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SAND2018-9720 C
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IEEE Quantum Computing Summit

Erik P. DeBenedictis[1, 2]
[1]IEEE Rebooting Computing Initiative
[2]Center for Computing Research, Sandia

Introductions

- **Bill Tonti, IEEE Future Directions Committee**
  - **Bill proposed the activity and is responsible for funding**
- **Travis Humble, Oak Ridge**
- **Scott Holmes, Booz-Allen Hamilton**
  - **Technical Organizers**
- **Terence Martinez, IEEE Future Directions Committee**
  - **Meeting arrangements**
- **Lee Gomes**
  - **Writer**

- **Everybody else**
  - **Let's go around the room and have everybody state their name and affiliation**

Outline

- **Context, goals, objectives, and resources**
- **Quantum Computer Scale up**
- **Schedule of the Meeting**

Summit Overview

Context

- Quantum Computing is getting increased attention
- IEEE seems expected to play role in quantum computing
  - But IEEE is a blank slate right now; no commitments to anybody
- Objectives
  - Propose a position for IEEE on what's realistic
  - Propose future activities for IEEE
  - Propose a follow-on to this summit; we have a budget

Format of Summit

Guided working group

- Not a meeting for participants to present their work
- Five plenary presentations to provide context

Three 2-hour periods of three tracks, total 9 sessions

- Each group discusses one issue per session
- Create a couple PowerPoint slides and out brief
- Create some notes for Lee Gomes
- We'll jointly organize sessions so common interests are sequential in time (hardware/software/etc.)

Participants don't have to follow the issues as defined

Google Doc

The agenda is an editable Google Doc

- Google Docs is a double-edged sword
- https://docs.google.com/document/d/1gwQIhNbkMGiZEyHSmfimcYQsrWdY2c_Ly3uMP3b0yGQ/edit

Erik DeBenedictis has a directory with some files

- http://www.debenedictis.org/erik/qc-summit/
- If you forget the Google Docs link, it is in agenda.pdf in the directory

We're not going to use the Google Doc for much longer

Additional Logistics

A day-and-a-half

- All day Thursday; until 2 PM Friday
- I’m not leaving until later; could continue

Lunch and break provided

- Dinner on your own (but we may organize on the fly)

Lee Gomes will create the whitepaper

- The group will review the whitepaper and fix it or supply additional content as needed

Erik's View on Type of Things IEEE Can Do; Debate if you Disagree

IEEE ought to be an honest broker, neutral on issues where members compete

- IEEE should have no opinion on which qubit is better

IEEE can have opinions on some issues

- Examples: Ethical conduct awareness, blockchain

IEEE can offer its traditional services

- Conferences and publications on quantum engineering

IEEE Standards Organization

- IEEE Standards are ways companies can communicate with some legal implications
- Terminology, metrics, etc.

Quantum Computing or QIS, etc.?

Academic communities embrace the following hierarchy

- Quantum information sciences, comprised of
  - Quantum computing
  - Quantum communications
  - Quantum Sensors
- Post Quantum Cryptology

As far as I can tell…

- IEEE will cover it all at some point
- Quantum computing is in-your-face and urgent
- This group can issue a finding to rescope (question 10)

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Classical and Quantum Scale Up I

Top level issue (my view)

- The hype around Moore's law is amplifying hype about quantum computers
- I believe "hype control" will be the top-level contribution for IEEE

Technical origin and solution

- Moore's law doesn't apply to all integrated circuits, just ones that have been carefully designed to scale
- Qubits won't scale until one is carefully designed so it does
- Problem is that society jumps over the hard work

Classical and Quantum Scale Up II

A little more detail

- Moore's wrote his famous paper after industry redesigned one form of integrated circuit so it scaled
- Forget "is Moore's law ending?"; the first integrated circuit was bipolar and stopped scaling long ago
- Other people figured out how to make MOS, FinFET, etc. scale, but not GaAs

Quantum computers

- We've been making scalable device families for years; so why not a scalable qubit?

Quantum Computer Scale Up I

Classical

Quantum

Fragile structure in the third dimension, scaling probably not possible

"Flying wire" integrated circuit

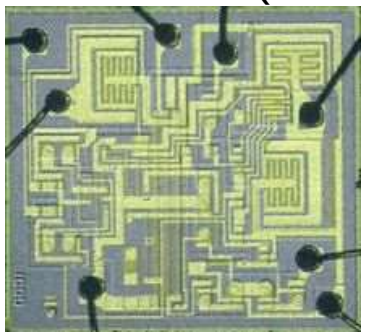
http://www.computerhistory.org/revolution/digital-logic/12/276/1417

Quantum "chandelier"

https://spectrum.ieee.org/computing/hardware/europe-will-spend-1-billion-to-turn-quantum-physics-into-quantum-technology.

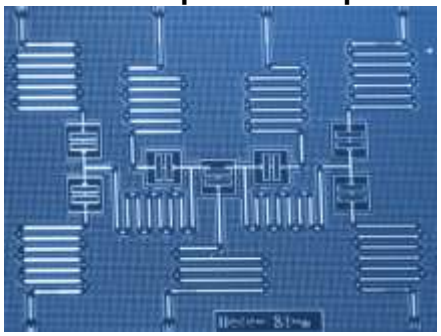
Solid-state structure, except bonding pads, probably possible

555 Timer (1971)



https://en.wikipedia.org/wiki/555_timer_IC

IBM 7 qubit chip



https://spectrum.ieee.org/tech-talk/computing/hardware/tiny-quantum-computer-simulates-big-molecules

Note: This is at the bottom of a "chandelier"

Quantum Computer Scale Up II

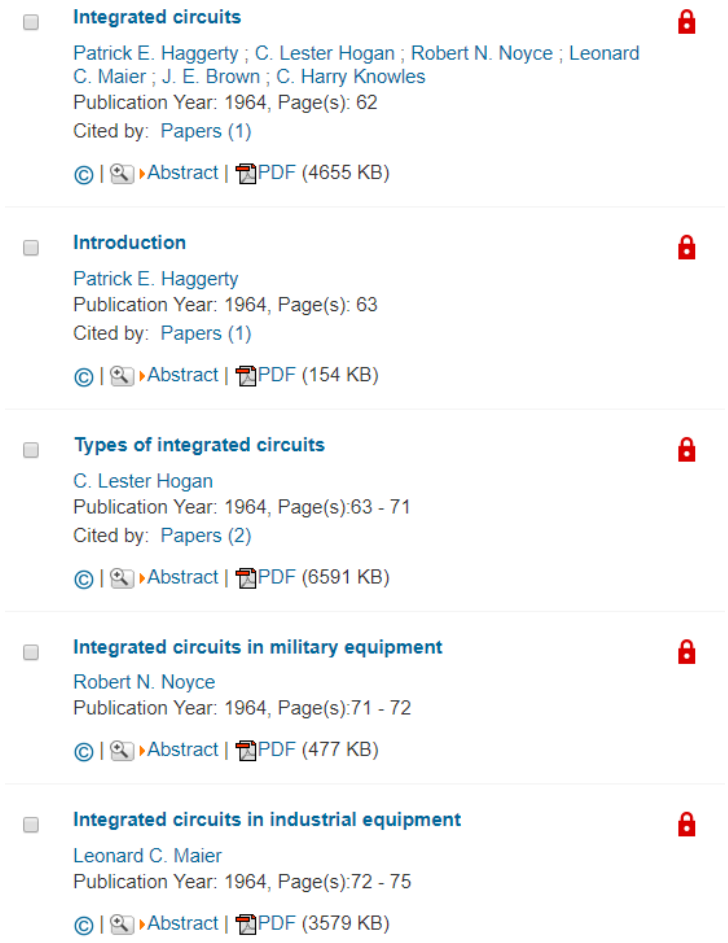
From https://www.nextbigfuture.com/2018/02/ibm-doubling-qubits-every-8-months-and-ecommerce-cryptography-at-risk-in-7-15-years.html

First Example of Scaling

- The integrated circuit Nobel prize was for TI “flying wire” integrated circuit, which wouldn’t scale physically due to wiring in the third dimension
- The “planar” integrated circuit eventually scaled, but only after electrical design advances like isolation wells and insulating layers
- Materials defects limit scaling of bipolar and MOS, but it was not known at the beginning that materials defects would be worse in bipolar

A Year Before Moore's Paper

- 10 articles in IEEE Spectrum special issue June 1964 →
- Moore's paper 1965
- The industry was reinvesting profits from improving avionics from discrete transistors to precursors to integrated circuits
- Is this the next few years of quantum computing?



Integrated circuits
Patrick E. Haggerty ; C. Lester Hogan ; Robert N. Noyce ; Leonard C. Maier ; J. E. Brown ; C. Harry Knowles
Publication Year: 1964, Page(s): 62
Cited by: Papers (1)
© | Abstract | PDF (4655 KB)

Introduction
Patrick E. Haggerty
Publication Year: 1964, Page(s): 63
Cited by: Papers (1)
© | Abstract | PDF (154 KB)

Types of integrated circuits
C. Lester Hogan
Publication Year: 1964, Page(s):63 - 71
Cited by: Papers (2)
© | Abstract | PDF (6591 KB)

Integrated circuits in military equipment
Robert N. Noyce
Publication Year: 1964, Page(s):71 - 72
© | Abstract | PDF (477 KB)

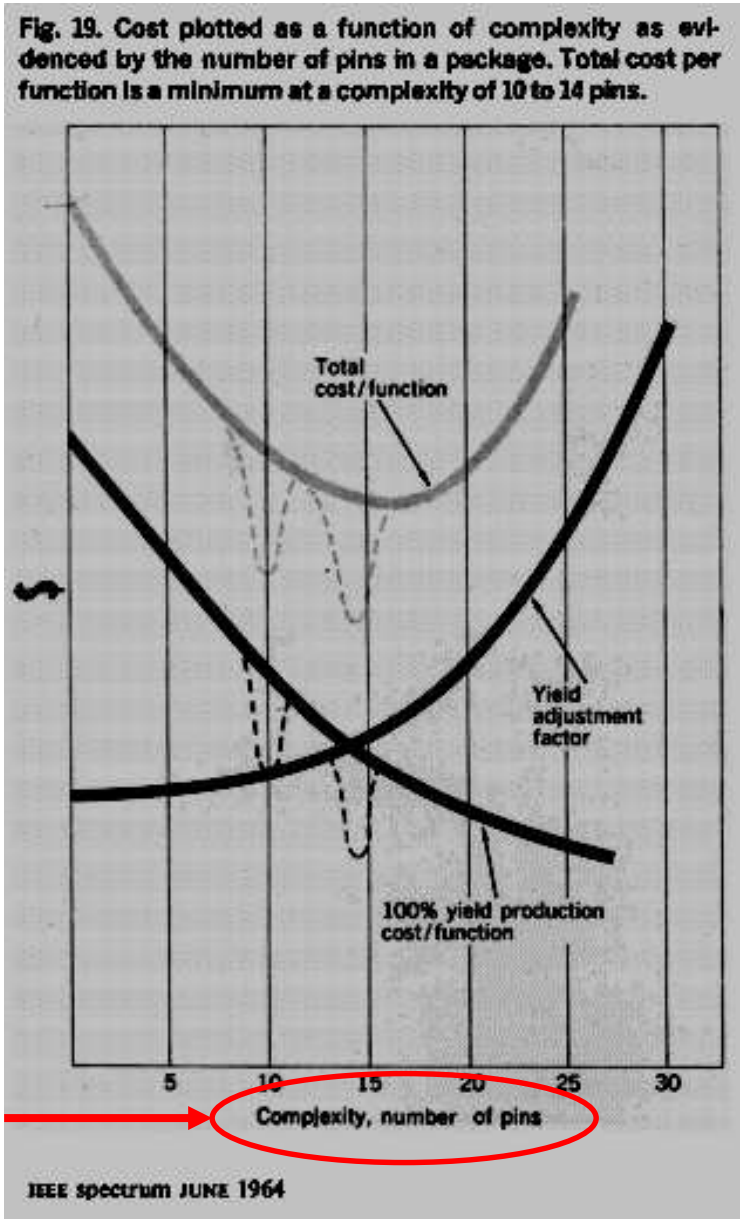
Integrated circuits in industrial equipment
Leonard C. Maier
Publication Year: 1964, Page(s):72 - 75
© | Abstract | PDF (3579 KB)

Pre Gordon Moore

Before Moore's contribution

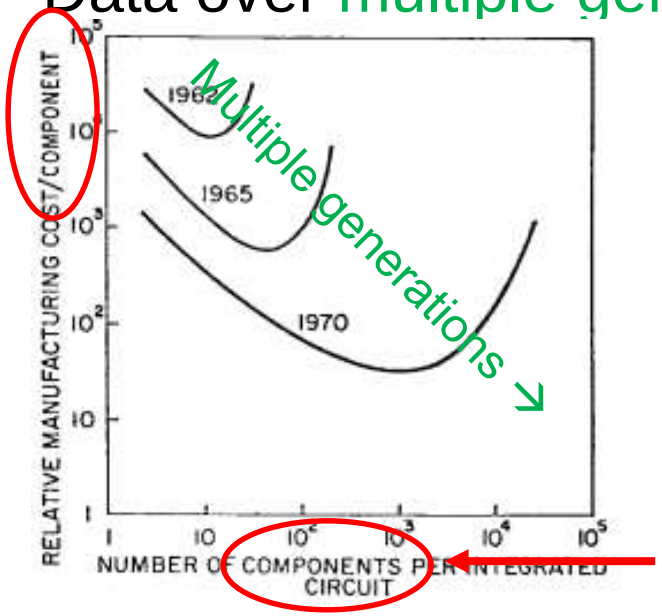
- Industry worked hard on improving integrated circuits so they scaled
- However, they didn't know they'd achieved a milestone because scalability had not been invented as a goal
- Note horizontal axis is number of pins

Complexity, number of pins

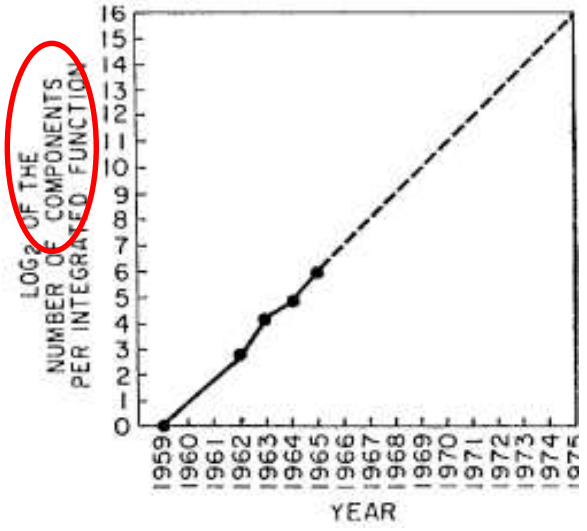


Gordon Moore's Contribution I

- Assessed cost per component given reliability, material (silicon), yield, complexity, die size, interconnection space, heat, speed, power per unit area, design automation, linear, RF
- Data over multiple generations and extrapolated



Number of components



Moore, Gordon E. "Cramming more components onto integrated circuits. Electronics 38 (8): 114–117." (1965).

Gordon Moore’s Contribution II

Functional complexity evolves from

- Pins
- Components
- Next is quantum speedup

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Schedule – Actual

- Thursday 8:30 AM Intro talk – Erik DeBenedictis
  - http://www.debenedictis.org/erik/qc-summit/erik-intro.pdf
- 9:15 AM Technical vision talk – Norbert Linke, hardware/physics
  - http://www.debenedictis.org/erik/qc-summit/NML_talk_GATech_IEEE_Summit_compressed.pdf
- 10:15 AM Technical vision talk – Andrew Sornborger, applications
  - http://www.debenedictis.org/erik/qc-summit/IEEEQuantCompSummitATS.pdf
- 11:00 AM Discussed deleting the proposed schedule and having an ongoing discussion group – passed by show of hands
- Noon: lunch
- 1:00 PM Continue discussion group (until 5:00 PM)
- 6:30 PM Two groups went to dinner
- Friday 8:30 AM Benchmarking discussion
- Noon: lunch
- 1:00 PM Continue discussion group (broke up 3:30 PM +/-)

Picture of Meeting Room