Claudia Flavell-While explores the surprising ancestry of modern electronic gadgets, and how a chemical engineer called **Tomio Wada** made it all happen

THE images of looters and rioters across England breaking into shops and making off with flat-screen TVs, laptops, smartphones and the like have gone around the world. The rioting underlined how desirable these items are and how important in a society driven by possession of consumer goods. But what few people will appreciate is the contribution chemical engineers have made to these must-have items.

And it's not just about the lithium ion batteries, developed by the chemical engineer Yoshio Nishi at Sony during the 1980s (see *tce* 836, February 2011). Nishi was preceded by another hidden pioneer of modern electronics who just so happened to have a background in chemical engineering: Tomio Wada. His achievement? Wada developed the world's first liquid crystal pocket calculator. The lowly EL-805 pocket calculator, launched by Sharp in May 1973, is the direct ancestor of today's flat-screen displays, be they on a TV, your smartphone, your laptop, microwave, or just about any other electronic device you care to name.

Wada studied chemical engineering at Doshisha University near Kyoto during the 1950s, after which he joined Sharp Corporation (then known as Hayakawa Electric Company) at its Central Research Laboratory in Osaka.

early development

Sharp was founded in Osaka in 1912 and the company initially produced all kinds of metal products, settling on radios and TV sets during the 1950s. The search for new products led the company to investigate calculators, and in 1964 the company produced the world's first transistor calculator. Calculators were in their infancy at the time and the complex electronics required made them prohibitively expensive – the 1964 model cost ¥535,000 or US$1,400 in the US – adjusted for inflation, that's almost US$10,000 today.

Pocket calculators followed a few years later, and once prices had dropped to below US$300 they even started selling in reasonable numbers. However, the early calculators were huge and heavy, they contained hundreds of transistors and their displays used fluorescent character display tubes or light-emitting diodes. This was a huge drain on the batteries – typically an AA battery would only last an hour.

The attraction of liquid crystal displays is that they reflect the light, so don't have to be actively lit, which promised to reduce power consumption 100-fold and extend the battery life to around 100 hours. At ¥26.800 (US$350), the Sharp EL-805 was almost affordable.

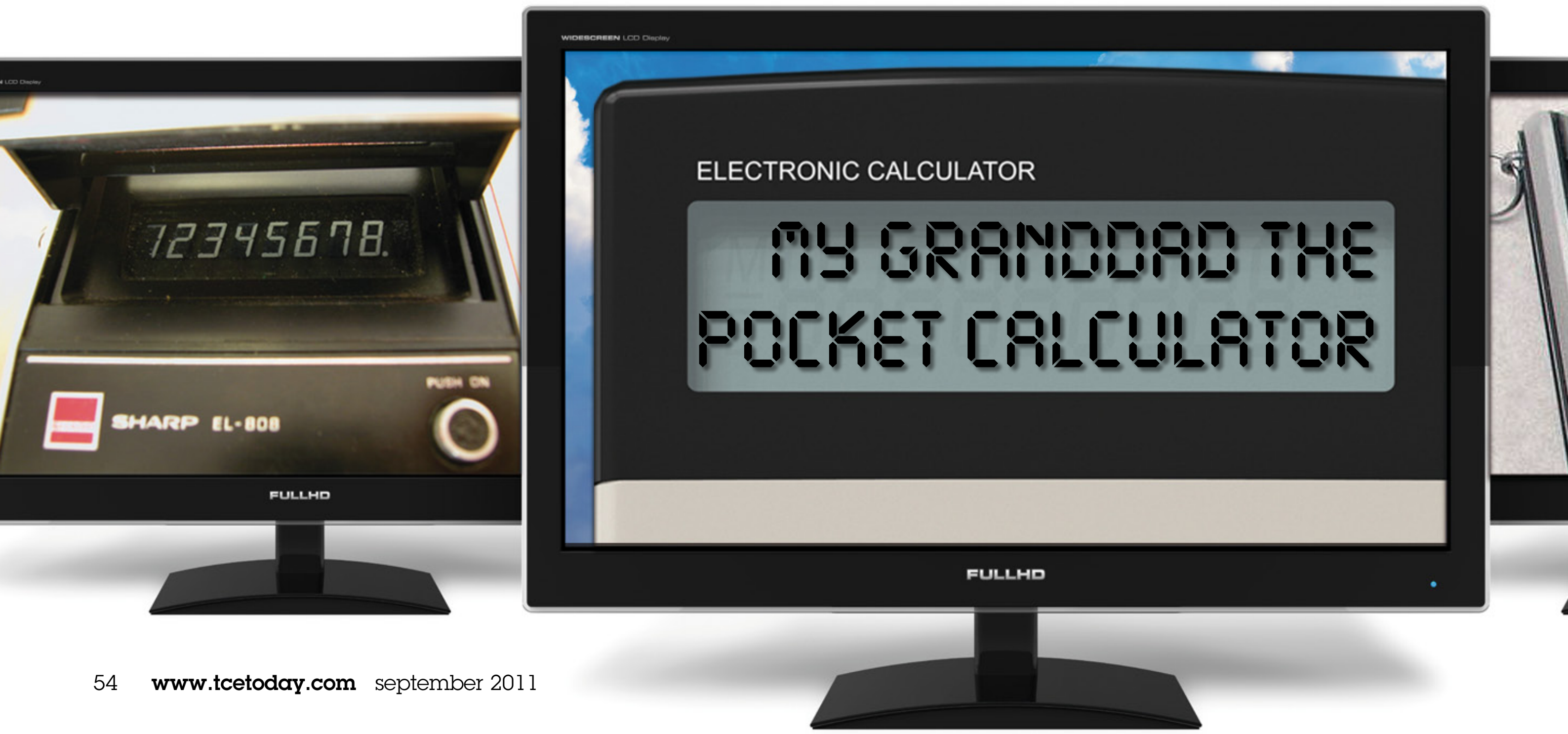
However, developing these early LCD displays was far from easy.

a forgotten curiosity

It was in 1888 that the Australian botanist Friedrich Reinitzer noticed that a material he was working with, chloresteryl benzoate, appeared to have two melting points: at 145°C, the material melted and turned into a milky, cloudy liquid. If he raised the temperature further to 179°C, it would become clear. The physicist Otto Lehmann studied the strange behaviour further and discovered that the liquid initially appeared milky because it had a double refraction effect, which is characteristic of a crystal. The term 'liquid crystal' was born.

But few companies or researchers saw any application for these strange materials and while a number of companies such as E. Merck in Darmstadt, Germany, produced them in small quantities, they remained a largely-forgotten curiosity for the next 80 years.

Liquid crystals come in a variety of types: thermotropic crystals, which change their



state at set temperatures, and lyotropic, which change state as a result of interacting with water or other solvents. Within both categories, there are some that form cigar-shaped molecules and others that form discs. Lastly, the crystals can form either a highly-ordered state, where the molecules are not only parallel but also arranged in distinct layers (smectic) or in a less-ordered 'nematic' state, forming parallel threads but not layers.

LCD displays generally use cigar-shaped thermotropic crystals in a nematic configuration, where their alignment can be easily changed with a magnet, an electrical field or mechanical stress.

Much of the initial work on LCDs took place at the RCA Laboratories in Princeton University, US, in the early 1960s. There, engineers led by George Heilmeier discovered that they could precisely control the way in which certain nematic liquid crystals reflect and scatter light. Further research produced a material that allowed them to do so at room temperature. The key advantage is that such displays do not generate any light but merely reflect it, making displays easier on the eye and much more power efficient.

While the technology attracted interest, difficulties with materials and funding as well as a conflict of interest with its well-established cathode ray tubes business prevented RCA from developing it further. Heilmeier joined the White House on a one-year appointment and then became president of Bell Communication Research.

calculator wars

Wada and Sharp entered the story a few years later, thanks to a documentary on scientific advances filmed by the Japanese broadcaster NHK. Sharp at the time was engaged in the so-called 'calculator wars', a period of fierce price competition among the early calculator producers. To win the war and preserve a modicum of margin, Sharp's management believed it needed a novel, non-emitting (passive) display that didn't weigh a lot, didn't take up a lot of space, and did not consume much power.

In the NHK documentary, which aired in Japan in 1969, Heilmeier demonstrated what he termed an "alphanumerical display and window with electronically controlled transparency".

Watching it, Wada instantly realised that LCD displays could be the secret weapon that would help Sharp win the calculator wars. There were just two problems: LCDs had never been successfully mass-produced, and Sharp had no experience whatsoever in the field.

Sharp executives initially tried to convince RCA to handle production, but RCA was not interested in producing LCDs for anything other than digital watches. A disappointed Wada insisted that despite its total lack of experience, Sharp had to go it alone.

Wada's colleague Hirohisa Kawamoto wrote in his account of the history of LCDs: "Though educated as a chemical engineer, Wada had never heard of liquid crystals before. No technology existed on liquid crystals within Sharp and almost no literature was available in its library. Until the late 1960s, only a few compounds – most of them exhibiting liquid crystal phase at temperatures higher than the room temperature – were used as standard materials for scientific experiments."

project 734S

Sharp drew up a special project team for the task and set them the goal of making calculators with LCD displays commercial reality within 18 months, instead of the three to five years usually allowed.

Wada led the 20-strong team working on Project 734S (the deadline was April '73, and S because it was secret) on a mission to find a liquid crystal that would operate at room temperature and that was suitable for a high-contrast display. Not knowing what compound Heilmeier had used, the team tested 3,000 different liquid crystals and synthesised over 500 mixtures.

Eventually they settled on a mixture of two Schiff's bases, EBBA and BBBA, which formed a nematic liquid crystal and worked at 0-40°C. The team also worked out the nature and quanitity of additives it had to add to produce sufficient ionic current without reducing the lifespan of the display; whether to operate the calculator on AC or DC current, and had to find a transparent but electrically conductive plate to mount the LCD on. Wada discovered that a government laboratory in Osaka had developed an indium tin oxide plate that appeared perfect for the job, only to be told that the research was aimed to help small companies and could not be shared with a company the size of Sharp. He eventually managed to persuade the ministry that the liquid crystal industry could bring considerable benefits to Japan's industry in years to come, and that many small companies would stand to benefit from this too.

"concerns about the reliability and longevity of the calculators proved to be unfounded: one EL 805 was still found to be working 28 years later"

The difficulties did not end there. Wada's team had to develop a photolithographic process for etching the conductive patterns onto a glass plate. Also, it had to work out how to hold the two glass plates that would form the 'bread' in a liquid-crystal sandwich apart by a set and constant distance; how to pre-align the liquid crystal molecules; and how to design the digital circuits for the calculator's computer (Sharp settled on using complementary metal–oxide–semiconductors (CMOS), which are efficient and work well with LCDs).

vive la revolution

Working against the clock, Wada's team delivered – and on time. Development was complete at the end of March 1973, and on 15 May, the EL 805 was launched. It was a revolution in the world of calculators: weighing in at 200 g and only 2.1 cm thick, it was small enough and light enough to fit into a shirt pocket, and it would run for 100 hours on a single AA battery. By comparison, the competition's calculators were around 25 cm thick, weighed 25 kg, and consumed 9000 times more power.

Concerns about the reliability and longevity of the calculators proved to be unfounded: one EL 805 was still found to be working 28 years later.

While it took another three decades before LCDs would become the ubiquitous staple of modern life they are today, sitting on every desk and in every household, it's impressive to note that the humble pocket calculator could have spawned such a rich technological lineage – and that chemical engineers made such a central contribution to their development. **tce**

Next month: **Vladimir Haensel**, remembered for platforming and the catalytic converter