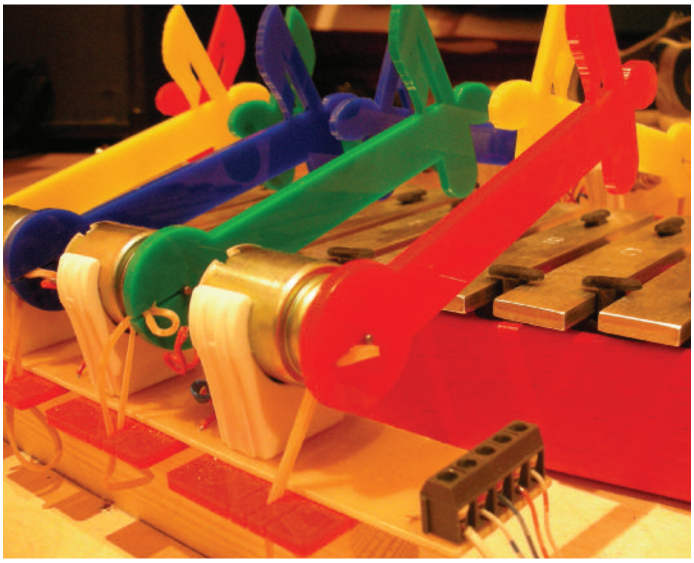
ONE OF THE JOYS of working closely with education partners is seeing the wide range and ingenuity of different projects that use PICAXE microcontrollers.

Several years ago the PICAXE-08M chip introduced the concept of playing musical ringtones within student projects, and this functionality is now also available on 14, 20 and 28 pin PICAXE chips. In the latest twist in the story of the association between music and PICs, Allen Bower, D&T Advisor for Staffordshire, has devised a three-day 'Technomusicology' workshops, where students program a PICAXE chip to play their own compositions on a real-life glockenspiel.

The project arose after funding was made available for some special 'Gifted and Talented' student workshops. During a meeting with his local music adviser Allen discussed his ideas for integrating technology and music by using a PIC to control a musical instrument – based on his interest in bells and bell ringing. When Allen expressed his frustration at not being able to afford bells or expensive solenoids to 'play' the bells, the advisor simply sighed, "Why not use a glockenspiel?"







CREATING THE PROTOTYPES

Several prototypes were made – greatly assisted by colleagues from Hope Valley College, Derbyshire and their laser cutter. The main design issue was getting the 'hammers' to return correctly, with several attempts to use reversing motors ending in failure.

The final solution, like all great designs, was simplicity itself – using a rubber band to pull the hammer back up when the motor was de-energised. A laser-cut hammer is attached directly to the motor spindle, with the energised motor producing enough torque to move the hammer down. When the motor is switched off the elastic band pulls the hammer up to the default position. This ingenious mechanism has several advantages:

- DC motors are much, much cheaper than servos, steppers or solenoids
- As the motor never completely spins, the mechanism is almost completely silent
- The mechanism is extremely reliable
- The elastic band can easily be adjusted to increase/reduce movement
- Student programming uses simple on/off type commands, so the technicalities of programming reversing motors do not arise.

THE TECHNO-MUSIC-OLOGY UNIT

The prototype used a PICAXE-18 project board, giving 8 output lines to control the actuators. However as a soprano diatonic glockenspiel typically has 13 notes, the production kits now use a PICAXE-28X1, so all 13 notes can be used.

The motors are held in pipe clips, fastened to a baseboard through a printed circuit board carrying up to eight outputs either side. Each motor is simply driven from the PICAXE output pin via a TIP31 transistor. Programs can be generated in BASIC using the free Programming Editor software or in flowcharts in software products such as PIC-Logicator, Flowol or Yenka PICs.

THE EVENT

The activity was set in D&T week in June 2007, and ran over a three-day period. Part of the aim of project was for the senior school to integrate with its feeder-primary schools. The schools came into the Kingston Centre in Stafford. The morning was spent manufacturing the units and the afternoon was spent in programming.

In his naivety Allen initially thought that it would be sufficient for the pupils to program tunes such as happy birthday and jingle bells – not so when you work with a Music Adviser! She set the schools the task of developing a three-part composition, with the glockenspiel unit playing the role of soloist, or, alternatively, forming an integral part of an ensemble.

A follow-up 'celebration' event at a Staffordshire school witnessed unbelievable levels of creativity, with some groups arriving with whole band equipment. One school spent a day in their music lab putting a backing track together and creating an anthem called 'Technomusicology'.

THE KIT

Following requests from many schools to reproduce this event, a kit of parts for this project is now available from Revolution Education, (order code MOD028). This includes all the parts including the PICAXE-28X1 board, motors and laser-cut hammers – the school just provides an MDF base to assemble the unit on. See www.picaxe.co.uk for more details. ■

■ **Clive Seager is technical director of Revolution Education Ltd, developers of the PICAXE system. Allen Bower is the D&T advisor for Staffordshire, UK.**

Ashley Green describes the role of robotics competitions in encouraging young people to study science and technology

FLL Milton Keynes regional tournament, Open University, December 2006

when robots learn to dance

EACH YEAR, thousands of young people across the UK pit their wits – and their machines – against each other in a range of robotics competitions. Hundreds of teams are involved, learning about design, technology and programming – as well as problem-solving, communication and teamwork. This is an international phenomenon, involving growing numbers of children in countries across the world.

The competitions take a variety of forms, but within the UK the largest are First Lego League (FLL) and RoboCup-Junior (RCJ). These are both part of larger, internationally-based competitions, founded in 1998 and introduced into the UK in 2001.

FIRST LEGO LEAGUE

Last year, more than 100,000 young people in about 50 countries were involved in FLL. In the UK, 400 teams participated in 26 regional tournaments. There are two parts to each year's FLL Challenge: a research project that involves preparing and giving a presentation to a panel of judges, and a robot game in which pre-programmed autonomous robots score points by interacting with LEGO models on a 1.14m x 2.36m mat.

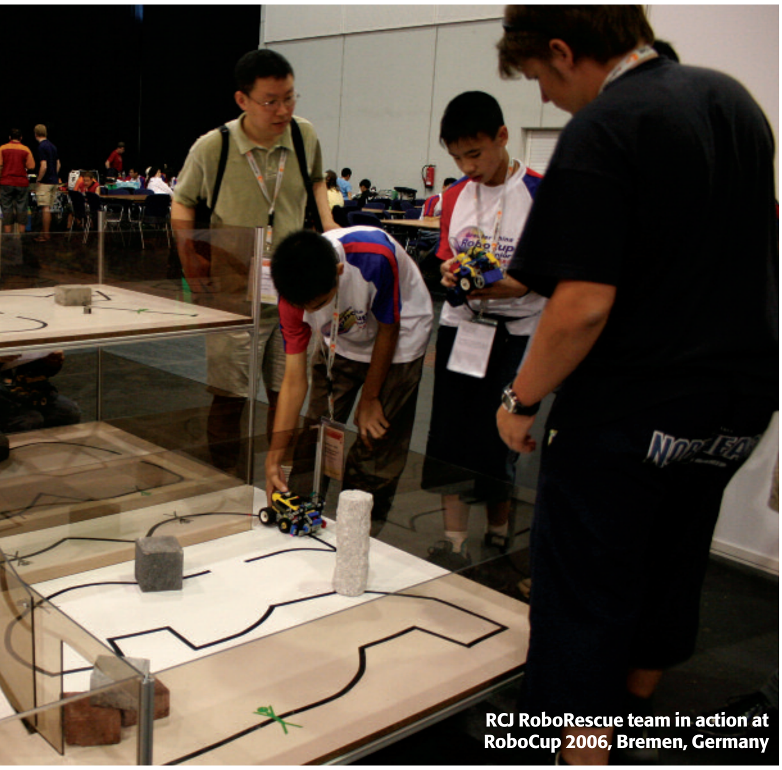
The winners of last autumn's UK regional tournaments competed against one another in the FLL UK and Ireland final at the University of Birmingham in February. Winning teams from that event represented the UK at the FLL World Festival in Atlanta, USA and the FLL Open Asian Championship in Tokyo, Japan, both in April.

The theme for the 2008 FLL Challenge is 'Climate Connections', in which participants are being asked to explore why many experts believe Earth's climate is changing and how these changes impact us and our planet. Registration for FLL 2008 opens in May at www.firsthand technology.org.uk.FLL is organised in the UK by Chris Proctor of First Hand Technology.

ROBOCUPJUNIOR

It is estimated that, world wide, more than 200,000 young people

First Lego League national final, University of Birmingham, January 2007



RCJ RoboRescue team in action at RoboCup 2006, Bremen, Germany

(of whom about 90 per cent are Chinese) are participating in RCJ this year. RCJ offers several challenges, designed to test the ability of team members to work together and compete effectively against rival teams.

In RoboDance, one or more robots perform to music in a display that emphasises creativity in costume and movement. The contestants may dance along with their robots, and may even compose and/or perform the music. This allows considerable scope for artistic creativity and is particularly appealing to girls.

In RoboRescue, robots search for victims and avoid obstacles within a simulated disaster scenario. Autonomous robots move through a series of rooms linked by a ramp. Each time they locate a 'victim', they stop and flash a lamp for two seconds. In RoboSoccer, teams of autonomous robots play soccer games using an infrared emitting ball.

Last year, 100 teams participated in 10 RCJ UK regional tournaments, with the regional winners battling it out at the RCJ UK finals in Shrewsbury. Eight winning teams from that event represented the UK at RoboCup 2007 in Atlanta, USA, in July. A team from two schools in Suffolk are current Secondary RoboDance world champions. RoboCup 2008 is being held in Suzhou, China in July. RoboCup 2009 will be held in Graz, Austria.

For details of RCJ UK events, including registration procedures, follow the Upcoming Events link at www.rcj-uk.org.

RCJ is organised in the UK by Stephen Norbury of Calday Grange Grammar School and Ashley Green of The Open University.

EDUCATIONAL VALUE

The excitement and interest generated by robotics competitions are indisputable, but what educational benefits do the participants gain from their involvement? Several studies have been conducted to address this issue.

In a study of RCJ contestants, 'Using Robotics to Motivate "Back Door" Learning' (*Education and Information Technologies* vol. 9, no. 2, June 2004), Marian Petre and Blaine Price report that in order to make their robots work many of the children had been carried into "new and sometimes daunting territory", and that they "had come to terms with topics (such as programming, gearing, and mathematical representations) which they had previously found difficult". Petre and Price also found evidence of a more systematic approach to learning in general, leading to improvements in problem-solving skills, better planning, improvisation, learning from mistakes, team working, information sharing, interpersonal skills and patience.

Similar conclusions are drawn in a study of FLL contestants (Building for the Future, University of Cambridge Entrepreneurship Centre, 2003). This study reports that the competition "helped promote a can-do attitude", and "taught the children how to solve problems using trial and error techniques". Other benefits cited in the Cambridge study include introducing children to "working to tight time-constraints and under pressure", and helping quieter students gain "confidence through public speaking". Critically, the robotics project was found to "enhance the image of science and technology in the school, in a time where more students are lacking the motivation to study".

EVERYONE A WINNER

The UK has a serious problem with declining numbers of students (particularly girls) choosing to pursue careers in engineering and technology. This is a concern to major businesses and industries, which depend on well-motivated and highly skilled engineers and scientists.

It is important to inspire young people at KS2 and KS3 because the subjects that engage them at this stage will determine their course choices and, ultimately, career routes. FLL and RCJ aim to provide an inspirational learning experience, combining educational context with hands-on challenges that empower children to discover their own theories and solutions. In FLL, for example, the research project requires teams to make strategic decisions, just as they would in a real-world environment.

Dr Nicky Hughes, ICT teacher and mentor for the Suffolk-based RCJ Secondary RoboDance world champions, believes that the link between technology and creativity can be crucial in making engineering activities appealing to girls. Winning required them to overcome significant technical difficulties and to cooperate effectively.

"Where the programming was very challenging was to get the robots to do exactly the same things and in time to the music," says Dr Hughes. "The girls had to work very closely together, but they really enjoyed solving those problems. Producing something that really works is a fantastic experience for them. Their knowledge and understanding of what you can do with robots has just soared."

Robotics can also be a way of reaching children who otherwise struggle in the classroom. It seems to be particularly appealing to youngsters with learning difficulties. Children with dyslexia and Asperger's syndrome often excel in robotics competitions; the hands-on engagement gives them an opportunity to demonstrate their creativity in ways that standard classroom activities do not. Even children with severe disabilities (including blindness) have successfully and enthusiastically participated in robotics activities.

FACILITATING INVOLVEMENT

The majority of UK schools have been slow to introduce robotics into their teaching and extra-curricular provision, despite the evident educational benefits. But help is at hand. A growing number of UK universities are now offering loan equipment, teacher training and mentor support to encourage local schools to participate in team ▶

> 'A major impediment to embedding robotics in the curriculum is lack of staff expertise'

RCJ Secondary RoboDance world champion team 'Swan Song' at RoboCup 2007, Atlanta, USA

◀ robotics competitions. Several FLL regional tournaments are organised and funded by Aimhigher – the Department for Education and Skills' campaign to encourage young people to go on to higher education. Some 250 schools have obtained government STEM funding to establish science and engineering clubs, and more such funding may become available if that pilot scheme proves successful.

Most of the preparatory work done in schools for robotics competitions seems to be extra-curricular, but there are now at least two good opportunities to embed robotics in the curriculum. From this coming September, initially for year seven, systems and control will be a mandatory subject area in the KS3 design and technology national curriculum (control is also being moved out of the ICT curriculum).

Torben Steeg, curriculum advisor to the Electronics in Schools Strategy, notes that "The thrust of the reforms is to encourage more flexibility at KS3 to allow initiatives like STEM to flourish – there could be a very real opportunity for robotics to be a vehicle for this".

This is a point of view shared by David Barlex, director at Nuffield Design and Technology, who sees "robotics as an important part of the emerging STEM agenda in schools".

Another good opportunity for embedding robotics in the curriculum is in the new 14 to 19 Diplomas – particularly the engineering diploma and the manufacturing and product design diploma. Some £45m has been set aside for training teachers involved in the first tranche of diplomas (which include engineering and MPD).

ROBERTA-GOES-EU

A major impediment to embedding robotics in the curriculum is lack of staff expertise. An EU-funded project, originating in the German RoboCupJunior community and aimed at redressing the large gender imbalance amongst youngsters pursuing STEM studies and careers, may be able to play a significant role in helping teachers develop the required skills and confidence.

Roberta-Goes-EU harnesses the appeal of robotics to give girls and young women the chance to learn science, technology and IT in an exciting and interesting way. The 40-hour curriculum draws on examples from nature that have proven to be particularly appealing to girls. For example, one of the practical activities involves building and programming robot bees to perform a dance indicating the direction to the nearest pollen. The original curriculum is now available in English, and an updated version (based on the new Lego Mindstorms NXT system) will be available this summer via the Roberta-Goes-EU website.

The curriculum introduces, and leads the participants into, the RCJ RoboDance and RoboRescue challenges. The provision of accredited teacher training is fundamental to the project, and three Roberta Regional Centres are currently being established to serve the south, centre and north of the UK. The first Roberta teacher training workshop was held in Shrewsbury last October.

WARNING

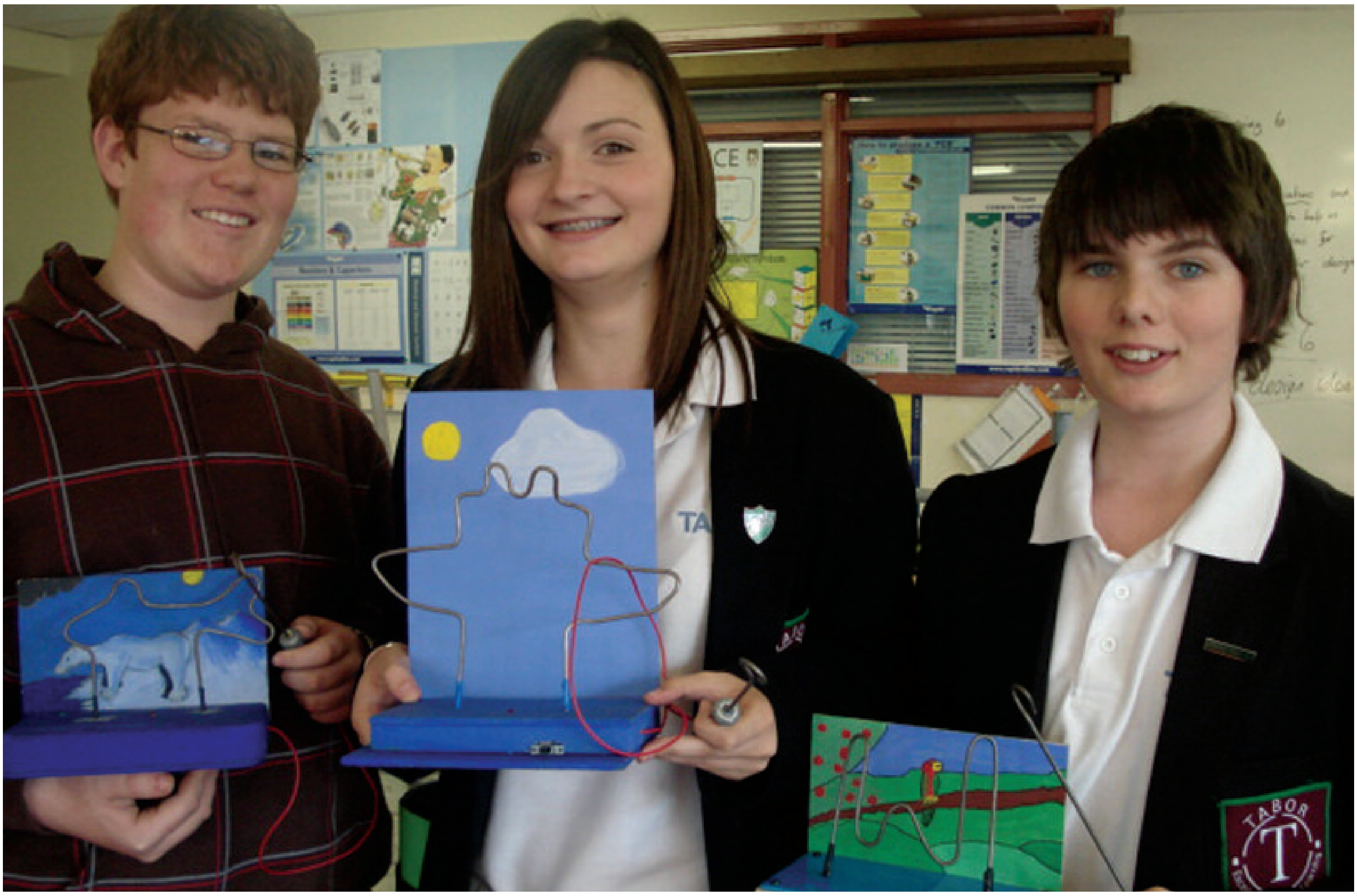
If you are thinking of getting involved in robotics competitions, beware – it is highly addictive. Speaking at RoboCup 2004 in Lisbon, Portugal, Elizabeth Sklar, one of the event's organisers, summarised the level of commitment RCJ attracts from teachers when she said, "As overworked as most schoolteachers are, the vast majority of team mentors are motivated enough by RCJ to volunteer their time and participate, sometimes even spending their own money. Despite the financial hardships, most mentors indicate their intention to participate in the international competition again." You have been warned! ■

■ **Dr Ashley Green is RoboFesta Research Fellow at The Open University, and a member of the international RoboCup Executive Committee (a.a.green@open.ac.uk)**

Further Information

- **"Using Robotics to Motivate 'Back Door' Learning", and "Building for the Future: An assessment of the success of the national FIRST LEGO League: http://rcj.open.ac.uk/html/Resources/resources.html**
- **Aimhigher: www.aimhigher.ac.uk**
- **First Hand Technology: www.firsthandtechnology.org.uk**
- **FIRST LEGO League: www.firstlegoleague.org**
- **Roberta-Goes-EU: www.iais.fraunhofer.de/roberta-eu.html**
- **RoboCupJunior: www.robocupjunior.org**
- **RoboCupJunior UK: www.rcj-uk.org**
- **RoboFesta-UK: www.robofesta-uk.org**
- **Science & Engineering Clubs: www.the-ba.net/the-ba/ccaf/Clubs/**

Anna Spruhan describes how, despite limited experience and shortages of equipment, she beats the odds to teach GCSE Electronic Products to year 9 students in just one year



catch 'em young

THE MOVE INTO electronics teaching can present a range of obstacles and challenges for design and technology teachers. This has certainly been true for me. I studied mechanical engineering and mathematics at Trinity College Dublin. Directly after university I worked as a draughtsperson in Finland, before returning to Ireland to take up an engineering/quality assurance post with a manufacturing company. From there I went to the Netherlands where I worked in quality assurance for a software house. Returning home, executing a change of direction, I started teaching, ending up in a primary school in Ireland. I realised that I really wanted to teach secondary school children, so I studied for my PGCE in UWIC (University of Wales Institute Cardiff) in Design and Technology. In July 2005, I took a job as a resistant materials teacher at Tabor Science College in Essex

MY SCHOOL

Tabor Science College is a semi-rural, co-educational comprehensive, with specialist status in science and mathematics. The college was established in September 2005, and was previously known as the Tabor High School, which opened in the early 1970s. There are just over 1,000 students and 72 teaching staff. Years seven to 11 are taught at the college, with a limited sixth form that does not teach design and technology.

Design and technology is only compulsory for KS3 pupils, and the college offers graphics, food, textiles, resistant materials and electronics. At KS4 the options are product design, textiles, food, and child development. Electronics is taught as a year eight module. This is basically a graphics product with some electronics tagged on (LED, resistor, switch and battery circuit). The development of the electronics curriculum has been an ongoing concern and a priority of the faculty for a number of years, but staff preferences and lack of experience have resulted in limited progress.

I HAVE AN IDEA

When I arrived at Tabor, my knowledge of electronics was very poor. I had done an electronics module as part of my engineering degree, but, ▶

'The development of the electronics curriculum has been a priority, but staff preferences and a lack of experience have limited progress'

feedback

STUDENT VOICES

I used a questionnaire to assess the opinions of the students. They were requested to give comments on their work, the help received from the teacher, and finally to express an opinion as to whether they would recommend the course to a friend. There were seven questions in all.

From the replies received, it was evident that the level of maturity of the students was more significant than their ability. In answer to the question "Did you get enough help from your teacher?" one student gave a high score, 5/6, commenting: "Yes, as I was sufficiently educated to do everything, and she helped me a lot after school". Another student gave a score of just 2/6 for the same question, with the explanation: "The teacher didn't help too much, she just told us what to improve". This sounds like help to me...

When quizzed over whether they were happy with their coursework and the game, the majority of pupils responded with a high mark. However, only two pupils said that they would recommend this course to a friend, principally on the grounds that the course was "too complicated and hard".

For many of the students, the difficulty level of the course came from being pushed to do homework, and then redo it if it wasn't done to the best of their ability. One boy wrote: "There was a lot more work that I was expecting, and there is a lot more work than what other classes have".

The problem seems to be not so much that the course was intrinsically difficult, but that it involve a significant amount of work, which the students were expected to complete. My feelings are that the more mature and more motivated students would have found this relatively high work load easier to cope with.

frankly, I couldn't remember a thing. Fortunately, I found a free, four-day ECT training course in electronics, based in London and run by Bridget Elton.

Aside from substantially improving my knowledge of electronics, this course gave me a great idea. One of the other teachers on the course mentioned that they had taken students to GCSE in year ten. I spoke to my head of department, Bryan Baker, but there seemed no prospect of me doing something similar at Tabor, as I didn't teach year ten or 11 students.

Why not, I asked myself, take year 9 students to GCSE? I would do a short course electronics products GCSE, working with a group of able, gifted and talented (AG&T) students. It would be a great opportunity for them, as well as a talking point on their CVs, and from my perspective it would give me a chance to teach at GCSE level.

Bryan is a very supportive manager, and someone who is ready to take a chance on new and innovating ideas. He agreed to back my idea, provided I was willing to put in the necessary work. A deal was made. We would choose a group of year nine students who were on Tabor's AG&T list and who had also received high scores in their MidYIS (Middle Years Information System) exam. I would take this group for the first rotation and teach them electronics, and explain to them that we were going to apply for an early GCSE. If the students were working well, I would continue with this group and opt out of the rotation for the year.

DOWN TO WORK

I spent a lot of my 2006 summer holidays revising the basics of electronics. The course started in September with 19 students, although this had fallen to 14 by mid-November.

We began by looking at definitions of energy and energy changes. From there we progressed to a systems outlook (input – process – output). We had 'Microelectronics for All' boards from Unilab, and we used these to start working on logic gates, so that students could see – through the use of logic for making decisions – why electronics is so important. I felt the best way to get the pupils really involved was to get them started on a project. The students are used to the design section, but not used to working with on a PCB. I chose a Rapid project for them to exercise their practical skills.

Careful now...

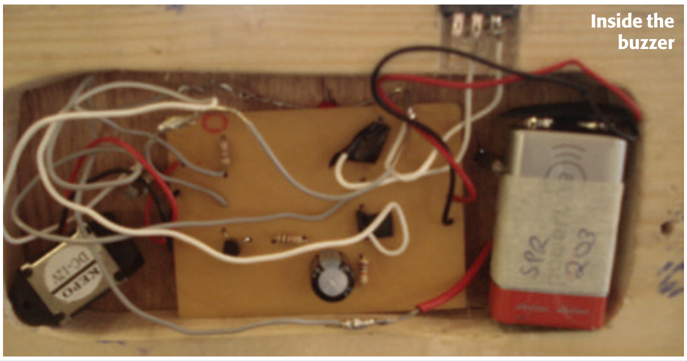
I was aware that I didn't really know enough about electronics to teach a GCSE, but, fortunately, there were other teachers in the area with the expertise to help fill in the gaps in my knowledge. At this time (October 2006) I also set up a forum for secondary school teachers of electronics in the Essex area (see the Web links at the end of this article for more information on the forum's activities). Simon Clapson (Tendring Technology College, Essex) is a forum member, and Simon and his team at TTC are providing invaluable support to the forum with free PIC training, held on a Saturday at TTC.

At our Tabor's open day in early October I was telling some parents about my plans for the GCSE and the electronics forum. One of the parents, Peter, a teacher of electronics in nearby Chelmsford County High Grammar School for Girls, said he'd be willing to come to Tabor's afternoon electronics club. The electronics club was started in order to help the year nine students learn more about electronics and have a go at practical electronics, rather than just focusing on theory and GCSE material.

From Peter I learned how to use breadboards and other electronics components. At the time, we had only three breadboards in the school. More were ordered, and I began to show the students how to work on them. We started on basic circuits – the year eight module circuit. We progressed to using an LED and a buzzer in parallel, but instead of the slide switch we had two pieces of wire that when touched together made contact to turn on the LED and buzzer. We had created our own alarm. This went on to form the basis of our GCSE project.

I showed the students how to create a timing circuit using a capacitor and transistor, and also a latch circuit using a thyristor. We were lucky enough in school at the time to have Crocodile Clips and Quick Link 123+, so we were able to create and test circuits on a PC screen.

'Year nine students still want to be spoon-fed rather than acting by themselves – they are still too scared to take a step away from the flock'



Inside the buzzer

GETTING THERE

I had a 'Beat the Bleep' game in school and the pupils decided it would be a good idea to create a game as their project. I found that working with year nine students, although very rewarding, can also be extremely difficult as many of them find it hard to think beyond their own immediate experience. For example, some of them find it difficult to think about the concept of why you might want something like a game. On the other hand, some students produced work of surprising quality.

Attending the four-day ECT training course had made me eligible for a grant (administered by the Design and Technology Association) and we used this to buy an etching tank. The school then purchased Circuit Wizard and Control Studio, and we downloaded the free PICAXE Programming Editor.

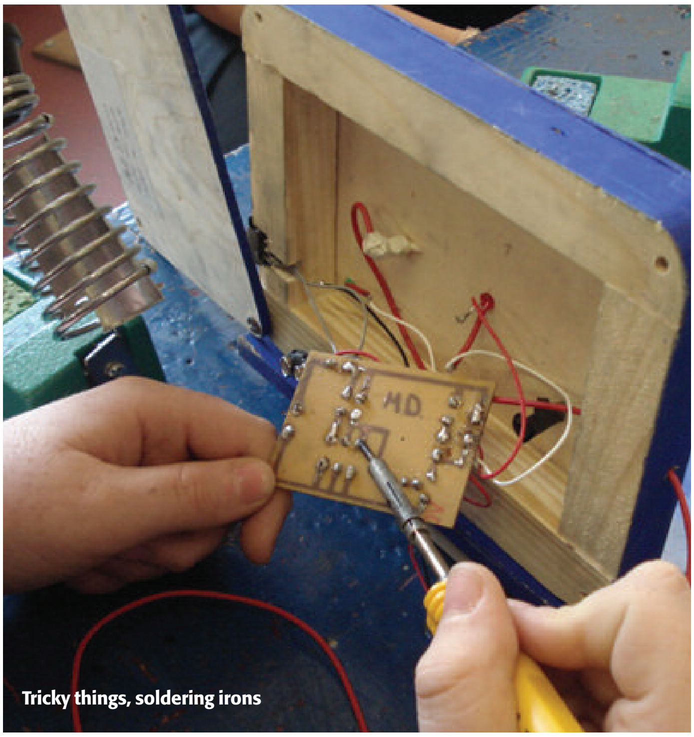
Unfortunately, when we were making the PCBs for the GCSE project we didn't have access to any electronic CAD software, so I had the pupils draw their chosen circuit using permanent marker on the copper-clad board, which we put it into ferric chloride acid to etch. Perhaps we were lucky, but none of the PCBs had to be re-etched. It may not be the best method, but it worked for us.

The students decided to make their casing out of wood and decorate it. Students were given a demonstration of how to use the vacuum former, but they all decided to work with wood. This was despite having used vacuum forming to create a cover from clear HIPS for the year eight electronics module.

After Easter we began working on PIC programming, looking at the questions on the papers, working through the Lonsdale Electronics Products workbook and exercise book. We also began using bread-boards to work with monostable 555 timers, and used the 'Microelectronics for All' boards to explain how a decade counter works.

LESSONS

In June, 14 students sat the AQA Short Course Electronic Products exam. Four took the higher paper and ten the foundation paper. One student achieved a 'B', nine a 'C' and four a 'D'. Clearly, in terms of exam results this has been a successful experiment, but, as with all experiments, there are lessons to be learned.



Tricky things, soldering irons

From the viewpoint of the students, the more mature individuals appreciated the opportunity offered by the course, and the work put in by the teacher. However, the feedback from the student questionnaire (see box 'Student voices') leads me to believe that year nine students are really not ready to tackle a GCSE. The name frightens them. The majority of them do not have the maturity, or the independent learning skills required to fully appreciate the course. Year nine students still want to be spoon-fed rather than acting by themselves. They are still too scared to take a step away from the flock.

From a teaching perspective, given the chance to run the course a second time around, I would definitely introduce a number of changes. I would start with systems (input – control – output) using a CAD approach. I would then look at a simple sensor project. Now that we have the necessary equipment in the department I would get the pupils to make their own circuit board. From there I would work on breadboards with 555 timers (these are still part of the AQA exam, but are on the way out). I have made up some Cyberpet boards using the O8M PIC and would teach the student how the program the PIC.

Four scheduled lessons over a fortnight to cover technology isn't really enough to cover the course thoroughly. I would therefore introduce a mandatory lesson for at least one hour after school each week. In this lesson I would try to let the students develop their own knowledge by investigation rather than by being taught. Perhaps they could work on a project that isn't for their GCSE.

My experience with a non-mandatory after-school lesson is that only some of the students will turn up, so you either end up repeating material in normal lessons, or omitting it altogether. Also, the day for the after-school lesson needs to be decided right at the beginning of the course, before the students have other commitments.

Finally, I would ask students to apply to do the course, rather than limiting applicants to AG&T students. In this way I should attract more motivated students – committed to staying to the end of the course and wanting to do well. I would also look at the maturity level of the students, as well as their academic ability.

SO WHAT HAPPENS NOW?

Somewhat against the odds, Tabor is running another year nine Short Course Electronics Products GCSE for the school year 2007/08. At the end of the 2007 Summer term I accepted a new job in charge of electronics at a school in Surrey. This new job started in January 2008, so, initially, I decided against repeating the year nine GCSE. However, the enthusiasm of a group of pupils forced a change of plan.

A group of six pupils, quite voluntarily, came forward and asked Bryan Baker whether they could be part of the early GCSE. I therefore agreed to do the course until Christmas, doing the electronics, and leaving Bryan to take over in the new year, concentrating on the paperwork and case making. This was all unplanned, so, strictly speaking, the only guaranteed electronics teaching for this new group was one after-school club slot once a week for one and a quarter hours. However, by including them in my rotation for the 2007 Autumn term at Tabor, I was able to provide them with some additional tuition. Let's hope they do well. ■

Forum for secondary school teachers of electronics in the Essex area:
www.digitalteachernetwork.net/projects/Understanding_Electronics/

ECT courses:
www.electronicsinschools.org/page.php?m=194&ps=168

Roger Dettmer looks at the IET's all-new, Web-based Faraday Programme

re-inventing faraday

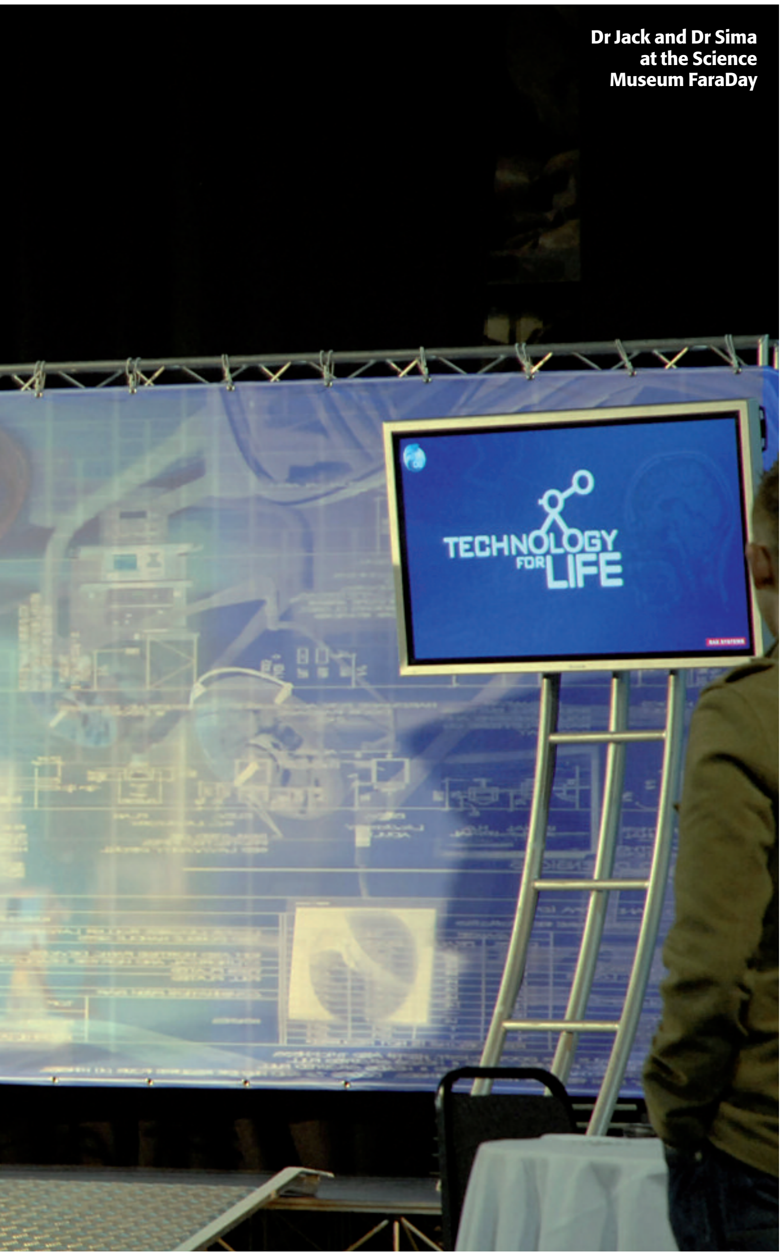
THE 2007/2008 school year has seen a radical transformation of one of the IET's key educational activities. For 80 years the annual Faraday Lecture has toured the country, inspiring young people with a vivid portrayal of the latest developments in science and engineering. From modest beginnings in 1924, the lecture evolved into a multi-venue spectacular, employing state-of-art sound and lighting systems to enthral the audience.

As an example of the Faraday at its best, it would be hard to beat the 1982/83, lecture, 'The Photon Connection', sponsored by STC, then one of the UK's leading suppliers of telecommunications equipment. This was the dawn of the optical communications era, with telecommunications operators beginning the switch to optical fibre transmission systems. Visually, and aurally, the lecture was stunning, and the audience just loved it. Nobody who attended the opening lecture at London's massive Dominion Theatre is ever likely to forget the appreciative roars of the audience of some 2,000 wildly enthusiastic school children.

The Photon Connection wasn't just highly entertaining, like all great Faraday lectures, it dealt with a subject with the power to transform the lives of its young audience. Anticipating the changes that optical fibre would bring, it ended: "The disadvantages of distance will diminish. And those of time. We will communicate anything to anyone, anywhere. With all the speed to light".

It sounded a little fanciful then, but, it was all true, and the massive deployment of optical fibre, with its capacity to transports huge amounts of data, at virtually no cost, has been the key enabling technology of the Internet, which in turn, has made possible the re-invention of the Faraday.

'The total audience was a small proportion of the school population; it was also dominated by pupils from grammar schools and the independent sector'



Dr Jack and Dr Sima at the Science Museum FaraDay

LIMITATIONS

The Faraday Lecture could be hugely impressive, but its impact was essentially limited to the number of children you could get into the theatres during the course of its tour round the country. Typically, there would be some 10 to 12 venues, and the total audience would be in the region of 20,000. That might sound a lot, but it has to be set against a year 9 population of around 900,000. Not only was the total audience a relatively small proportion of the overall school population, it was also dominated by pupils from grammar schools and the independent sector.

One of the objectives of the Faraday Lecture was to inspire pupils with the idea of studying science and engineering at university. In general, grammar and independent schools tend to have relatively strong science and maths departments, and the over representation of such schools meant that the Faraday was failing to address sufficient numbers of its key target audience – pupils whose school background, for whatever reason, had, at best, left them indifferent to the potential of science and technology.

There was also some evidence that the format of the Faraday Lecture was proving less attractive to schools. The pressure of a crowded curriculum, along with exacting health and safety requirements, mean that schools need a strong case for any out-of-school activities. The Faraday Lecture was essentially a one-hour, one-off event, and at least some schools were coming to the opinion that, as such, it did not justify the hassle of a 'day out'. In its last year, 2007, the total audience for the Faraday lecture was 15,000, representing a seat-occupancy rate of 39 per cent.

ALL CHANGE

Clearly, the Faraday needed a change of direction, and at the end of September 2007, after two years of planning, the IET launched the Faraday website (www.theiet.org/faraday), designed to provide a year-long resource, accessible to all schools. The key phrase here is 'accessible to all schools'. As Jan Stapleton, Head of the IET's Education 5-19 team explains, "The main reason for the switch was to get information to as many people as possible, and the only way to do this is through broadcasting and the Internet".

Anyone who regularly trawls the Internet in search of information will be all too well aware of the variable quality of websites, but the Faraday site is outstanding. It's based on the theme 'Technology for Life', chosen because of its wide appeal, and for showing the 'softer' side of engineering. The theme was also felt to be particularly attractive to girls already interested in maths and science who, traditionally, tend to go on to study medicine. "We wanted to show that you can make a difference as an engineer, just as readily as you can by becoming a doctor," says Jan Stapleton.

the experience


Video challenge winners from South Bromsgrove School

A GREAT DAY OUT

On 7 March nearly 400 students and teachers filed into the Science Museum to spend a day taking up various challenges, all centred around the 2007/8 Faraday Programme theme of 'Technology for Life'.

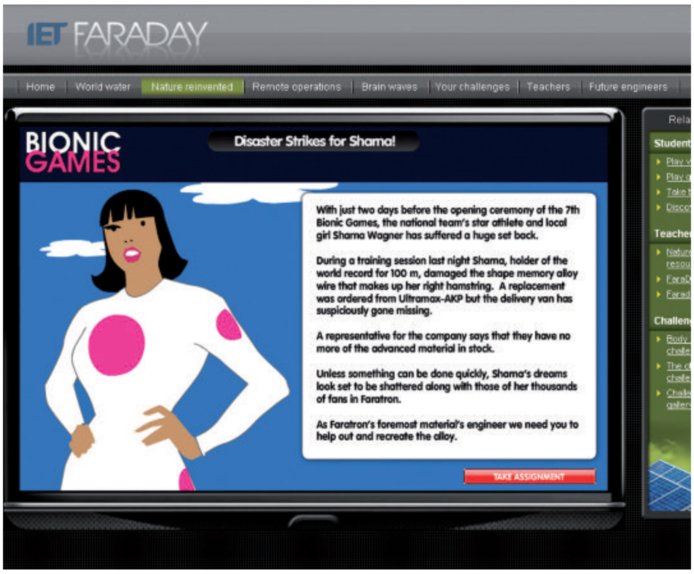
In the course of the day, encouraged by Dr Jack Lewis, Dr Sima Adhya, and a group of volunteer IET student members, the pupils variously evaluated projects for investment funding (the Da Vinci robotic surgical system won), followed an 'adventure trail' round the Museum's Welcome Wing, and used a range of advanced diagnostic tools to determine Dr Jack's mysterious illness (it was leishmaniasis – try Google if you're puzzled).

At the end of a thoroughly enjoyable day the prizes were awarded to the winners of the Faraday video challenge. The overall winner was South Bromsgrove School.

Deputy head, Paul Farr's , description of his school's motives for entering the Challenge competition is a testimony to the success for the new Faraday: "We entered mainly because it was fun for the students. We wanted them to be excited about science and technology and this project seemed to fit the bill. The spin off is that not only has it excited our pupils who were already keen on science but it has encouraged others to look again at these subjects."

> 'All this year's FaraDays were heavily over-subscribed, and there's already a waiting list for next year'

Faraday website homepage



Games help learning on the website

Dr Sima Adhya and pupils at the Science Museum FaraDay

Central to the website are four specially made short videos, illustrating how scientists, engineers and technologists apply their knowledge of engineering and health in their daily working lives. 'Nature Reinvented' looks at how engineers can improve on nature – investigating materials and prosthetics that can change people's lives; 'World Water' examines ways in which engineers can save lives – looking at the latest innovations which bring clean water to millions of people around the world; 'Remote Operations' reveals how engineers can be in two places at once – focusing on the use of telemedcine and robotics in surgery, and the fourth film, 'Brain Waves', looks at ways in which engineers can read your mind, with an introduction to the science and technology of biomedical signalling.

All four films are presented by the telegenic Dr Jack Lewis, who ties together the narrative from a range of experts from the cutting edge of science and technology. The streaming video is professionally produced, looks outstanding, and is delivered in a widescreen format.

The films provide an 'entree' to a range of other educational material: games and quizes, a video challenge, and follow-up information. In addition, teachers are provided with lesson plans and suggestions for classroom activities, all directly related to relevant areas of the National Curriculum.

The website has generated an enthusiastic response from educationalists, teachers and pupils, attracting some 5700 individual visits in its first three months of operation.

The 2007/08 Faraday programme came to an end in four, aptly named, FaraDays held in March and early April. In contrast to the Faraday Lecture, these were day-long events, held in science venues, rather than theatres. "The aim," explains Jan Stapleton, "was to give pupils the chance to see these venues, and take part in an all-day event where they could be fully-engaged. Also, the new Faraday is a year-long programme, and the FaraDays are intended to as a culmination to the year's activities, giving pupils the chance to showcase what they've done.'

All this year's FaraDays were heavily oversubscribed, and there's already a waiting list for next year.

To inspire pupils to think about some of the issues engineers need to consider in the course of their day-to-day jobs, they were invited to submit video responses to the challenges associated with each of the Faraday films. Schools entering the video challenge had to make an initial submission by film.

The best of these were selected, and a professional camera crew sent to the schools to help make the final entry. The prizes include £5000 for the school of the winning team and £500 to be divided among the team members. The winners received their prizes at the first of the FaraDays, held at the Science Museum, London, on the 7 March (see panel 'A Great Day Out').

WHAT NEXT?

Plans for the 2008/09 Faraday programme are already well advanced. The theme 'Engineering in Sport' should, again, have a wide appeal, and ties in with the Olympics in Beijng, due to start in August, and the London Olympics in 2012. A host of new changes are planned and, in particular, the 2008/9 website will be significantly more interactive, encouraging greater involvement from pupils and teachers alike. ■

Simon Maxfield explains why, despite the difficulties, he's committed to teaching Systems and Electronics in Design and Technology

'By the end of the project the majority of pupils can tell me all about LEDs, resistors and capacitors'

if you ask me

Why teach electronics?

THIS MAY be a little controversial, and it is entirely my own opinion, but isn't it much easier to gain good GCSE grades in graphics and resistant materials than in systems or electronics? I feel I can say this because, with an educational background in architecture, my initial experience of design and technology GCSE was teaching graphics and resistant materials. It was almost by accident that I subsequently made the transition to what for me is the more technically difficult world of electronics.

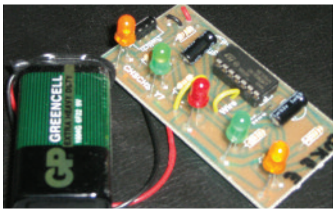
The transition began with the move to my second teaching post. On the day of the interview I quickly realised that the head of department had a love of anything that twinkled, moved and beeped – to the virtual exclusion of all other technologies. I nearly withdrew – thankfully I didn't – and, somewhat to my surprise, I got the job. However, my teaching remained firmly in the graphics/RM domain, meaning I could leave the technical stuff to my more 'nerdy' colleagues.

How things change. Today, I am leader of the same department, and systems and control is offered alongside product design and food technology at GCSE. I am currently teaching my first ever systems GCSE group and, what's more, they are doing it in one year!

However, as head of department, I know that when I look at the figures for CVA (contextual value added) and 'A star'-to-'C' percentages, the results for systems will, at best, be no better – and possibly slightly worse – than the other subject areas. Resourcing electronics has cost thousands, and I'm all too well aware that I could have given my leadership image and the department's results a boost by simply opting to make graphics and RM the choices to accompany food in the GCSE suite. So, why have I done it?

The answer is simple. Look around you; of the objects and appliances you can see, how many of them rely on electronics and control devices either to function, or in their manufacture? Virtually all of them I'm sure. Put simply, electronics and systems are now an integral part of a technological society. If our bright young citizens of the future are to have any success in the technology markets of tomorrow we need to immerse them in electronics and systems today. China and India seem fully committed to this approach, and the release of the revised curriculum would indicate that the QCA and the UK Government have also got the message.

Door sign



PCB (top view) and battery

GETTING STARTED

The role of the EiSS in funding training courses has been crucial in enabling me to make the transition to electronics teaching. To date I've attended two courses, each lasting four days. The first gave me accreditation from Marconi as an ECT teacher, and the second built on this initial experience. The course title, 'Taking things further', couldn't have been more apt.

How many times in your teaching career will you be offered CPD that contributes towards supply costs, generates capitation to spend on electronics resources and enables you to make contacts that will prove invaluable when needing advice? If you need more convincing, then ask yourself how often you get sustained periods of time to concentrate on new subject knowledge and curriculum design. I got all this, and more, from my two courses. They were practical, classroom-focused workshops where you had a chance to experiment.

Not only have the courses given me an increased confidence in previously unfamiliar areas of electronics, but the resulting work with pupils has proved a stimulus to our D&T department, helping to make it more modern and successful. We now aim to engage pupils in projects that are so intrinsically exciting and stimulating that the 'dry' theory is taught almost without the pupils realising what's happening. I am fortunate to have a parent that can manufacture professionally the PCBs we design. Not only does this make projects in KS3 much easier for the pupils to solder, and for me to fault find, but using professional-looking boards also helps the pupils relate the technology they are doing to what they see when they look inside modern gadgets, as the PCBs looks familiar. We are even beginning to experiment with surface mount components!

WHAT WE DO

Our year seven flashing door sign project is a good example of our approach to electronics teaching. This project takes around 12 hours to complete, and includes CAD/CAM, along with the use of our custom-designed and professionally-made 556 astable PCB. We spend some time with the pupils on Circuit Wizard allowing them to play with a pre-drawn simulation, encouraging them to experiment with resistor and capacitor values. We also show them the simulation of a multivibrator without the use of ICs, so that they can appreciate something of what's going on inside an IC. As the boards are well made, errors are few and first-time success of the boards must be in the region of 85 per cent, and where a board doesn't work it's always down to something very simple.

There's only one thing that really matters on this project – the faces of the pupils illuminating faster than the LEDs when they get it to work. What doesn't matter is whether or not the pupils can describe the working intricacies of a 556 IC chip. By the end of the project the majority of pupils can tell me all about LEDs, resistors and capacitors, as well as how to use resistors and capacitors to time an event. And, what's more, they're hooked on electronics.

The importance of this early enthusiasm for electronics cannot be overestimated. with pupils going on to actively engage in electronics in year eight and PICS in year nine, before opting for their GCSEs. If we can give the pupils an interest in the subject, the subject knowledge will follow naturally over time.

All new D&T staff at my school are sent on the first available EiSS course, regardless of their specialism. We need to swell the ranks of teachers who are willing to deliver electronics. At KS3 anyone can do it – you only need to be a couple of steps ahead of the class. When asked what I teach, I usually reply 'kids'. A good teacher will adapt and learn whatever they need to deliver. Taking the first step is hard, but there are people out there that are more than willing to help out. I am still a long way from being an expert but, having taught electronics for three years to KS3, I am now more than confident in delivering GCSE. Next stop 'A' level?

■ **Simon Maxfield is head of D&T at Cheslny Hay Sport and Community School, Staffs, and a member of the Electronics Education Editorial Advisory Panel**

■ **The programme of work for the flashing door sign project can be downloaded from the Electronics Education website – access the main web page (www.theiet.org/ee) and follow the links, first to the current issue and then to this article (this facility is expected to become available during the second half of 2008).**

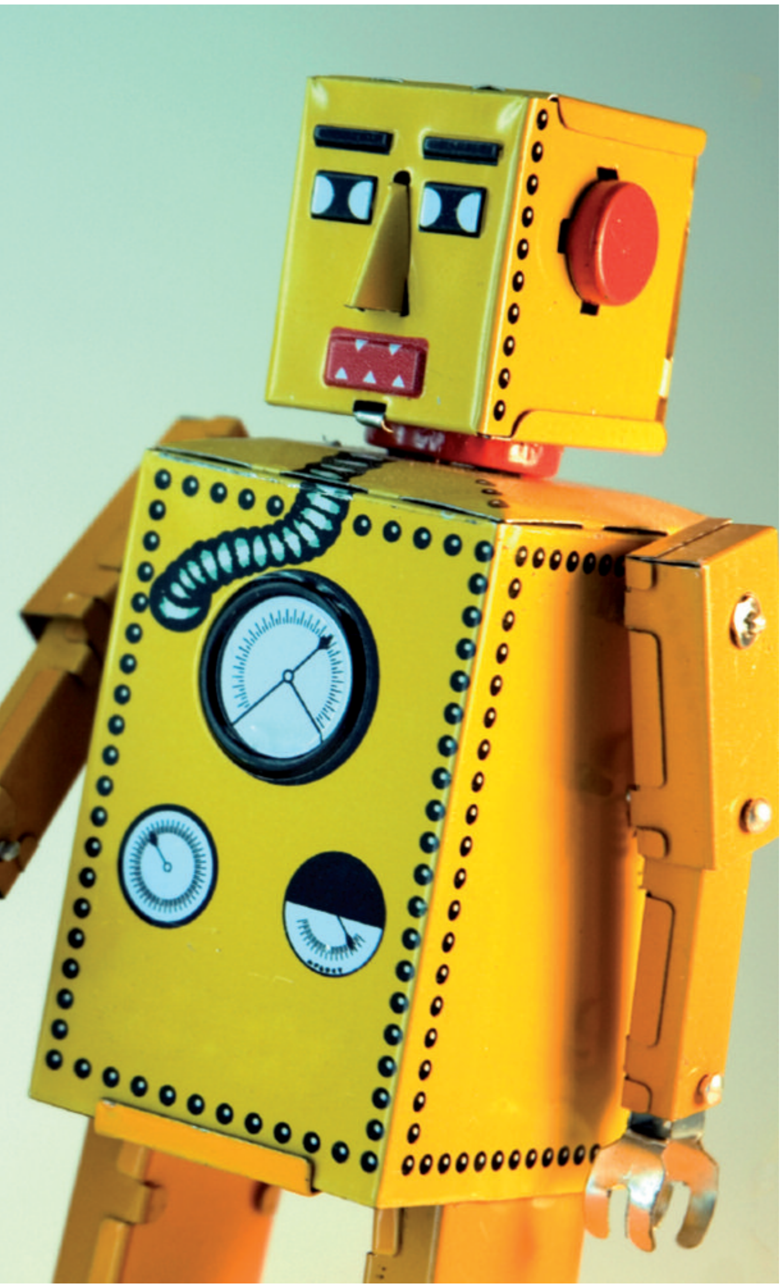
robotic attraction

Bart Huyskens explains how Belgian schools are using pre-defined subroutines and a robot buggy

IN AN ARTICLE in the Autumn 2007 edition of *Electronics Education* (page 17) I described the origins of the Formula Flowcode robot buggy, along with its basic features and functions. I now want to explain how, in Belgium, we use the robot in the initial stages of teaching electronics. The inherent novelty of much of the subject matters means that getting students started and motivated in electronics can be a real challenge. Once they have a grasp of the basics, and gain some confidence in the subject, electronics teaching becomes, relatively speaking, much less of a problem. But how do you overcome this initial hurdle?

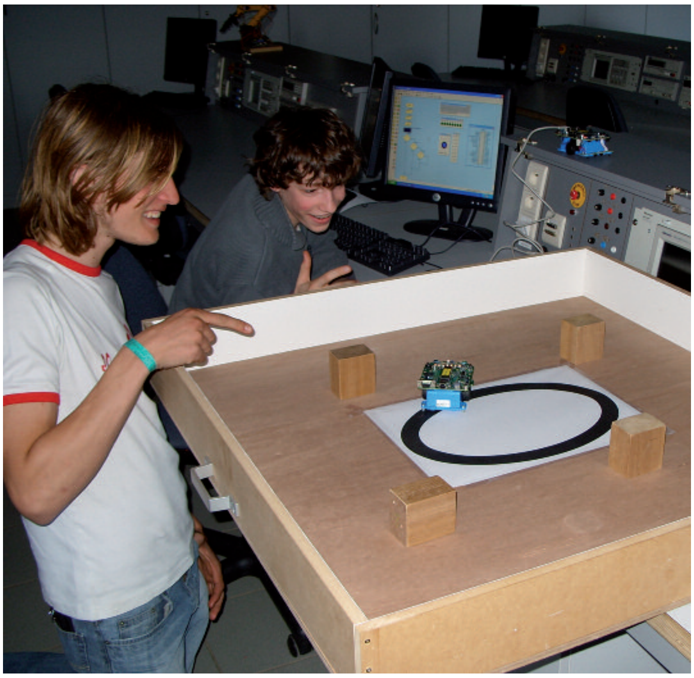
In the design phases of the robot project we decided our solution needed to overcome three problems that students face learning modern electronics. First, it should make programming very easy to learn; secondly, it should allow students to understand the circuit and relate the circuit diagram to the hardware; finally, it should motivate the students, giving them a real desire to learn. This last objective is realised via a series of carefully structured tasks, designed to develop programming skills and an understanding of circuits in a

'Within minutes they have the robot crawling over the desk, making sounds, and doing all sorts of things'



to get students hooked on electronics

The 'follow my line' program can cope with wavy lines and ellipses



way that students find instructive and enjoyable.

PROGRAMMING

Applying a traditional PIC programming approach to a robot buggy presents a real problem: to implement speed and direction control of motors you need to explain quite a lot about electronics and programming, along with some fairly complex topics, for example, pulse width modulation. Only after several weeks of work would students be able to do something useful with the robot. To solve this difficulty we wrote a suite of ready-made Flowcode subroutines that provide functions like 'go forwards 100', 'rotate left 100', etc, where the number denotes the speed. At the same time we developed a simulation model within Flowcode, so that students could try out their programs on-screen before downloading them to the robot. This means that students don't have to spend their first few lessons working with boring old LEDs – within minutes they have the robot crawling over the desk, making sounds, and doing all sorts of things. Incidentally, this approach of wrapping difficult concepts and hard programming into subroutines to enable a fast start is one that can usefully be employed in ▶

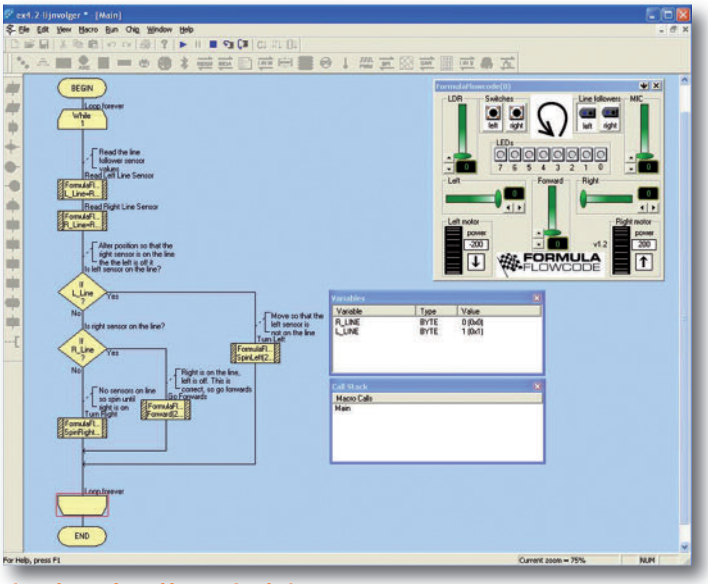


Fig 1 Flowcode and buggy simulation

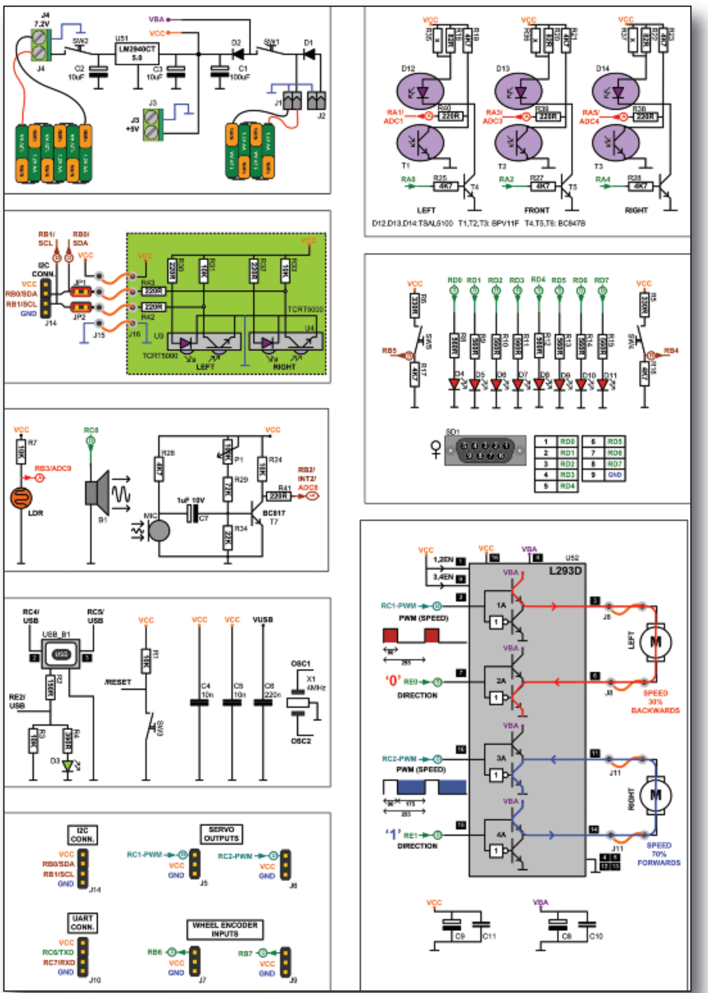


Fig 2 Buggy input/output circuits

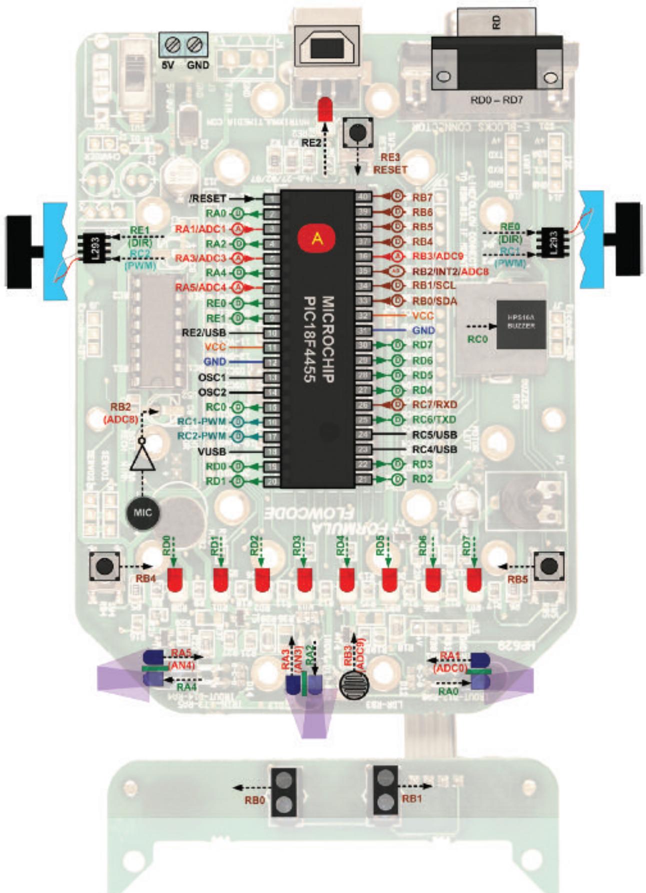


Fig 3 Processor connections

◀ many areas besides robotics.

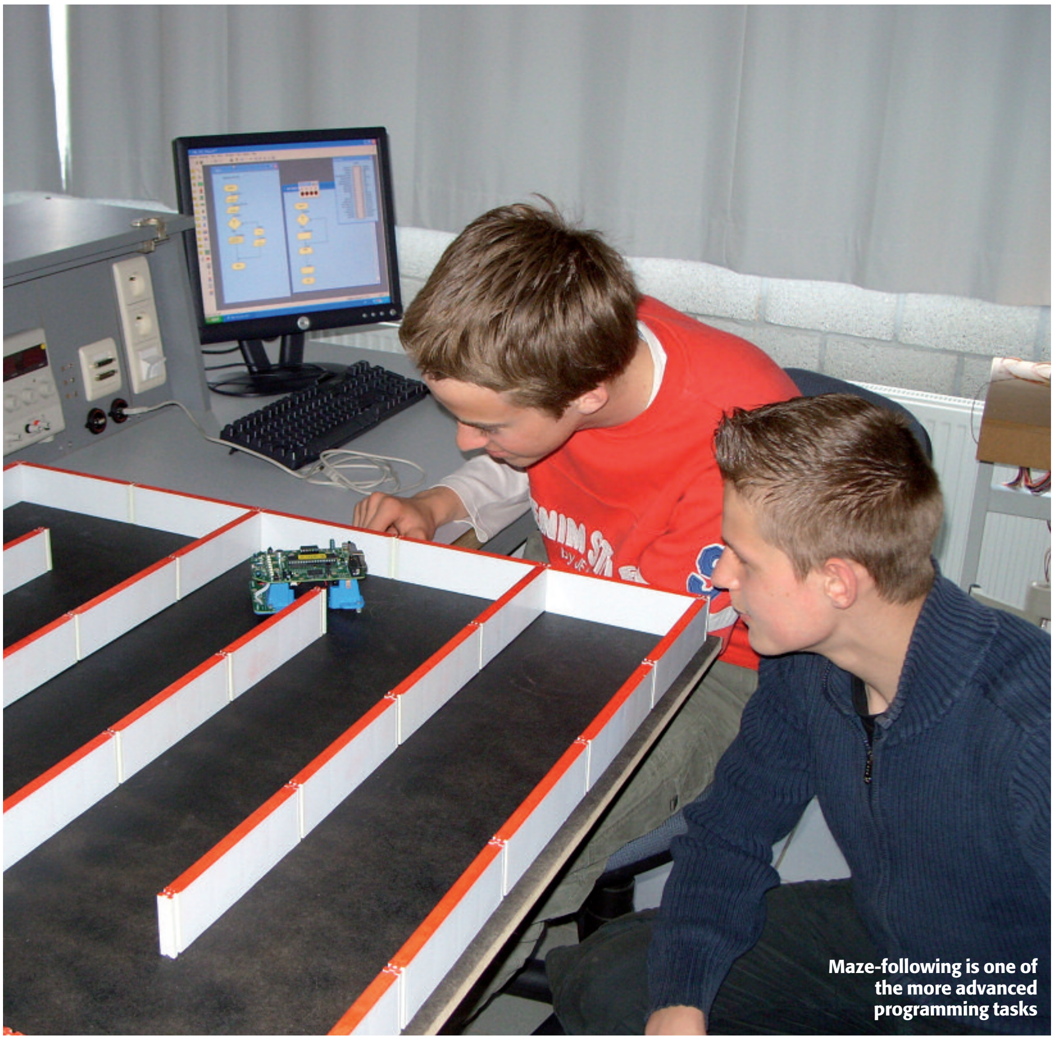
Fig 1, which represents a fully-functioning line-following program, shows these off-the-shelf subroutines in action. The Flowcode simulation (top right in Fig 1) shows motors turning, turning directions, the status of input/output lines etc. This makes programming simple. After they have seen what the buggy can do using the easy Flowcode routines, students always ask questions about how it works. This is the point where the learning begins. Building on this initial curiosity, students then study how the hardware actually works, and how they can write their own routines.

CIRCUITS

There are two major problems with introducing students to circuits and circuit diagrams: they find traditional circuit diagrams boring, and, because they tend to be over complex, they find the diagrams hard to understand. We overcame these problems by jazzing up the circuit diagram, adding a bit of colour and making sure that it was well structured and easy to understand. You can see the results in Fig 2. When it comes to programming, students need the processor pin out, rather than the complete circuit diagram, so we produced a separate pin-out diagram (Fig 3), with the connections between processor pins and the chassis input/out devices clearly identified.

These simple steps have been really effective. My students and fellow teachers are amazed that the electronics underlying the robot buggy are really so simple. I use the diagrams shown in Figs 2 and 3 to teach them about LEDs, resistors, transistors, Ohm’s law and even simple class A amplifiers.

'It's a whole new way of teaching, but if I look at my students now, I know it's a better way'



Maze-following is one of the more advanced programming tasks

In modern electronics-based products, the circuits are often laid out in a way that appears very different from the approach followed in electronics courses, and this can be confusing and demotivating for the students. In the robot buggy we have been careful to ensure that circuits are connected in just the same way as they would be taught in the classroom – proving to the students that theory really does work in practice. The way the LEDs are connected to the PIC, as shown in Fig 4 (a detail from Fig 2), illustrates this point particularly clearly.

MOTIVATION

The last part of the puzzle was a range of motivating structured tasks to accompany the robot, which were conceived at the same time as the hardware was being designed.

Students work through a set of interesting programming tasks including 'nuts and bolts' where they build the robot, 'robopop' where the robot can react to sound and produce ring-tone like music themes, 'follow my line', where the buggy needs to be programmed to follow a black line, working up to a maze-solving problem, and the development of their own robot chassis.

The electronics of the buggy are also designed to drive servo motors etc. In this way, the robot has filled in the missing and important link between electronics, mechanics and ICT – the three basic elements in the vast majority of modern products.

HELP NEEDED

For the Belgian curriculum I have developed a small book, which contains a complete course with a simple explanation of how this buggy can be used in class to teach all the basic electronics subjects in a modern and motivating way. It also contains full explanations of the circuits, and many hours of exercises and ideas for motivating projects.

Students use this book individually, learning everything at their own speed. It's a whole new way of teaching, but if I look at my students now, I know it's a better way. This book is not available in English, yet, but if there were sufficient interest, I am sure that a translation could be provided. Please contact me if you would be interested in using this book in an English-speaking school. ■

■ **The Flowcode PIC programming environment and the Formula Flowcode robot buggy are available from Matrix Multimedia (www.matrixmultimedia.com)**

■ **Bart Huyskens (barthuyskens@scarlet.be) is an electronics teacher at the St Joseph's Institute,Schoten, Belgium**

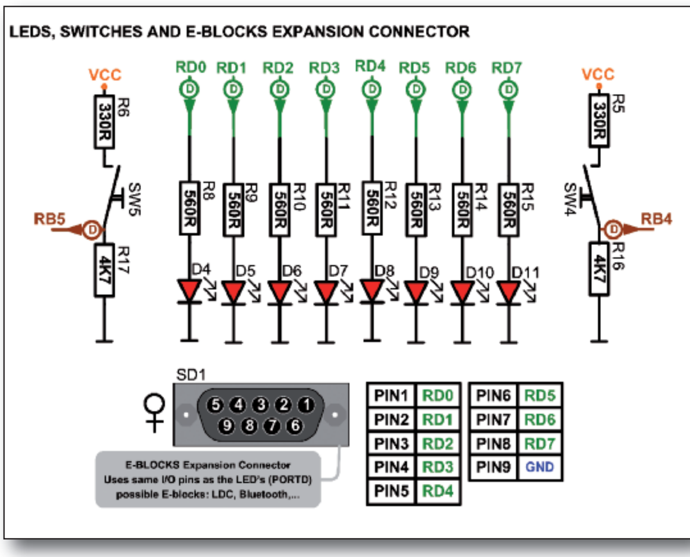
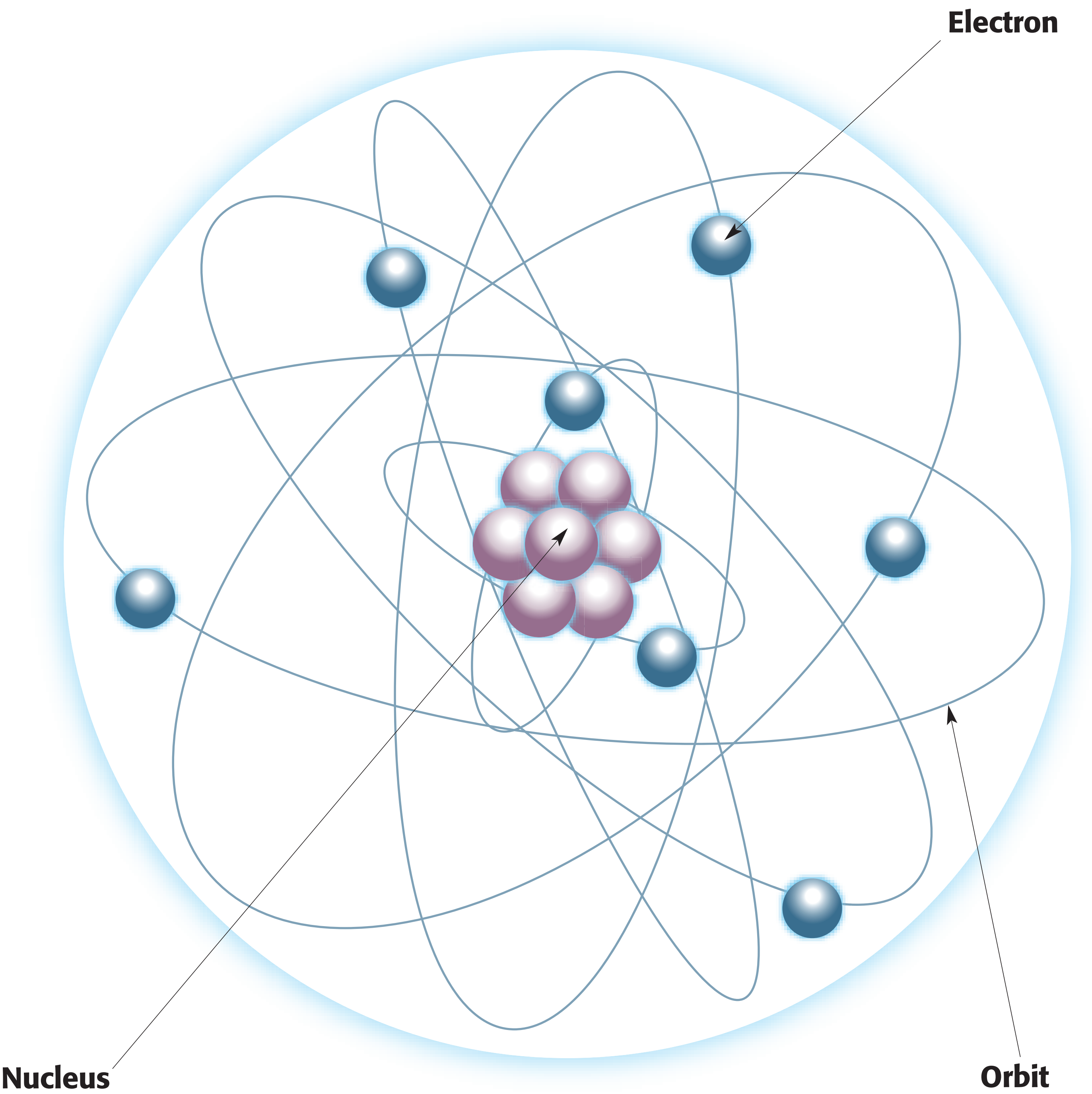


Fig 4 LED-PIC connections

INSIDE AN ATOM

Fig 1: Simple model of an atom



> ‘When a voltage is put across a material, a force on the (negatively charged) electrons in each atom attracts them to the positive side of the voltage’

resistance and conduction

In the fourth article of an on-going series devoted to a review of essential ideas in electronics, **Torben Steeg** presents an in-depth examination of resistance and conduction

IN AN EARLIER article in this series (devoted to current, and published in Autumn 2006) resistance was introduced, rather vaguely, as a measure of how good, or bad, an object is at allowing current to flow. This use of the word resistance is consistent with normal English, where resistance implies opposition of some kind – to the flow of electrons in the context of electronics.

The earlier article also noted that resistance is measured in ohms (symbol ‘Ω – the Greek letter omega) with a perfect conductor having a resistance of 0Ω(no resistance to current flow) and a perfect insulator a resistance of ∞Ω(infinite resistance). It was also said that, in real work, in school electronics you will find that short lengths of wire have effectively 0Ωresistance and poorly conducting parts of a circuit will be measured in MΩ (1MΩis a million ohms, i.e. 1,000,000Ωor 10^6Ω.

Finally, the article said that resistance, voltage and current are linked together through Ohm’s Law:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}, \text{ or}$$

$$I = \frac{V}{R}.$$

These ideas will be all further explored in this article.

CONDUCTING AND RESISTING

Some materials – called conductors – allow an electric current to flow easily. Materials that don’t allow an electric current to flow are called insulators. So conductors have a very low resistance to the flow of an electric current and insulators have a very high resistance to current flow. Examples of good conductors include metals, some forms of carbon and some salt solutions. Insulators include plastics, wood and most non-metals.

Why is this? What differentiates materials that conduct from those that don’t?

ATOMIC PHYSICS REVISITED

Previous articles in this series have made use of a simple model of an atom where a positively charged nucleus (centre) is surrounded by negatively charged electrons. The complete atom is uncharged because the charge on the nucleus is exactly balanced by the charges on the electrons (Fig 1).

When a voltage is put across a material, a force on the (negatively charged) electrons in each atom attracts them to the positive side of the voltage. Whether or not the electrons actually start to move because of this force depends on the strength of the force holding the electrons to the host atoms.

CONDUCTORS

In metals one (or more) of the electrons in each atom is held in place quite weakly; these are called ‘free’ electrons, and they constantly move randomly from one atom to another. When a voltage is applied across a metal these free electrons are able to drift towards the positive voltage (this process is described more fully in the article on current – *Electronics Education*, Autumn 2006). As the electrons move, the atoms of the metal (and any impurities) ‘get in their way’, limiting the current.

How well a piece of metal, such as a wire, conducts (its resistance) depends on three factors:

- The kind of metal – metals differ both in the number of free electrons (those available for conduction) each atom has, and the degree to which the crystal structure of the metal impedes current flow. The parameter characterising how strongly a material opposes the flow of electric current is called its resistivity. The Greek letter ρ (‘rho’, pronounced like ‘row’ as in row boat) is used to represent resistivity.
- The thinness (or thickness) of the wire – the thinner it is the higher the resistance because there is simply less space in the material to allow the electrons to flow (Fig 2).
- The length of the wire – the longer the wire the higher the resistance because each electron has to pass more atoms on its way along the wire.

Don’t be confused by the distinction between resistivity and resistance. Resistivity is an inherent property of a material (like density), while resistance is a property of a specific sample of that material (like weight) with a given length and cross section. For a material with a particular value of resistivity, the resistance will get larger as the cross-sectional area gets smaller, and will get larger as the length of the sample increases. This can be summarised as an equation:

$$\text{Resistance} = \frac{\text{Resistivity} \times \text{Length}}{\text{Cross sectional area}}, \text{ or}$$

$$R = \frac{\rho \times L}{A},$$

where ρ is resistivity, L is length and A is cross sectional area.

Resistivity is measured in ▶

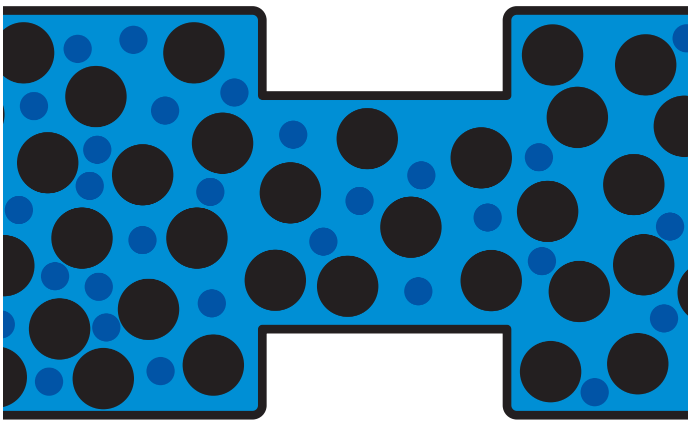


Fig 2: A thinner wire has a higher resistance

'Air normally acts as an insulator, but if the voltage gets too high then the air breaks down and starts to conduct'

Fig 3: Lightning – the breakdown voltage on a grand scale

units of ohm metres (Ωm) and is very small for good conductors. The resistivity of some conductors is shown in Table 1. Note that units of resistivity used in this table are nano Ωm (10^{-9}, or a billionth of an Ωm).

You can see from this table why wires are usually made using copper (but why not silver?). You can also see that although graphite is considered to be a conductor, it is a much, much poorer conductor than mainstream conducting materials like copper.

A fourth factor that affects resistance is that a metal's resistivity increases with temperature. A simple way to explain this effect is that a higher temperature makes the atoms vibrate more – which makes it more likely that a moving electron will be scattered, or impeded, by an atom. (This is a fair description of the process, but, as with many of the 'classical' explanations in this article, a description based in quantum theory would provide a subtler explanation.)

INSULATORS

In insulating materials the electrons in each atom are held in place by strong forces. Typically, when a voltage is placed across the insulating material the force attracting the electrons to the positive voltage is weaker than the force holding the electron in the atom – the electrons don't move so there's no current.

If the voltage across an insulating material is increased to a very high level, there will come a point when the force attracting the electrons to the positive voltage is larger than the force holding them in the atom and current will start to flow. This voltage is called the breakdown voltage (because the insulation has broken down). At the breakdown voltage there is usually a very sudden change from insulation to conduction. A good example of this is a lightning bolt (Fig 3). Air normally acts as an insulator, but if the voltage gets too high then the air 'breaks down' (electrons are stripped from the various air molecules) and starts to conduct, producing a sudden and very large current.

The parameter characterising a material's inherent quality as an insulator – paralleling the role of resistivity in conduction – is called its dielectric strength, and is based on the breakdown voltage. Breakdown voltage increases with the thickness of the material, and dielectric strength is breakdown voltage of a material sample 1m thick. Dielectric strength is represented by the Greek letter epsilon, ϵ, and is measured in MV/m (million volts, 10^6 volts, per metre). The dielectric strength of some insulators is shown in Table 2.

What this means in practice is, for example, that a voltage of 3kV over a distance of 1mm (equivalent to 3MV of a distance of 1m) in air would cause a spark. You can use this to calculate the voltage difference next time you get a spark from a car or a nylon carpet.

READING THE BANDS

Every circuit you build will include resistors (Fig 4). Resistors are used to control the current in a circuit, and, as we have seen, the larger the resistance, the smaller the current flow. Resistance values are generally available from 1Ω to 10MΩ and the actual resistance of a particular resistor is indicated by the coloured bands on the resistor body which can be interpreted using the resistor colour code (Fig 5).

It is important to understand the significance of the tolerance band on a resistor. As in the example shown in Fig 5 the tolerance on the resistors usually used in schools is ±5%. This means that the actual value of the resistance can vary above or below the value you read from the first three bands. A 1,000Ω resistor with 5% tolerance could have a value anywhere between 950Ω and 1050Ω This is not a problem for circuit design as exact control of current is rarely important.

E12 SERIES

In your circuit design you might need a resistor with any value between a few ohms and 10MΩ Clearly it would be impractical for you to keep (or suppliers to stock) ten million different resistor values. Instead you will find just a few values of resistance available. The most commonly used series of resistor values is called the E12 series. This is based on the 12 'core' values 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68 and 82, with each core value being available in multiples of 10, up to a million. So, for example, you can have a 68Ω resistor, a 680Ω resistor etc., all the way up to a 68MΩ resistor.

As you can see, the core values are not evenly space between 10 and 100. In fact, the values have been chosen so that the tolerances almost bridge the gaps between them; the actual (as opposed to percentage) tolerance is larger on a higher value resistor so the gap to the next value can also be larger. You will also find an E24 series (with 24

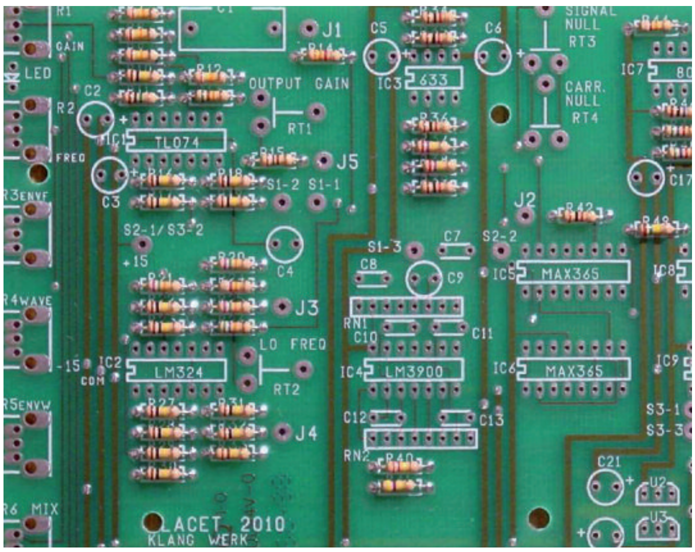


Fig 4: Resistors everywhere

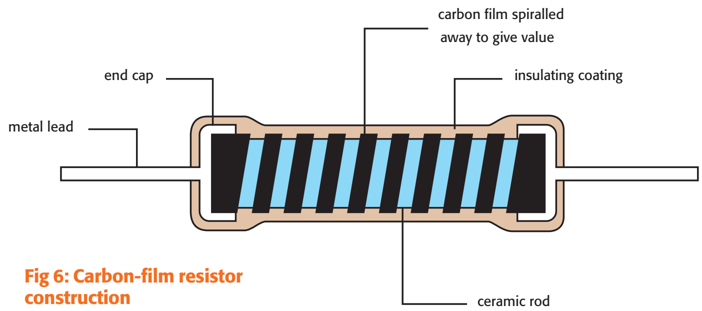


Fig 6: Carbon-film resistor construction

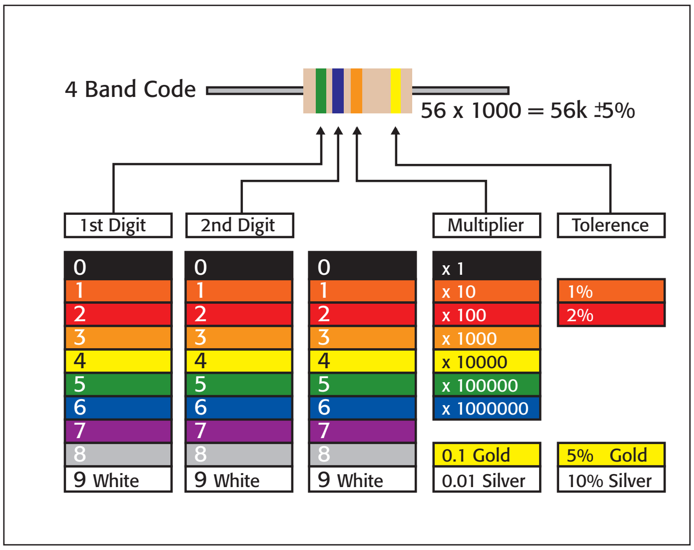


Fig 5: 4-band resistor colour chart

Table 1
The resistivity of some materials

Material	Resistivity (Ω m) x10⁻⁹
Silver	15.9
Copper	17.2
Gold	22.4
Aluminium	26.5
Tungsten	56.5
Iron	97.1
Platinum	106
Lead	220
Mercury	980
Nichrome (Ni ,Fe, Cr alloy)	1000
Graphite (Carbon)	30,000-600,000

Table 2
The dielectric strength of some insulators

Material	Dielectric strength (MV/m)
Dry air	3
Quartz	8
Neoprene rubber	12
Nylon	14
Pyrex glass	14
Silicone oil	15
Paper	16
Bakelite	24
Polystyrene	24
Teflon	60

base values) in electronics catalogues; these are usually high-precision (and high-cost!) resistors.

When you design a circuit, you choose component values which make it work as well as possible. For example, your calculations may give a value of 145Ωwhich doesn't exist, so you would select the nearest higher value, in this case 150Ω Each E12 value is about 20% bigger than the last so the nearest value is never in error by more than about 10%.

IN PRACTICE

A very common use of a resistor is for current limiting to protect a component. For example, a supplier's catalogue might tell you that a high-intensity white LED might require a current of 30mA and cause a voltage drop of 2.5V; more current than this will damage it. If you are using this LED in a circuit with a 4.5V supply then you can use Ohm's Law to calculate what resistance to place in series with the LED to limit the current The voltage across your resistor will be 2V (4.5-2.5), the current will be 0.03A (30mA).

From Ohm's law we have:

$$I = \frac{V}{R} \text{ , or } R = \frac{V}{I} \text{ ,}$$

$$\text{so that } R = \frac{2}{0.03} \text{ , or } 67\Omega.$$

So you would choose a 68Ω resistor from the E12 series.

CONSTRUCTION

It is a common assumption to think that resistors are made of very small coils of wire, because that is how resistance is often introduced in science lessons. For very high power applications such resistors are available, but they are very expensive. For normal use, two other types of resistor are commonly found in schools; carbon film and metal film.

Carbon-film resistors are made of a solid ceramic core which is coated with a thin carbon layer (or 'film') which is the conducting layer. A spiral strip of this carbon film is then taken off – the amount removed controlling the resistance of the film. Metal leads are attached to the carbon film with an end cap and the whole thing is surrounded in an insulating layer with the colour code printed on (Fig 6).Carbon film resistors are very popular for low-power applications as they are cheap, though lacking in precision.

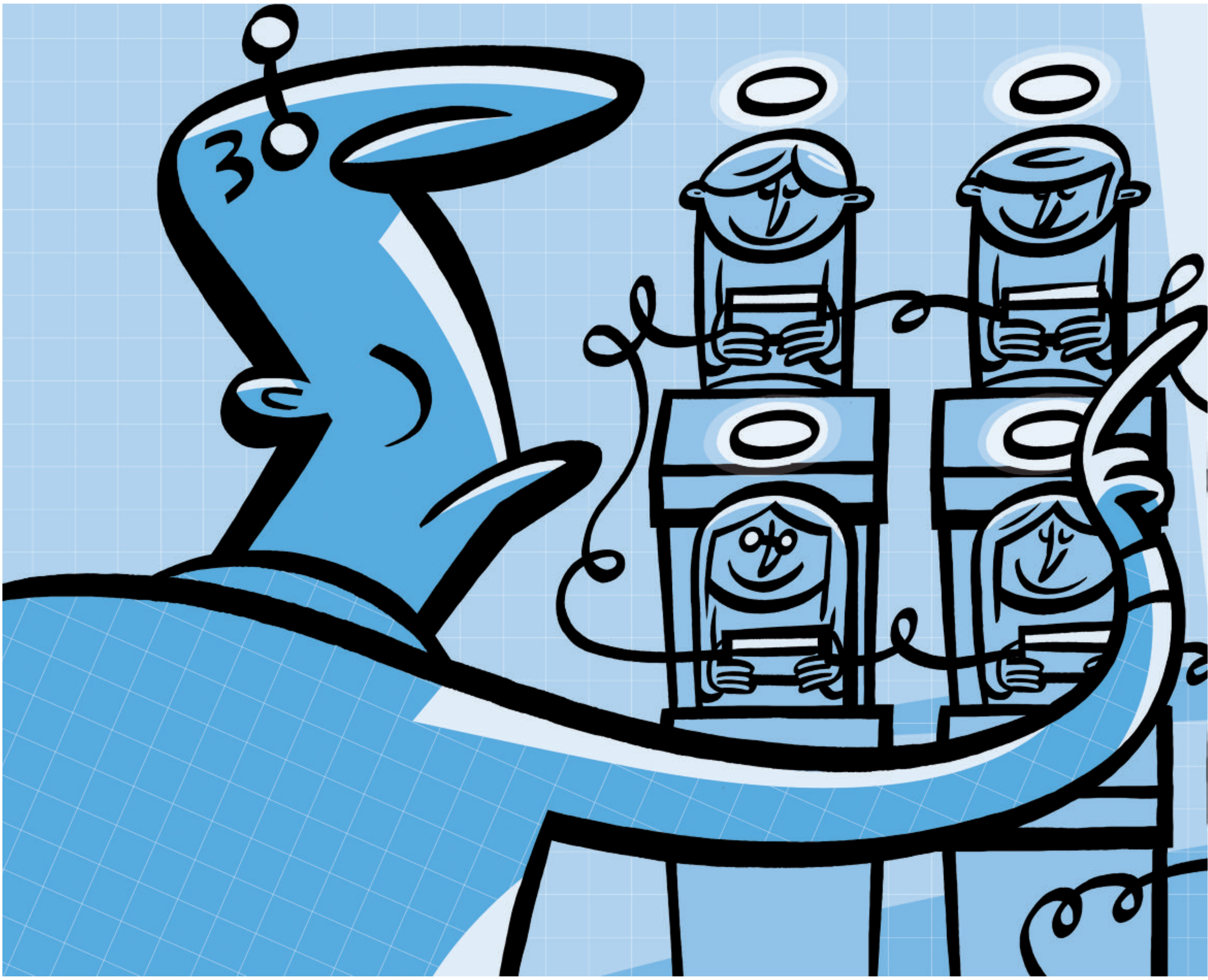
Metal-film resistors are constructed in the same way as their carbon-film counterparts, but the ceramic core is coated with metal, often a Nickel/chromium (Ni-Cr) alloy. In comparison with carbon-film types they have more precise values and better electronic characteristics (such as maintaining their value when the temperature changes), but they are more expensive.

BRIDGING THE GAP

There is a group of materials whose conduction properties are between those of full conductors such as metal and full insulators; these are semiconductors. Semiconductors, such as silicon and germanium, are not very good conductors, but their conducting properties can be changed by adding atoms of different chemicals. This ability to control the conduction properties of a material has been hugely significant as it underpins the whole of modern electronics. The majority of components that you work with in electronics from transistors to PIC chips depend on semiconductor technology, but a full description of semiconductors will have to wait until a later article in this series. ■

■ **Torben Steeg is a freelance consultant in education. He can be contacted via torben@steeg.co.uk**

■ **Downloads**
Earlier articles in this series can be accessed via the *Electronics Education* website – www.theiet.org/ee. The first voltage article is included in the Spring 2005 issue, the second voltage article appears in the Summer 2005 issue, and current article is in the Autumn 2006 issue.



Beach

effective fault-finding: part 2

John Martin describes how on-board programmable controllers can be used to identify faults on PIC-based PCBs

THIS IS THE SECOND in a series of three articles on fault finding. The first article, published in the Spring 2008 edition of *Electronics Education*, looked at techniques for fault prevention and finding with 'hard-wired' (non-PIC) PCBs. This article looks at the situation where pupils are adding components to PIC-based PCBs (where the PCB itself is fault free) and the ways in which the PIC can be used during the build process to simplify testing and fault finding. The third article will look at the situation where pupils are designing, building and testing their own PCBs.

GOLDEN RULES

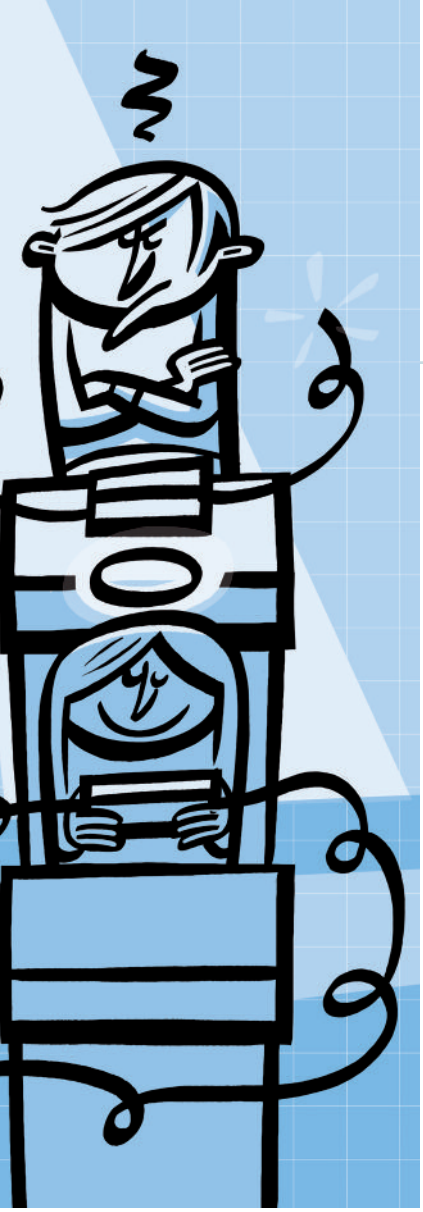
In my first fault-finding article I recommended a set of six 'Golden Rules', building on the three 'golden rules' advocated by Joe Brock in his article 'Find that Fault', *Electronics Education*, Autumn 2007. The six golden rules are:

- Before doing any work with pupils, make sure you have constructed and tested the circuit yourself and thought about the problems your pupils might have
- Always concentrate on a high quality of build
- Never, ever let the pupils work without a 'perfect' (i.e. complete and fully labelled) circuit diagram
- Pupils should always have a block (or system) diagram
- Pupils should know the relationship between the block diagram, the circuit diagram and the PCB
- Build a subsystem, test; build a subsystem, test…

These rules apply to any electronic work, whether it is based on non-programmable systems (as discussed in my previous article) or on PICs. The great benefit of PICs is that they make applying what I believe is the most important rule, namely, 'Build a subsystem, test; build a subsystem, test…', a great deal easier, because the PIC itself can be used as a 'test instrument', removing the need for pupils to interpret readings on voltmeters, or follow all the details of block diagrams or circuit diagrams.

The essence of what is involved is to test each

'The great benefit of PICs is that they make applying... the most important rule, namely, 'build a subsystem, test; build a subsystem, test' a great deal easier'



subsystem by downloading a simple program (written by the pupil or teacher) onto the PIC, designed solely to exercise the subsystem the pupil has just built. In this way, the pupil has immediate feedback on whether that subsystem is working or not and, if there is a problem, they know that the fault is in the small subsystem they have just completed – they do not have to check the complete circuit. This makes fault-finding much simpler.

PET EXAMPLE

To illustrate the principles involved I will describe how this approach would be used in the case of the Revolution Education Cyberpet (Fig 1). This has been chosen because it is a relatively popular and simple PIC-based circuit. However, it should be emphasised that the principles described apply to any PIC-based circuit – whether commercially sourced, designed by a teacher or designed by a pupil.

The Cyberpet is a kind of DIY Tamagotchi – a 'digital pet' that the user can look after and play with. Educationally, it provides a motivating context for electronic construction, PIC programming and a basis for integrating product design and electronic design. It can respond to 'stroking' (pushing a push switch), day and night (with a light sensor). It has two 'eyes' (LEDs) and can 'talk/sing' (with a piezo sounder).

The Cyberpet uses Revolution Education's PICAXE 08 microcontroller. Programs are downloaded from a PC to the PICAXE 08 using a download lead. This lead connects to the PICAXE 08 using an on-board socket and a simple interfacing circuit (Fig 2). This system, including the interfacing circuit, is standard on all PCBs designed to be used with the PIXAXE 08.

One very useful feature of the PICAXE system is that the PIC does not need to be removed from the PCB when it is reprogrammed (as, for example, when downloading the various test programs). Removing the PIC often leads to bent pins and damaged PICs.

The main circuit diagram for the Cyberpet (Fig 3) shows how the PIC is connected to the input subsystems (the light-dependent resistor and push switch) and the output subsystems (the two LEDs and the piezo sounder).

The corresponding block diagram is shown in Fig 4. (Figs 2, 3 and 4 have all been taken from the Cyberpet data sheet). The program download circuitry is not shown in the block diagram – it is, in effect, part of the microcontroller.

The PCB as supplied by Revolution (Fig 5) clearly identifies the components and the values of the resistors. However, one of our golden rules requires that we, 'Build a subsystem, test; build a subsystem, test…', and it is not immediately obvious from the PCB, or the supplied circuit diagrams, which resistor or LED goes with which subsystem.

A 'perfect' circuit diagram and PCB should have a label for every component, and it should be clear where they fit on the PCB. Perfect versions of Fig 2 (the download connections), ▶

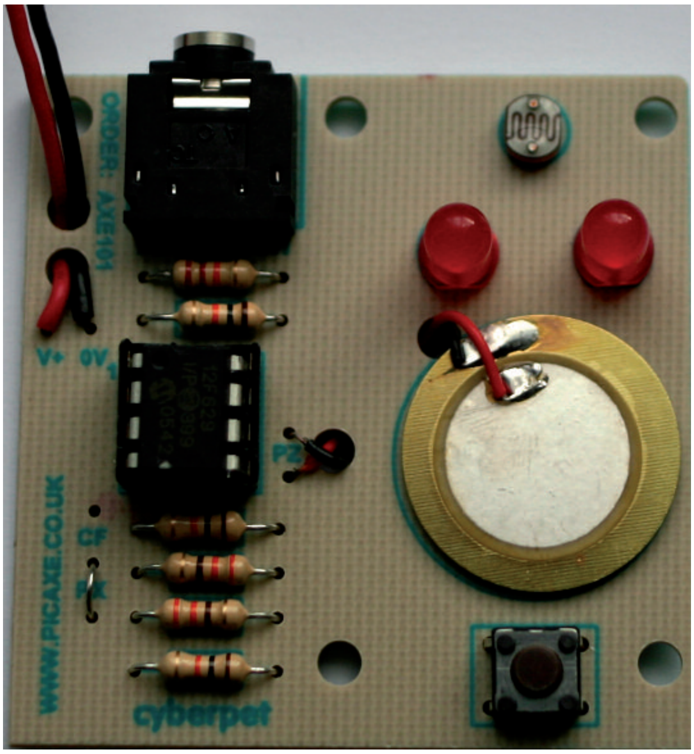


Fig 1: Cyberpet

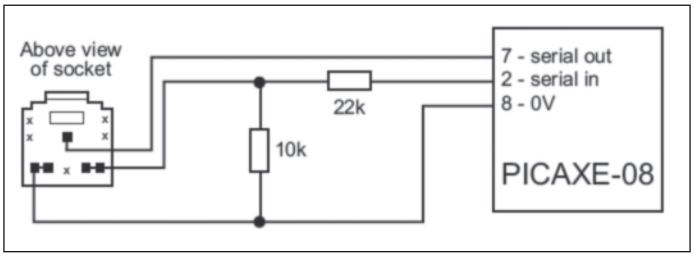


Fig 2: Download connections for PIXAXE 08

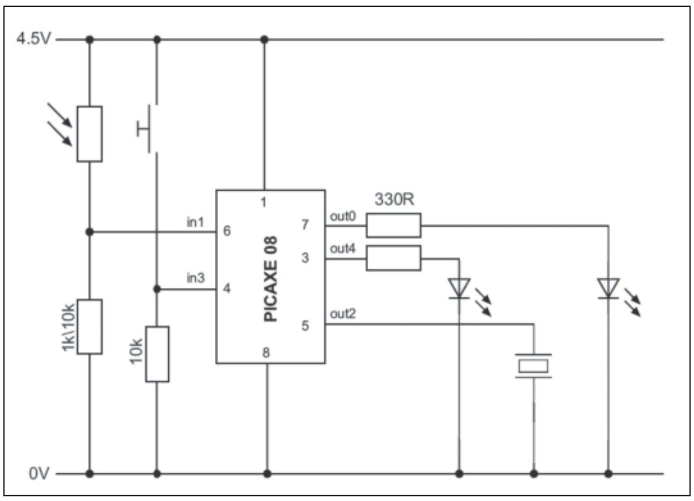


Fig 3: Main circuit diagram for the Cyberpet

'What needs to be clear from the PCB and the circuit diagram is which component belongs to which subsystem and where each goes'

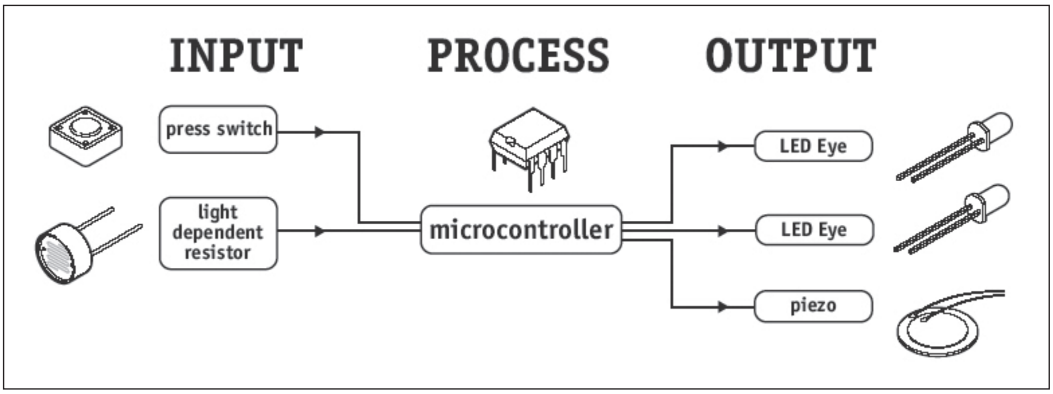


Fig 4: Cyberpet block diagram

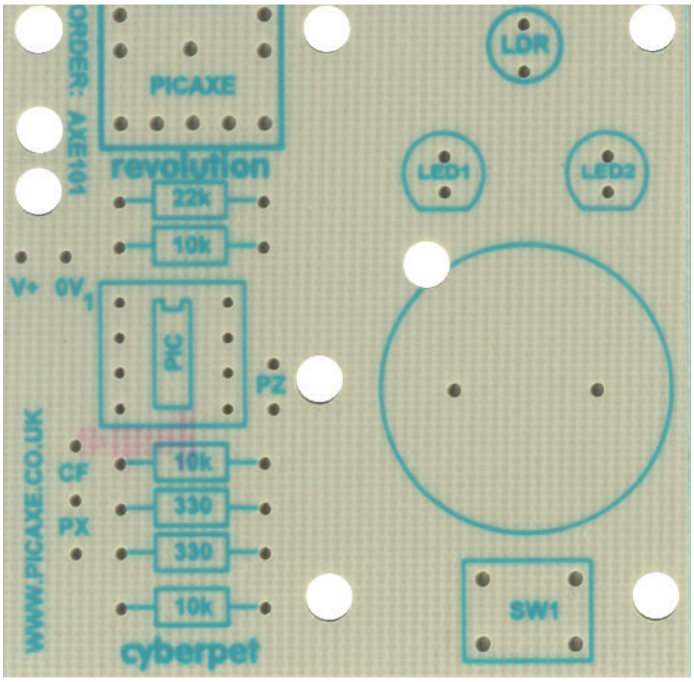


Fig 5: Cyberpet PCB

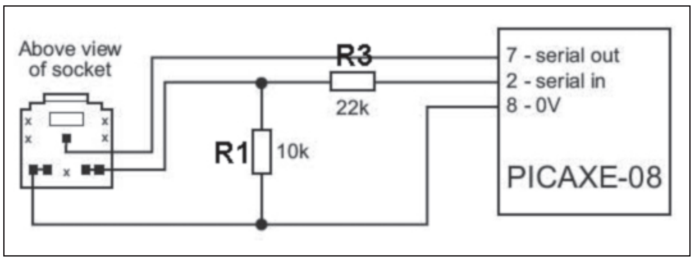


Fig 6: Download connections with resistors labelled

◀ Fig 3 (the Cyberpet circuit diagram), and Fig 5 (the supplied PCB), are shown in Figs 6, 7 and 8 respectively.

What needs to be clear from the PCB and the circuit diagram is which component belongs to which subsystem and where each goes. In this instance:

■ The download subsystem consists of the PICAXE download 3.5mm socket and the resistors R1 and R3

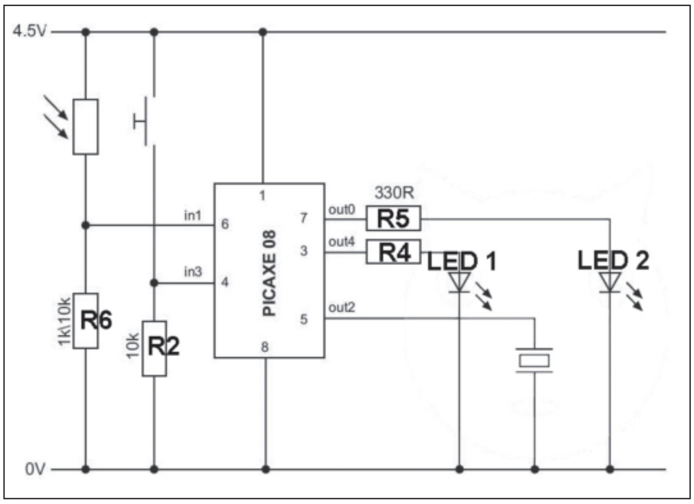


Fig 7: Main circuit diagram with resistors labelled

■ The Process subsystem consists of the PICAXE 08

■ The LED 1 output subsystem consists of LED 1 and the resistor R4. It is powered from PICAXE output 4

■ The LED 2 output subsystem consists of LED 2 and the resistor R5. It is powered from PICAXE output 0

■ The piezo sounder output subsystem consists of just the piezo sounder. It is powered from PICAXE output 2

■ The light sensor input subsystem consists of the light-dependent resistor and the resistor R6. A wire link between the pads marked 'PK' on the PCB is also part of this subsystem. The signal goes to PICAXE input 1

■ The switch input subsystem consists of the push switch and

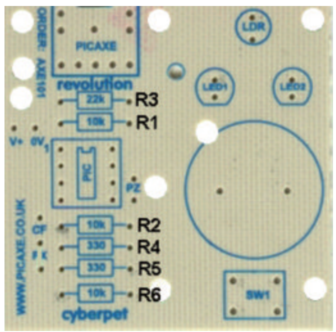


Fig 8: PCB with resistors labelled

the resistor R2. Its signal goes to PICAXE input 3.

BUILD SEQUENCE

Our 'Build a subsystem, test...' golden rule needs to be kept firmly in mind when planning the build – the rule essentially defines the most test-friendly

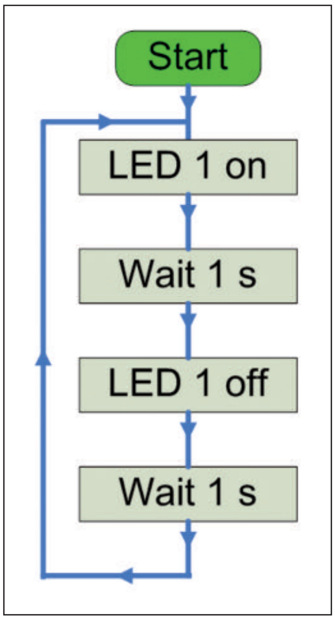


Fig 9: Flowchart of test program for LED 1 subsystem

build procedure. The notes in the Cyberpet data sheet suggest constructing the complete circuit starting with the smallest components (resistors and wire links) and then progressively adding larger components. The advantage of this approach (which is commonly advocated) is that it is easier to place the resistors flat on the PCB. However, it means that testing is only done at the end of the complete construction process, rather than one subsystem at a time.

In the case of any PIC-based system, the PIC itself is the most useful 'test instrument' available to us. We can built each subsystem in turn, with each subsystem being tested (by downloading appropriate short test program) before moving on to the next subsystem. Here's how this approach can be applied to the Cyberpet:

■ **Step 1:** In any electronic system the first thing to build and test is the power supply. In this case we need to solder in the battery connector. A very convenient way to test that all is well in any PICAXE 08 system is to add the IC socket and use a multimeter to check that the

a few modifications

A SECOND OPINION

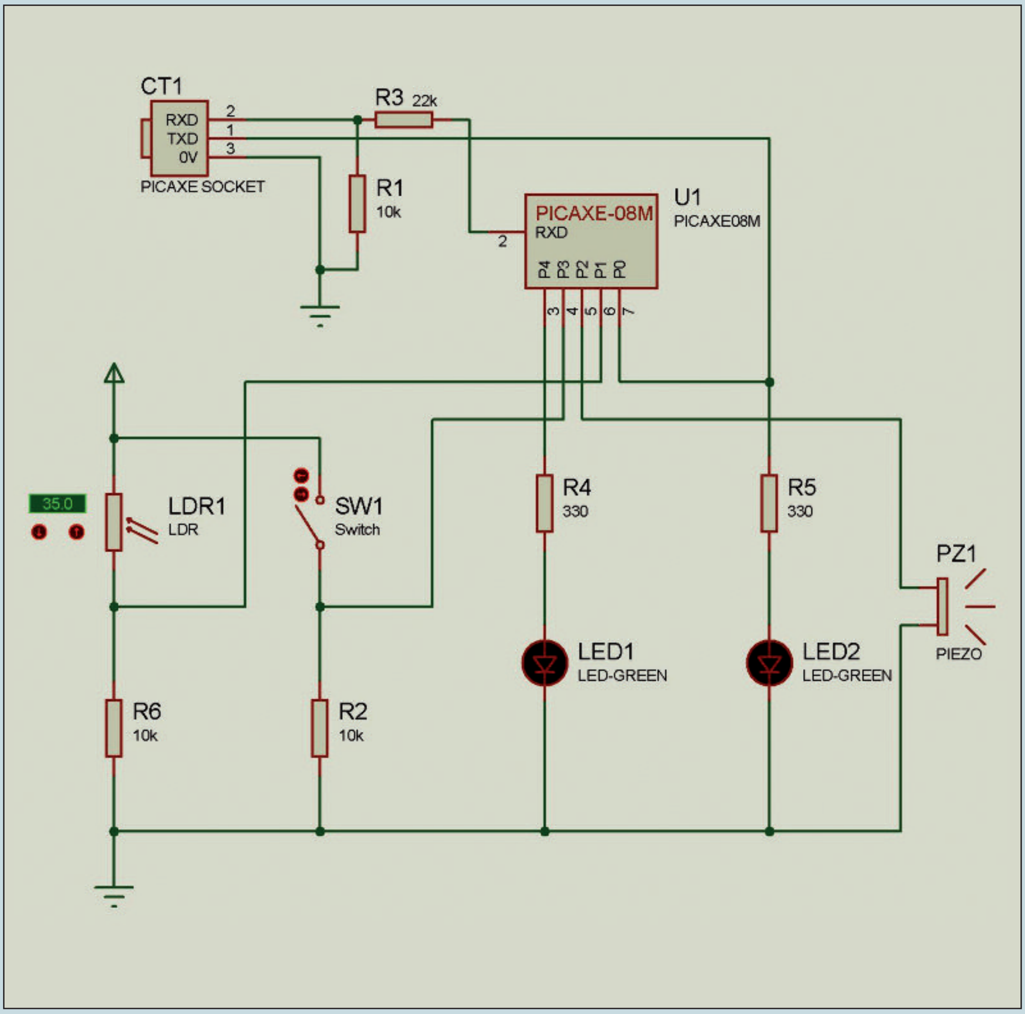


Fig A: A PICAXE VSM simulator circuit

I agree entirely with John's approach, it is the ideal in an ideal world. However, the Cyberpet project is widely used at KS3 in class groups, and my feeling is that many schools may struggle to manage the physical and time issues involved with 25+ KS3 students repeatedly moving back and forth between computer/test area and soldering iron.

To help with this issue, I would propose slightly modifying John's approach by soldering all the resistors to start with; then adding and testing input/outputs one by one. However whatever 'assembly' approach is used I agree it is absolutely essential to test each block separately.

On commercial PCBs it is usual to add IDs (R1, R2 etc) rather than values. However, on our educational boards we have found students make far fewer mistakes if the actual value is written on the board instead – we do want to help them succeed first time and have a positive learning experience!

As can be seen from Fig 1, we designed the right hand side of the board to be text free. This was done purely for aesthetic reasons, resulting in an attractive end product, but it does mean there isn't enough space for both ID and value. However, we have now PICAXE VSM simulator software, and, as can be seen from Fig A, this displays both ID and value.

■ **Clive Seager, technical director, Revolution Education (cseager@rev-ed.co.uk)**

'Instead of downloading a program to the PIC from a computer, a set of test programs can be pre-written and stored on labelled PICs'

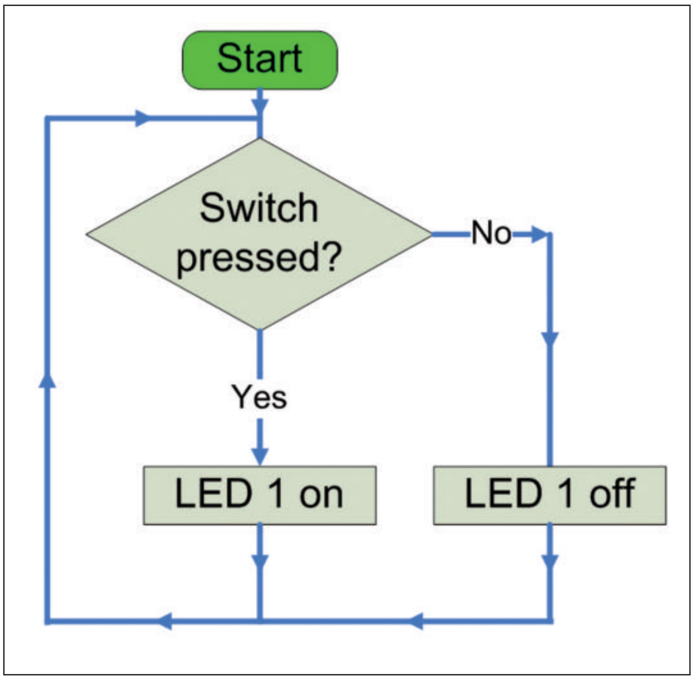


Fig 10: Flowchart of test program for the switch subsystem

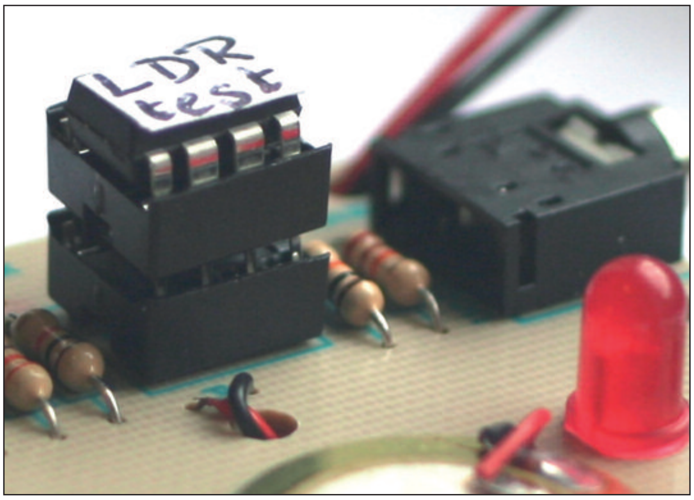


Fig 11: PIC mounted in a second protective DIL socket

voltage between pins 8 and 1 is +Vs, the supply voltage

■ **Step 2:** We need to build the PIC subsystem next so that we can use it as our 'test instrument'. This involves adding the PIC, and also the circuitry for the download subsystem. It is possible to check that the PIC and download circuitry are working by downloading any PICAXE 08 program – if there is a problem with the hardware there will be a warning message on the computer screen. The most likely cause of a problem is poor soldering of components or incorrect resistors. Failing that, try the other on-screen suggestions

■ **Step 3:** The simplest thing to test next is one of the output subsystems. The input sensors can only be tested at this stage by using a voltmeter. It's much easier to test them later – see step 6 below. A very simple test program (Fig 9) will check LED 1

■ **Step 4:** LED 2 can be checked using a program very similar to the program used to check LED 1

■ **Step 5:** The piezo sounder system is the final output subsystem. It can be tested by sounding a note on and off

■ **Step 6:** To test a digital input sensor we have to have some means of knowing that its signal is going high and low. We can do this with a test program that checks the input signal and turns an output subsystem on and off in response. If we build the switch input subsystem next, then the test program shown in Fig 10 will turn on the LED if it is pressed.

■ **Step 7:** The light sensor subsystem can be tested in a very similar way to the switch

■ **Step 8:** Now that each subsystem has been built and tested, the complete PIC system can be tested with a larger program that re-checks each part.

The flow charts shown in Figs 9 and 10, illustrate the general principles which can be used in any of these programs. PICAXE microcontrollers can be programmed using PIC Logicator from Economatics, Flowol from KITE, PICAXE Programming Editor (a free download from Revolution Education) and Crocodile Technology from Crocodile Clips.

A POSSIBLE PROBLEM

This PIC-based approach to testing does depend on having enough computers (i.e. three or four for a class of 20 to 25 pupils) and also that these computers are readily accessible. It may not be practicable in your school if all the computers available need to be booked and are remote from the workshop. I am grateful to Clive Seager, who developed the Cyberpet, for alerting me this point (See panel 'A Second Opinion').

There is, however, a way round this potential problem. Instead of downloading a program to the PIC from a computer, a set of test programs can be pre-written and stored on labelled PICs. To protect the test PICs from damage when they are inserted into and removed from the IC socket a useful technique is to put each test PIC into a second IC socket (Fig 11). The second IC socket is inserted and removed from the board, and in the event of becoming damaged will cost just a few pence to replace.

The next, and final, article in this series will look at further measures I would recommend to ensure success when pupils are designing, building and testing their own PCBs. ■

■ **This article is based on material on the Electronics in Schools web site (www.electronicsinschools.org)**

■ **John Martin is director of the Technology Education Development Unit in the School of Computing, Science and Engineering at the University of Salford and an accredited Electronics in Schools trainer (d.j.martin@salford.ac.uk).**

Web Links

■ **The original article by Joe Brock can be viewed on the *Electronics Education* website: www.theiet.org/ee – follow the link to the Autumn 2007 issue.**

■ **The first article in this series: 'Effective Fault Finding – Part 1' can be viewed on the *Electronics Education* website: www.theiet.org/ee – follow the link to the Spring 2008 issue.**

■ **The Cyberpet is available from Rapid Electronics (www.rapidonline.com) and from Revolution Education (www.picaxe.co.uk)**

■ **Revolution Education data sheet for the Cyberpet: www.rev-ed.co.uk/docs/AXE101.pdf**

■ **Economatics: www.economatics-education.co.uk**

■ **Crocodile Clips: www.crocodile-clips.com**

■ **KITE: www.flowol.com**

on the edge

LIGHTING GOES FLEXIBLE AND TRANSPARENT

Reporting from the frontiers of technology **Siân Harris** describes how new devices based on organic compounds could transform the way that we light our homes, offices and even our furniture

FOR MOST OF US, lighting is only something that we really notice when it is not quite right, such as when it fails to give enough light to something we want to read or when it is too harsh and bright for a relaxing, intimate meal. For lighting engineers, however, such aesthetic considerations are part of a wide array of technical issues that are constantly being developed and refined in the quest to find better-performing and more energy-efficient light sources.

There is a pressing environmental need for such new developments, as nearly one- fifth of worldwide energy consumption is attributed to lighting applications. This is mainly because of the dominant role of incandescent bulbs, which, despite being cheap and showing colours well, are hugely inefficient in their energy use.

Traditionally, their main competitors have been fluorescent tubes. These perform much better in terms of their energy consumption, but have aesthetic drawbacks such as in the way they render colours and the potential problems of glare.

Four generations of lighting technologies: incandescent light bulb, fluorescent TL, compact fluorescent and OLEDS

Photographs: Philips, Siemens

They also contain hazardous substances such as mercury. One alternative is light-emitting diodes (LEDs), which are based on inorganic semiconductors. These are energy-efficient and are already starting to make headway in the lighting market with more powerful LEDs appearing every year.

There is another promising option on the horizon, however, which could revolutionise the way that we think about lighting and its applications: organic light-emitting diodes (OLEDs). These consist of layers of organic compounds, often polymers, which emit light when an electric current is applied across them. If the goals of lighting researchers are realised, these devices should far surpass many current lighting technologies in energy efficiency, lifetime and colour rendering.

It is not these factors that have caused furniture designers and architects to join lighting engineers in being excited about this emerging technology though. What has inspired them is the fact that, unlike incandescent bulbs, halogen lamps or LEDs, which are all point sources, OLEDs are flat area sources – they emit light uniformly from everywhere on their surface. This means that diffuse, glare-free lighting effects can be created without the need for special screens, mirrors or reflective ribs such as those used to diffuse the light from fluorescent tubes.

What's more, other features of OLEDs could open up new lighting possibilities. For example, OLEDs can be made transparent. This means that the windows of a house or a car sunroof could double up as an OLED light source at night. The technology for this is still some way off, but demonstrations have already shown 55 per cent transparency, so this capability should become feasible in a few years' time. Similarly, with the right substrate, OLEDs could be made flexible, creating all sorts of new possibilities for lighting designers.

There is a drawback to all these plans though: OLEDs for lighting applications are still at an R&D stage and all of the key parameters require further development.

CHALLENGES

The headline-grabbing figure in any lighting comparison discussion is energy efficiency, measured in lumens per Watt (lm/W). If predictions about OLEDs are right, then they could potentially give energy efficiencies of up to 170lm/W. This would far exceed the light bulb, with an energy efficiency of around 12lm/W and even beat fluorescent tubes, which have energy efficiencies of 60-100lm/W. OLEDs aren't there yet, but several manufacturers have reported white OLED efficiencies of around 30-40lm/W at brightness levels that would be suitable for applications, and Konica Minolta, in Japan, has even reported an efficiency of 64lm/W. Higher efficiencies have also been shown for the individual colours. Monochrome green OLEDs, for example, have been demonstrated with an energy efficiency of over 120lm/W, which already surpasses that of fluorescent tubes and inorganic LEDs.

Lifetime is another important issue for lighting technologies, particularly if the light forms an integral part of a wall or an expensive piece of furniture. Red OLED lights that live for over one million hours have been reported, and white OLED lights have already been demonstrated to last for 20,000 to 30,000 hours, which is several years, but the industry wants to push this further. This is particularly important as the lifetime has to include the length of time it might be on the shelf before somebody buys it in addition to the time it is being used. To achieve this, the devices need to be protected from their surroundings. OLEDs are both air and moisture sensitive, and would only last a few hours if they weren't encapsulated. The downside of this is that the

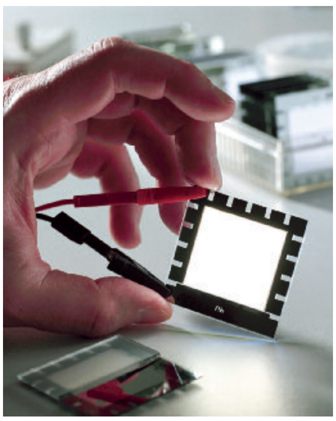
OLEDs come in a variety of colours

better the encapsulation schemes are, the more expensive the devices become.

Colour rendering is another important issue for any lighting scheme. When people buy a jumper they want it to look the same colour in the shop as when they take it out into the sunlight. “For decent lighting applications you need a colour rendering index of 80 or above,” explains Peter Visser of Philips Lighting, who leads the European OLED research initiative OLLA. “Low-pressure sodium street lights are quite efficient but have a colour rendering lower than 50, which is why it can be hard to find your car in a large car park lit with these yellowish lights.”

In the area of colour rendering, the incandescent bulb currently excels, with older fluorescent tubes and inorganic LEDs performing less well. OLEDs can easily produce a high colour rendering because they are broadband emitters (emit light across the full colour spectrum).

Another issue that needs to be addressed for OLEDs is their size. Although they emit homogeneously from their whole area, they are still small. Current laboratory models are generally around 15 or 20cm^2, which is suitable for research purposes. And, although architects dream of 100cm^2 panels, smaller panels could be used in applications if they were made brighter. In practice, early applications are likely to use an array of small OLEDs to form, for example, a desktop lamp. However, in the long term their size is expected to increase as the production equipment is scaled up from the laboratory to the production stage.



Prototype white OLED

Perhaps the biggest challenge that OLEDs face is cost. People are used to spending very little on incandescent light bulbs. And any new technology is likely to be much more expensive to start with, especially if it includes extra design features such as transparency and flexibility. “To put things in the market we need the whole chain to be well established,” comments OLLA’s Visser. “To go from the research stage to full production always takes a certain amount of time.”

Despite the challenges of boosting the performance and bringing down the costs, the lighting industry is excited about the potential of OLEDs. In a recent press statement about its lighting technologies, Philips said that it expects to have its first pilot project with organic LEDs within the next one to two years. And last year when Japan’s Konica Minolta and General Electric of the US signed a strategic alliance agreement to accelerate the development and commercialisation of flexible OLED devices for lighting applications they claimed that their goal is to bring OLED lighting to market by 2010.

The first commercial lighting applications are likely to be fairly small, niche applications. Signs for emergency exits, for example, do not require particularly high powers or a specific colour of white light, although they do face strict rules governing their lifetime. OLED lights could also provide back-lights for LCDs in portable devices. And within the next decade, as volumes and performance improve, other applications such as general home and office lighting could all turn their attentions to OLED lighting. ■

■ Siân Harris is a regular contributor to IET member magazine, *Engineering & Technology*