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THE FUTURE OF QUANTUM COMPUTING

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A BRIEF HISTORY OF COMPUTING

Malcolm Hodgson and Christopher O'Flaherty,
BDO Financial Services Technology Junior Analysts

The logic behind modern day computers came from the early 1800's, and not for the purposes that we use them for today. Computers were created to solve an interesting number calculation crisis in the United State of America. In 1880, the American population had grown so much that it took over seven years for officials to calculate their census results. Of course, their numbers were now 7 years old and the population had changed significantly by the time they had their numbers.

In an effort to find a faster way of calculating large numbers, The Americans gave rise to punch-card based computers, these we so large, they had to be placed in their own rooms. This is very different to the word we live in today, where a computer that fits into the palm of a person's hand with more computing power than several of their clunky predecessors.

The following is a summarised history of the evolution of computers:[1]

- **1801:** A loom in France that uses punched wooden cards to automatically weave fabric designs is invented by Joseph Marie Jacquard, similar punch cards were used in the creation of the first computers
- Just over 20 years later in **1822**, Charles Babbage, an English mathematician, looks to steam power to create a calculating machine that would be able to compute tables of numbers. This was a failure and it took almost a century later for the world's first computer to come into existence.
- **1890:** Going back to the French loom punch cards, Herman Hollerith designs a punch card system following the 1880 American census debacle. Hollenrith's computer worked swimmingly, and he would later establish a computer company that we know today as IBM.
- **1936:** Alan Turing (inventor of the Turing machine) begins work of a universal machine which would be able to compute anything that is computable, more than just single sums and limited information. His ideas led to the central concept of the modern computer.
- A year later in **1937**, Physics Professor J.V. Atanasoff attempts to build the first computer that didn't have gears, cams, belts or shafts. 4 years later in 1941, The professor and one of his graduate students, Clifford Berry, design a computer that could solve 29 equations at the same time, marking the first time a computer was able to store information on its main memory.
- **1943-1944:** Considered the grandfather of digital computers, the Electronic Numerical Integrator and Calculator (ENIAC) is invented by Professors, John Mauchly and J. Presper Eckert. This mammoth machine filled a 20-foot by 40-foot room and had 18,000 vacuum tubes. 2 years later, the Professors are commissioned by the Census Bureau to build the first commercial computer for business and government applications: Universal Automatic Computer (UNIVAC).
- **1947** saw the end of the vacuum and the rise of the transistor, an electric switch with solid materials, invented by William Shockley, John Bardeen and Walter Brattain of Bell Laboratories.
- **1958:** Jack Kilby and Robert Noyce invent the integrated circuit, known to us as the computer chip. A huge stepping stone in the conception of the modern day computer. For his efforts, Kilby was awarded the Nobel Prize in Physics in 2000.
- **1964:** The general public is introduced to a machine that isn't just for scientists and mathematicians. Douglas Engelbart developed a prototype of the modern computer, with a mouse and a graphical user interface (GUI), that everyone could make use of.

[1] https://www.livescience.com/20718-computer-history.html

- **1971:** Computer memory evolved as Alan Shugart lead a team of IBM engineers to invent the "floppy disk," allowing data to be shared among different computers.
- **1973:** Researcher for Xerox, Robert Metcalfe, develops Ethernet, giving computers the ability to connect to each other and other hardware.
- Between **1974-1977**, a few personal computers are released to the general market, including Scelbi & Mark-8 Altair, IBM 5100, Radio Shack's TRS-80 and the Commodore PET.
- **1976:** Steve Jobs and Steve Wozniak start Apple Computers.
- We fast forward to **1985**, when Microsoft announces the release of Windows software.
- Five years later, in **1990**, Tim Berners-Lee, a researcher at CERN, the high-energy physics laboratory in Geneva, develops HyperText Markup Language (HTML), birthing the World Wide Web.
- **1994:** "Command & Conquer," "Alone in the Dark 2," "Theme Park," "Magic Carpet," "Descent" and "Little Big Adventure" are among the games to hit the market as PCs become gaming machines
- **1996:** Google is born. Sergey Brin and Larry Page develop the Google search engine at Stanford University, merely 24 years ago.
- **1999:** The term Wi-Fi becomes part of the computing language and users begin connecting to the Internet without wires.
- **2004:** Facebook is born.

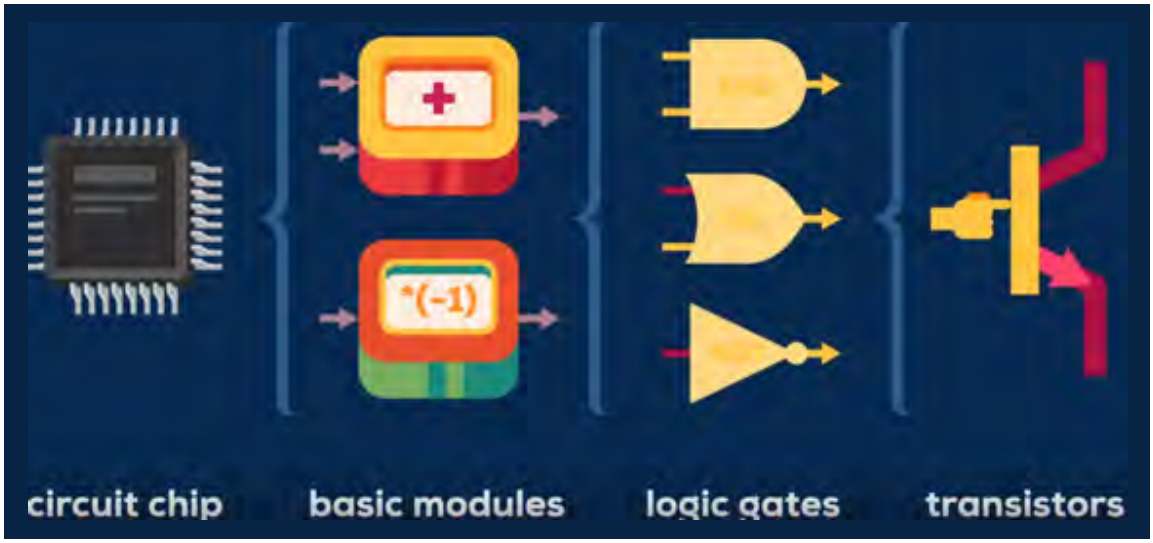
Today, we carry more computing power on our smartphones than was available in these early models. So, where to from here?

TRANSISTORS AND THEIR LIMITATIONS

Looking back at 1947, William Shockley, John Bardeen and Walter Brattain's invention of the transistor has long been one of the foundations of the modern computer. The invention of the transistor was an unprecedented development in the electronics industry. It marked the beginning of the current age in the electronics sector. After the transistor's invention, advances in technology became more frequent, the most notable of which was computer technology.

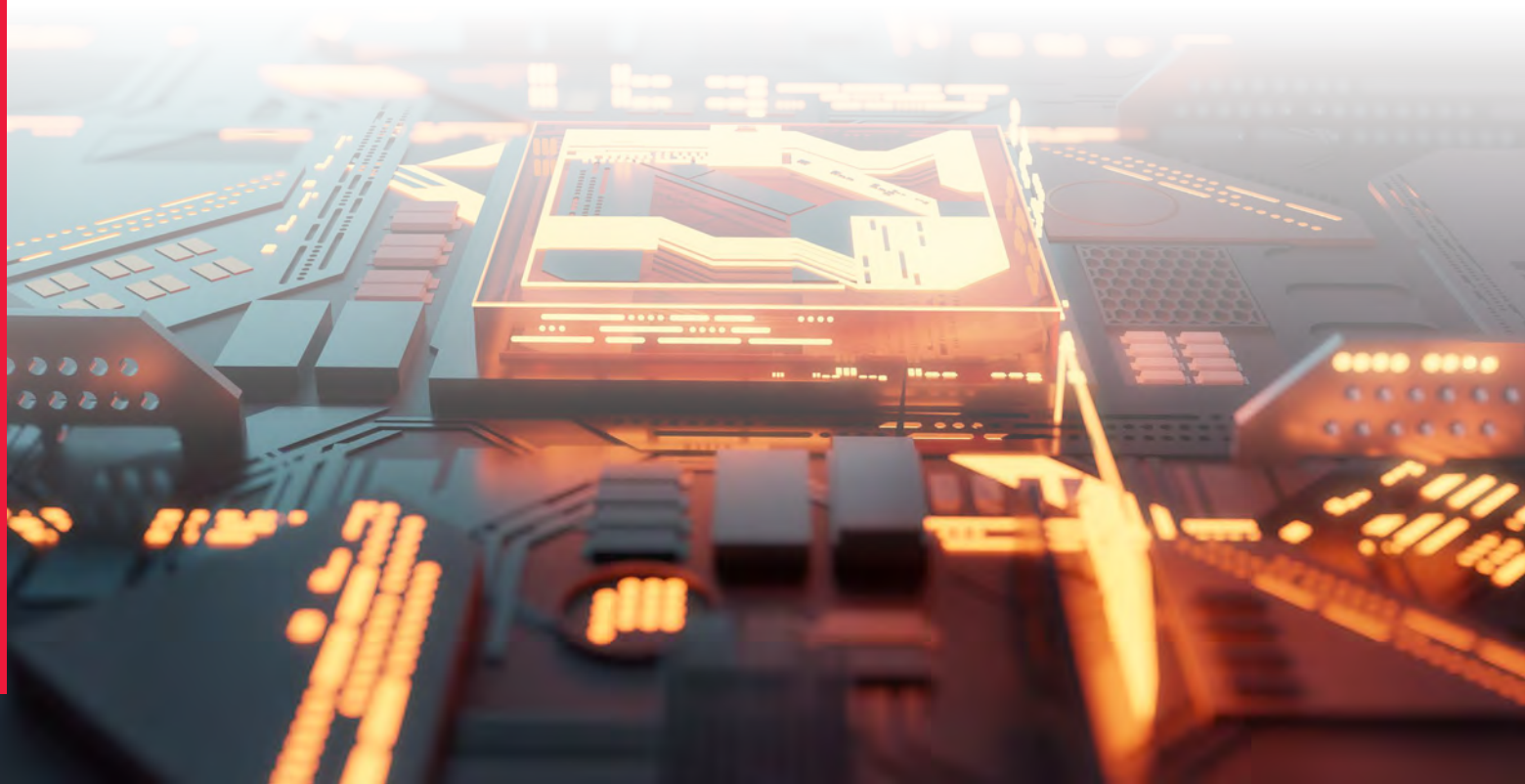
A transistor is an electronic device that works by controlling the flow of the electrical current. An example of a transistor is something combined in large numbers with microcircuits into a single circuit board and used in a computer.

Currently, a transistor is 8 times smaller than the HIV virus and 500 times smaller than a red blood cell.[2] Computing power as we know it today is fast approaching its peak. This is due to the fact that if one can no longer decrease the size of the transistors therefore, increasing the number of transistors, one cannot increase the processing power.



Source: https://www.youtube.com/watch?v=JhHMJCUmq28&t=54s

[2]https://www.borisinberlin.com/what-is-quantum-computers/



THE INTEGRATION OF MOORE'S LAW

"Moore's law is the observation that the number of transistors in a dense integrated circuit (IC) doubles about every two years." This observation is named after Gordon Moore, the co-founder of Fairchild Semiconductor and CEO and co-founder of tech company Intel.

The observation that Moore made is a projection of a historical trend that stemmed from an empirical relationship linked to gains from experience in production, and nothing at all to do with Physics.

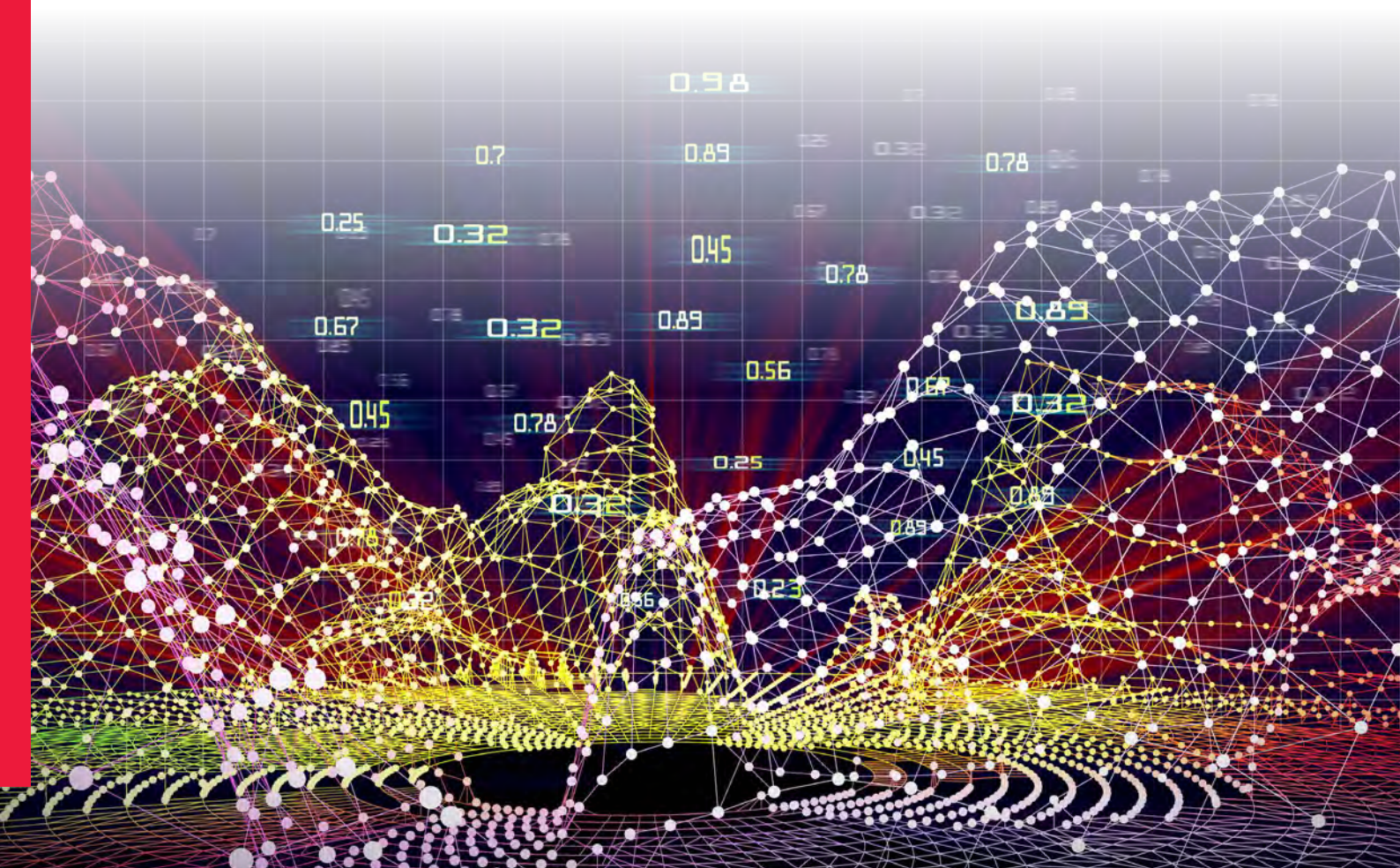
Moore's first observations were made in 1965 when he suggested that the number of components per integrated circuit, would double every year. He ascertained that this trend would hold for 10 years. In 1975, 10 years after he made his initial observation, he adjusted his initial forecast and suggested that the number of components per integrated circuit,[3] would now double every two years. This is what has become what we now call Moore's law.

The semiconductor industry has been using Moore's predictions to guide their planning and to set development targets. The law has facilitated advancements in digital electronics such as:

- The reduction in quality-adjusted microprocessor prices
- The increase in memory capacity (RAM and flash)
- The improvement of sensors
- The number and size of pixels in digital cameras

It has been reported that the development of IC fabrication processes has remained on par with Moore's law as of 2018, but when Moore's law will cease to apply is still unknown, as overall advancements in Microprocessors have slowed since 2010. As we look ahead to the years to come, new technologies need to be closer examined if we are too overcome the limitations of transistors. Technologies such as quantum computing.

[2]Moore, Gordon E. (1965-04-19). "Cramming more components onto integrated circuits" (PDF). intel.com. Electronics Magazine. Retrieved April 1, 2020



WHAT IS QUANTUM COMPUTING?

Quantum computing is the use of quantum-mechanical phenomena such as superposition and entanglement to perform computation.[4]

The fundamental difference between Quantum and normal computers is that while normal computers will still do day to day operations, Quantum computers are not likely to be in every household in the near future. Like the first computers, these will be used for specialised industries long before we expect them to hit electronics stores.

A Quantum computer operates by controlling the behaviour of electrons and photons. However, it does this in a way which is completely different to regular computers. A Quantum computer is NOT a more powerful version of a regular computer. Regular computers utilise binary logic, 1's and 0's. Quantum Computers however utilise what are known as Quantum bits, aka qubits. A fuzzy region is created wherein 1's and 0's are fluid and at the same time, the result can be either 1 or 0. This is known as Superposition.

Quantum computers possess the ability to achieve high levels of processing power, using the concept of superposition. Superposition is the physics principle and is one of three that make up the fundamentals of quantum computing. The second is 'Entanglement'. This is the idea that one is able to 'link' these qubits in order to exponentially harness their power'. The final physics principle is that of 'Interference' and this is very similar to that of what noise cancelling head phones use. It essentially cancels out the incoming sound waves through producing the inverse of those sound waves.

Let's use a quick example of cards. You have 4 cards, 3 are kings, 1 is a queen, all are face down, we need to find the queen. A normal computer would start at the first card, move onto the second and continue going until it found the queen. It would take a normal computer an average of 2.5 turns to find the queen. However, with a 2 qubit Quantum computer it would always get it on the first turn. Why? Every qubit that is entangled increases the processing power by 2^n where n is the number of qubits. Thus, in a two-bit Quantum computer you are able to see all 4 states at once.

Quantum Computing has the potential to move mountains in the technological landscape. As a game changing technology, it will result in many interesting solutions. Potential uses of Quantum Computing include[5]:

- Quantum encryption. This is already being tested by banks and other companies globally. There is potential to break types of encryption which have been deemed 'unbreakable' but also to create new encryption methods stronger than ever before.
- Quantum computing has the potential to transform healthcare. The design and analysis of molecules for drug development is a challenging problem today. Exactly describing and computing the particles in a molecule is a computationally difficult challenge. A Quantum computer operates utilising the same Quantum properties as the molecule it is trying to simulate. For this reason, breakthroughs in science and medicine are expected through quantum computing.
- The teleportation of information, without physical transmission, is too a possibility with quantum computing owing to entanglement. This is due to the fact that when something is changed in one particle, it can impact another and thus a channel for teleportation is created. This could result in a future Quantum internet.[6]

[4]The National Academies of Sciences, Engineering, and Medicine (2019). Grumbling, Emily; Horowitz, Mark (eds.). Quantum Computing: Progress and Prospects (2018). Washington, DC: National Academies Press.
[5]https://www.google.co.za/amp/s/www.predictiveanalyticstoday.com/what-is-quantum-computing/amp/
[6]https://www.ted.com/talks/shohini_ghose_a_beginner_s_guide_to_quantum_computing?language=en

- The combination of Artificial Intelligence and Quantum Computing will lead to what is known as the quantum advantage. This is where AI will be enabled to develop quicker and thus could lead to the Singularity.
- Advances in complex modelling including weather forecasts and traffic flows to high density cities.[7]

It is evident that Quantum Computers have the potential to change life as we know it, however, what is the current state of Quantum Computing?

Key technological giants, including Google and IBM, have taken strides into achieving Quantum supremacy wherein these giants have started to use and apply the technology. However, a number of other companies have started to utilise quantum computing technology including the likes of:

- Accenture
- Alibaba
- Amazon
- AT&T
- Atos Quantum
- Baidu
- Intel
- Microsoft

You can read more about how these companies are utilising quantum computing here.[8]

Quantum computing will change life as we know it in various ways. It will change numerous fields and will enable great technological leaps. The combination of quantum computing and other emerging technologies present unlimited possibilities. It is impossible to see what the future holds, but with the rise of the fourth industrial revolution and emerging technologies changing life as we know it, it is exciting.

[7]https://www.forbes.com/sites/bernardmarr/2020/08/17/what-is-quantum-supremacy-and-quantum-computing-and-how-excited-should-we-be/amp/
[8]https://www.analyticsinsight.net/top-10-quantum-computing-companies-2020/

WE TAKE IT PERSONALLY.
FOR FURTHER INFORMATION, CONTACT:

CHRISTOPHER O'FLAHERTY
BDO Financial Services Technology Junior Analyst
coflaherty@bdo.co.za

MALCOLM HODGSON
BDO Financial Services Technology Junior Analyst
mhodgson@bdo.co.za

NEVELLAN MOODLEY
Head of BDO Financial Services Technology
nmoodley@bdo.co.za

/BDOSouthAfrica


/bdoafrica


/bdo_sa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