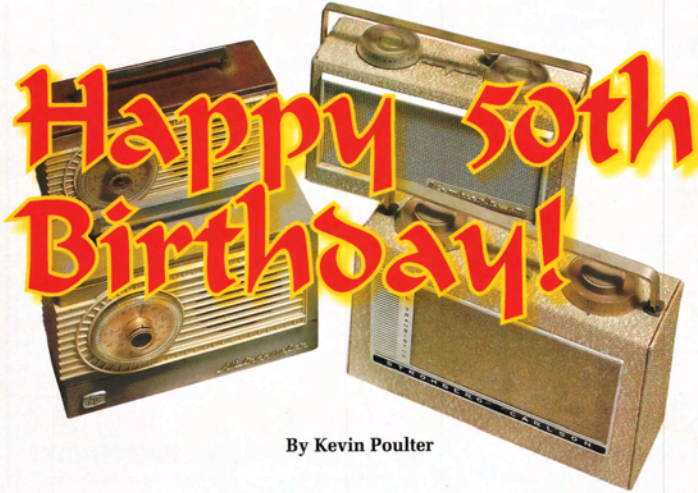
The humble "trannie" turns



By Kevin Poulter

Transistors revolutionised our world immeasurably, galvanising amazing advances in radios and entertainment. Now every home, vehicle, business and hospital has equipment relying on the equivalent of thousands if not millions of semiconductors.

For example, the Apple PowerPC G5 computer has more than 58 million transistors, a high-performance silicon-on-insulator (SOI) process for faster operation, and copper interconnects for improved conductivity. IBM manufactures these processors in a $3 billion, state-of-the-art facility in New York.

The development of transistors didn't occur overnight. The crystal diode was employed for reception before 1920, while during WW2, solid state rectifiers were used, especially in radar.

Radio engineers and scientists contemplated that adding extra elements to diodes could be the basis of a device with significantly less power requirement than the thermonic valve.

Some saw longer term innovation. Computers were not unknown but were very expensive, space-hungry and underpowered. The ENIAC in 1946 required 300,000 valves and a large room to achieve a performance immensely inferior to today's PCs.

The first transistor

Early attempts to develop a 'triode' transistor resulted in notable failures until scientists in the American Bell Laboratories made a breakthrough.

In December 1947, John Bardeen and Walter Brattain developed the first point-contact transistor. They intended it to be more like a junction-effect transistor, but great excitement ensued.

William Shockley, the theorist leading the research, wanted better, so he continued develop the junction transistor. Later the trio shared the 1956 Nobel Prize in physics for their discoveries.

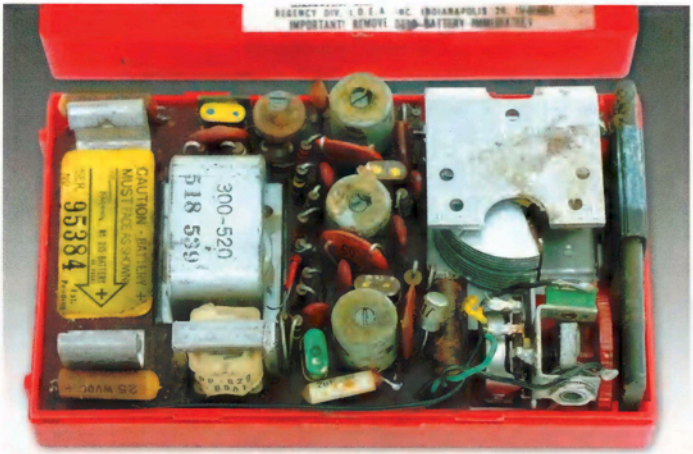
Bell Labs nervously contacted the military to clear their discovery for public release. The concern was the defence hierarchy might put it under wraps but nothing was heard.

As the transistor was being refined, Bell kept their discovery a secret until June 1948. Recognition and sales were essential to recover escalating development costs, so Bell invited the press to view their transistor. Few realised the possibilities and press was mainly one or two lines. In July 1951, Bell announced the junction type.

Eight days that changed the world

Bell was now armed with a superior reason to proceed. In September 1951, Bell Labs staged their much-heralded Transistor Symposium, a week of intensive education and the license to reproduce both types of transistors.

50 years old this month...



Inside the very first mass-produced transistor radio , the Regency TR-1. It beat the Tokyo Tsushin Kogyo TR-55 by a mere nine months. Don't recognise the name? It later became the giant Sony Corporation.

The entry fee for this world-changing technology club was twenty-five thousand dollars. Licensees had just eight days to learn everything Bell knew about transistors.

The first transistor was a point-contact transistor, a wafer of N-type germanium as the base block. Two phosphor-bronze wires were pushed into the wafer, similar to the 'cats whisker' of a radio crystal set.

Within a year of the first transistor radio, Sony released their first to the Japanese market. This wooden-cased TR-72 is a 50s example.

Brief high-current pulses fused the wires to the germanium, a technique called 'electrical forming'. This caused some phosphorus to diffuse from the wires into the germanium, creating P-type regions around the points. If forming was done correctly, a PNP structure with a narrow N region was created.

Point-contact transistors were only manufactured for a few years before replacement by the junction transistor. Point-contact transistors had a common-base current gain ('alpha') well in excess of one and negative resistance, useful in oscillators and switches.

In 1959, Robert Noyce proved more than one transistor could be placed on a single piece of semiconductor material. Later resistors and other components were integrated, making the integrated circuit.

The first junction transistors were the grown-junction type. A single crystal of germanium was grown and doped at the same time. The crystal was pulled slowly from a melt containing N-type impurities. P-type impurities were later added and left for a short while, then more N-type was added again. The result was an N-doped crystal with a thin P-type

Mullard (Philips) manufactured transistors in Hendon (SA). Transistors were supplied in valve boxes. Valves were still being manufactured, so there was an ample supply of boxes. The transistor leads were bent to reduce rattling in the box. Below, more OC71s, sleeved in the Defence Research Establishment colours.

layer in it. The crystal was then cut into small blocks, each forming a single NPN transistor.

Early transistor semiconductor production resembled the production of quartz frequency-control crystals. Mullard's techniques included lapping (rotary grinding) the germanium slices on their untreated side to reduce roughness and thickness. The slices were then cut into small circular wafers by an ultrasonic drill.

Etching followed, to further reduce the thickness, forming the base of the transistor and worth more than their weight in gold! The indium collector and emitter pellets were alloyed to the base germanium, which at this stage might only have been around 0.1 millimetre thick.

The grown-junction process was soon superseded by the alloy diffusion technique, where two beads of the element indium, the 'impurity' used to create P-type germanium, were fused onto a thin N-type germanium block, one on either side. Some indium diffused into the germanium, creating a PNP structure. This process was easier to control and reproduce than the grown-junction approach, yielding a thinner base layer and delivering superior high-frequency response.

The field-effect transistor (FET) is probably the closest device to the Bell Lab team's original dream of a solid-state equivalent to the vacuum tube. Twelve years passed before the superior bipolar junction transistor (BJT) was available for commercial use.

It was one step to have a laboratory transistor, but a long way from the production of reliable quantities with practical applications.

The Raytheon CK703 point-contact transistor was likely the first to be marketed. Raytheon's claimed first release in 1948 is just months after Bell Lab's announcement.

The Western Electric (Bell) M1752 was the first junction transistor available outside of the research lab, in 1951. It was an NPN grown-junction low-power AF transistor but a fault was soon apparent – the plastic encapsulation was not hermetic, so moisture ruined the transistor.

It took time to discover the acceptable characteristics and limitations of transistors, so some manufacturers tried to make tetrode and even pentode transistors.

Most started producing point-contact transistors, which at the time had better high-frequency behaviour than junction types. The junction transistor soon was superior in performance, simpler and more consistent in manufacture.

European companies also applied for licenses. Mullard/Philips especially affected Australia's

Left: Raytheon CK703 point-contact transistor, likely the first commercially available, in 1948. Raytheon went on to make the first ever mass-produced junction transistor, the CK722. Right: Bell Labs/Western Electric M1752. This NPN grown-junction low-power AF transistor was the first junction type obtainable outside a research lab, in 1951. Transistors were available for years before the first radio was available to the public.

Internal view of the ubiquitous Mullard/ Philips OC71 – still being used in do-it-yourself projects into the 1970s and 80s!

entry into transistor radio production, establishing local component production here. Early European transistor licensees included STC and GEC (UK). Both English firms' research labs were not far behind the Americans. For example, STC had a point-contact transistor in 1949. GEC's first transistor, the GET1, was in prototype at this time.

The first commercial junction transistors were primitive by modern standards, with a maximum collector-emitter voltage of 6V and collector current of just a few milliamps. Particularly notable was the Raytheon's first mass-produced transistor, the CK722, which made solid-state electronics affordable to the amateur constructor. Improved types were soon developed, extending frequency response, lowering noise levels, and increasing power dissipation.

The earliest transistors were made from germanium, a metallic semiconductor. However it was known that silicon offered advantages in terms of breakdown voltage and power handling ability. Silicon was more difficult to refine because of its higher melting point but by 1955, the first silicon transistors were commercially available. Texas Instruments played a leading part in the early development of this technology.

Texas Instruments 900 series were the first silicon transistors on the market, in 1955. They included types 903, 904, and 905, NPN grown-junction types, used as RF amplifiers. By 1956, Texas Instruments manufactured the 2S series of transistors, using the standard TO-5 metal case.

Six years after Bell's initial announcement, on October 18, 1954, the Regency division of I.D.E.A. announced the world's first consumer transistor radio, the TR-1.

Regency had finally overcome hurdles like a fifty percent board failure rate.

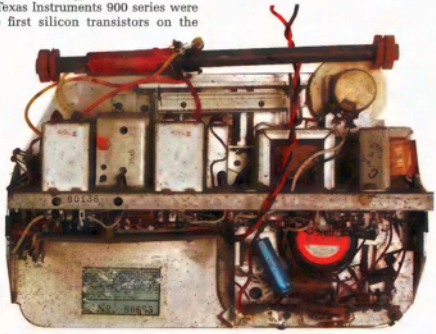
Two of the world's first Regency transistor radios (circa 1954-5) with a 1956 black Zenith Royal 500.

The author's experience suggests that at the time major problems would include mastering the dip-soldering, ensuring all the components had a secure solder joint after a single fast dip in the solder bath. Inferior plating on the component leads and circuit board, air bubbles plus component overheating were some of the early dip-solder challenges.

The Regency TR-1 pocket radio was announced for sale on November 1 1954, at US$49.95, just in time for Christmas. I.D.E.A. stated before the Regency's release: "the success of the Regency is due, in large measure, to a high-performance, low-cost transistor developed by Texas Instruments... wherein power gains of 34 decibels and 40 decibels are achieved in intermediate frequency and audio stages respectively. Only four transistors are used in the entire radio...one transistor as a combination mixer-oscillator, two as intermediate frequency amplifier and one as an audio amplifier. A germanium diode is employed as a detector."

Texas Instruments enthusiastically described the Regency: "The 'pocket size' is a significant achievement, since it includes a high fidelity, high volume speaker and a single battery supply as well as all associated receiver circuit components...Audio volume fidelity and reception range are the equal of or superior to that of the small vacuum tube-equipped portable radios."

Many component manufacturers contributed to the Regency's compact design with semiautomatic production of the final assembly, including



Leading brand Transistor Radios like this Philips model 198 were manufactured in valve radio plants. The factories and their design teams were geared to old techniques including extensive use of metal. Most early transistor radios therefore resembled their recent predecessors, with features like a metal chassis. The outside case of this Philips was pressed cardboard, though many early transistor radio cases were wood with a vinyl exterior.

Two AWA radios (left and centre) with an Elvis record of the era. The gold radio (centre) was designed for ladies. This model was identical with the brown leather finished model, but had a slimmer profile. This was easily achieved, as there was plenty of free space inside. Why the other men's/family model was not as slim is a mystery. The transistor radio on the right is an AWA too, re-badged as Westinghouse. Re-badging was fairly common then and now, for example, K-Mart brand transistors.

dip-soldering of the printed circuit board assembly.

The Regency's performance was not startling. The momentous advantages were the first entry into solid-state, the size, plus a minuscule 4mA drain on the easily obtained 22.5V hearing aid battery, which delivered 20 to 30 hours of use.

The Regency was also one of the first radios since the twenties to re-introduce personal listening through an earpiece – great for listening in bed. They certainly were popular, with around 100,000 sold in the first year.

For their commitment, Texas Instruments produced nearly half a million transistors, constrained three million dollars of plant, lost over a million dollars, but laid the foundations as a leader in semiconductors.

TI's gamble paid off, recovering to make net sales of US $200 million in 1960. Much of TI's production was supplied to IBM, after the computer giant saw the benefits of solid state.

While the new solid-state components were called transistors, the public soon rather erroneously called their solid-state radios by the same name – "transistors" and later on, "trannies".

Mullard, an English tube manufacturer, became a wholly-owned subsidiary of the Dutch Philips company. They planned to convert Mullard into a semiconductor manufacturing plant. Their goal was to capture 95% of the European market and they did this within a few years. Mullard's OC series of transistors and OA family of diodes dominated Europe for about 20 years and were extensively used in Australia for decades.

Mullard developed a unique glass encapsulation, releasing three new alloy-junction transistors, the OC70, OC71 and OC72 in 1954. The OC71 glass case was painted black to avoid photoelectric effect. In fact, hobbyists in the 60s scratched off the paint to make it photosensitive for applications like a flash slave.

Mullard added an aluminium can over the OC71 glass tube, to make the higher power OC72. This transistor was rated at 100mw power total, when an external fin was pushed on to make an extra heatsink. Matched pairs of OC72 transistors were sold for push-pull audio, typically offering 200mW audio output.

Millions of the OC series of transistors were used in Europe for a period of almost 20 years. Mullard issued many other germanium and silicon diodes and junction transistors of all types in this encapsulation.

Philips produced technically superior transistor radios, however their primary interest was transistor and component research and production.

As a consequence, Philips led in the supply of components and research, strongly supported by numerous books and technical leaflets they created on their latest products. This information flow included complete circuits for manufacturers to adapt, so they would use more Philips/Mullard components.

Japan had well-developed research, establishing them as leaders in the development of transistor radios, however the Soviet Union appears to have lagged until the 1960s. Valves held on

In the 70s, some of the last Astor radios were pocket size.

Novelty Radios became popular in the 70s. National bought out a 70s zany radio, the Toot-a-loop (left), but named it the Wrist Twist here. The right rear unit (with balancing balls) is a JVC brand. National made many novel types, like the three in the right foreground. Bright colours, especially oranges and reds, were in vogue at the time.

tenaciously. In 1957 a Japanese tiny three-valve unit sold in US stores for just ten dollars. To minimise current drain, there was no audio stage, just an earpiece.

A Japanese tape recorder and home appliance manufacturer called Tokyo Tsushin Kogyo saw the possibilities, but had difficulty with the $25,000 licence rights, due to their government's foreign exchange limitations. Approaches to the government authority were eventually successful and they joined the solid state fraternity. The company planned to release the world's first transistor radio, until the Regency beat them to the post.

Their first transistor radio, the TR-55, entered the Japanese market in August 1955, nine months after the Regency. When the TR-63 was ready to enter the US market in 1957, they realised their name was unpronounceable by Americans.

A new name was needed. The latin word 'sonus' meaning sound was promising and at the time bright young Japanese men were referred to as 'sonny boys', so the name SONY was established as their logo. In January 1957, the overall company name was changed to Sony.

The Sony TR-63 was slightly smaller than the Regency, but didn't fit the even smaller Japanese shirt pockets, so Sony had a batch of shirts made for their local sales team to demonstrate the pocketability.

Transistor radios were made in all shapes, from spray cans to Vegemite, Big M and promotional items. 'Linda' dolls were made by a number of companies in Asia. The tuning and volume controls were not conventional.

The '70s HMV Capri, as new in box.

Two features stood out – an ultra-miniature tuning capacitor and a 9V battery that would become the standard for mini transistor radios.

By 1958/9, over 30 Japanese brands were sold in USA. A staggering six million were sold in the US during 1959, becoming Japan's second largest source of US dollars, at $US62 million!

By the 60s, Japan's world-wide electronics revolution was in full swing. While they offered cheap compacts, their top shelf transistor radios boasted fine build quality, excellent performance, lavish use of chrome on the exterior case and superb fine-grain, gloss leather outer cases.

Japanese radios were extensively sold on the international market, with National and Sony dominating duty-free stores in every exotic tourist port of the globe.

Europe and other manufacturing countries also commenced producing transistor radios. The British protectorate of Hong Kong soon manufacturing budget quality, small radios. Like many products from this duty-free country, early designs were British. The quality did not compare to the world's best, but the price was right.

Few could have predicted the transistor radio's dramatic changes to our culture. When valve radios were the only choice, every home had a mantel or radiogram to bring news and older entertainers into lounge rooms and kitchens.

Parents placed high value on the family radio and its programming, so children often had restricted access. As a consequence, they mainly heard the old time music their parents liked.

Once affordable transistor radios became available, nearly every teenager wanted one. Soon they were able to play their style of music anywhere they liked, from the bedroom to the beach.

It opened a whole new world of independence for the young and motivated the success of rising stars like Elvis Presley, Bill Haley, Lesley Gore, the Beach Boys, Little Eva, Fats Domino, Roy Orbison and many more.

Most Australian and overseas manufacturers could see transistor radios were inevitably destined to replace power ravenous valves, but had considerable difficulty with the transition.

The dilemma – for decades they produced large heavy radios with excellent reception but now an upstart was on the scene.

Kriesler transistor radios, 1960s.

Picture massive Australian manufacturing plants geared to produce valve radios. Each had ageing valve designers, hundreds of employees and giant metal presses to stamp chassis. Early transistors did not perform well, so it's therefore easy to understand Australian manufacturers' reluctance to dive into this newfangled invention.

Possible outcomes included losing loyal customers dissatisfied with the performance of transistor radios. Perhaps the greatest problems were that the designers had to revise most of their electronic theory. Also significant sections of their plant and production lines were totally unsuited to transistor radio assembly.

There was a human element too – it was becoming obvious the simpler automated construction of small transistor radios and outsourcing of plastic mouldings would lead to the sacking of hundreds of people. Many had developed strong friendships in the organisations and had recently survived a war.

All these factors led to many Australian radio brands producing valve equipment into the early 70s, especially television sets.

Australian car radio manufacturers especially could see the lower current drain benefits, so until transistors approached the quality of valves, they released hybrids – radios with a mix of valves and transistors. PYE even produced a radiogram called the 'Transista' but few consumers realised only the tuner was solid-state!

The levers that finally forced local manufacturers to make the full transition were competition from imported all-transistor radios, the tiny power drain and the fear of being the last cab off the rank.

To avoid customer rejection and to utilise existing production facilities, many of Australia's first transistor radios looked remarkably similar to their last valve version. Not only were the cases very similar, but there was a metal chassis! Naturally most were quite heavy.

An example is the HMV J4-17 Rangemaster, released in 1961 priced at 30 pounds, nine shillings. They have great similarity to the valve HMV 65-54 and the size and weight made them a portable mantel. The sound was acceptable, though servicing can be difficult, as the five-inch loudspeaker

The Zenith Transoceanic RD7000 multiband was the king of receivers for many years. Features included an array of huge antennas, log platform, map light and international time calculators.

was mounted first, then layers of parts added on top.

Another problem with most transistor radios was the battery cost up to thirteen shillings and there was no provision for a mains power supply.

Remarkably, there is little evidence of the first fully Australian-built all-transistor radio. Local magazines proclaimed overseas advances, but little was said of local progress, perhaps as Australia was behind overseas developments. Further, the availability of fully imported plus locally sub-assembled radios blurred the event.

In radio circles, the general opinion is a number of Australia's leading brands released all-transistor radios about the same time, around 1958. John Sheard, who was a radio retailer in Mt Gambier from 1954 to 1989, recalls the first fully Australian-made transistor radio he saw was PYE. Another early arrival at his store was the American designed Admiral, though it had many US parts.

Around 1960, John also recalls testing a Stromberg Carlson model with optional solar cells on the top. He found it played perfectly with good volume in the sun without batteries.

Philips manufactured solid-state components at Hendon, South Australia, with transistor types like OC71 sold in valve boxes (see photo). Philips had plants around Australia. One ex-employee laments: "Even though they made resistors and capacitors at Hendon with the radio/TV manufacturing line in the adjacent building, we could not access components until they had been shipped to the Sydney (or Melb.) warehouse. That's why many chassis didn't have a single Philips component".

Other Australian component manufacturers designed new components for transistors as well. Companies like Rola, EMI and MSP, accepted the challenge of developing compact loudspeakers with high efficiency and acceptable frequency range.

In addition, all other components like tuning gangs, capacitors and resistors were miniaturised. Nearly every component was available from Australian production, unlike today.

Choice magazine saw the growing popularity of these new portables, so they reviewed transistor radios available in 1961 and again in 1972. Their tests were authoritative, as technicians were engaged to properly test performance.

Choice noted in 1961 that their initial survey revealed over 80 different models, but later that year they found only about 30 were still available, due to a contraction or recession in the retail market.

ACA's tests in 1961 resulted in recommending the Philips model 200 and the Westinghouse model W812P. They concluded the Westinghouse was probably a rebadged AWA 208P, which they had not included in the tests, so it's likely the AWA would have shared the winners dais too.

Tests made in 1972 showed radios in the $25 to $31 range were winners, including the HMV Capri, Kriesler and Thorn Graduate.

As test bench results are more discriminating than actual listening tests, Choice rightly suggested the buyer could test transistor radios themselves in a store, to make their own decision. Nearly all transistor radios received local stations reasonably well, so people often chose attractive models. As a consequence, models like the AWA Transistor Seven sold for many years in large numbers.

Australia's transistor radio production had begun, leading to local production of nearly every type of entertainment unit and instigating immense changes in culture, employment and industry for decades to come. **SC**

More reading, sources and credits:

Kevin Poulter, (03) 9558 3652, email@radioworld.info

Web references are displayed at: www.radioworld.info, click on 'first transistor'

HRSA, Radio Waves, (03) 9539 1117, www.hrsa.asn.au

Chris Rogers, John Sheard, Tony Maher, Andrew Wylie (UK)

Foundations of Wireless 1958

Mullard Reference Manual of Transistor Circuits 1961

Choice Magazine 1961 and 1972

Radio and Television 1963

Mullard Data Book 1964-5

Philips Pocketbook 1969

Introduction to Electronics, Devices and Circuits 1982

Introductory DC/AC Electronics 1989

The Portable Radio in American Life 1991