Quantum Circuits for Superconducting Digital Computing

Berkeley DEEP TECH Innovation Lab

Our Rapid Single-Flux Quantum (RSFQ) Multi-Output Toggle Flip-Flop (TFF) is an innovative circuit design for superconducting digital computing, enabling **area-efficient designs with reduced power and latency**.

- **Reduces** the number of **JJs** needed by **40-70%.**
- **Cuts power** consumption up to **70%.**
- **Lowers delay** up to **64%** compared to traditional designs

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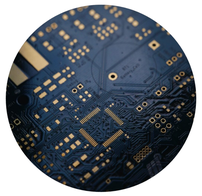


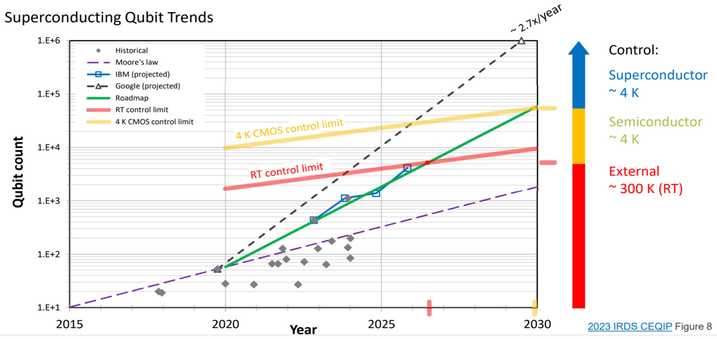
- **Applications:** Quantum computing, high-speed digital circuits, cryo-sensors, HPC accelerators, AI/ML accelerators and datacenters.
- **Why We Need It:** This TFF reduces the need for multiple cells in circuits, solving challenges of inefficiency and scaling in traditional RSFQ architectures.

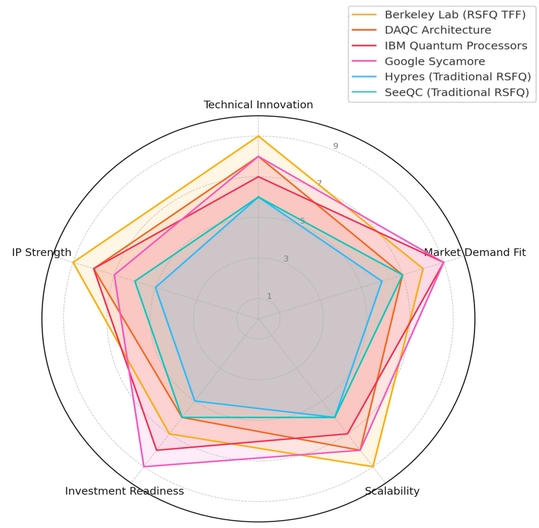
Key Market	Key Actors	Current Actions/Focus	Positioning & Potential
Quantum Computing	IBM, Google, D-Wave	Developing superconducting qubits, advancing quantum computing platforms.	Strong Growth Potential
High-Performance Computing (HPC)	NVIDIA, Intel, Cray	Investing in energy-efficient processing units for AI and data-intensive tasks.	High Demand
Cryo-Sensors	Superconductor Technologies Inc., LUX	Innovating in superconducting sensor applications for medical and scientific use.	Steady Growth
Datacenters	Google, Microsoft, Amazon Web Services	Exploring energy-saving technologies for next-gen data centers.	High Impact Potential

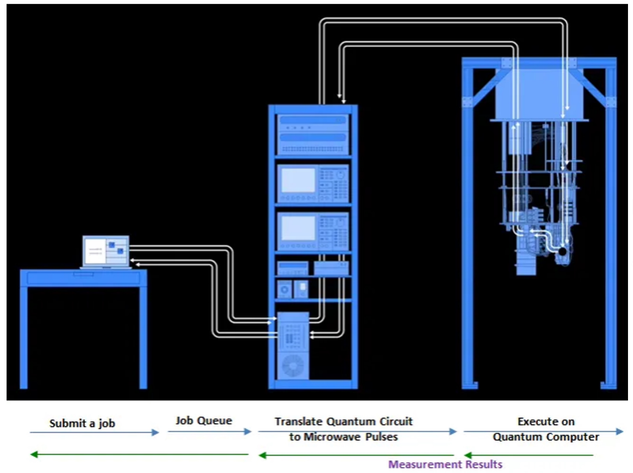
Competing Solution	Advantages	Limitations
Traditional RSFQ	Established, scalable	Limited to two outputs, requiring additional cells for scaling, higher latency
CMOS-based designs	Widely adopted, versatile	Slower, power-hungry, unsuitable for cryo
Adiabatic Quantum-Flux-Parametron (AQFP)	Energy-efficient in theory	Immature, high tuning complexity

A Promising Alternative to CMOS - Reduce Operational Cost + Enhance Error Correction

How We Outperform Traditional and Emerging Competitors:







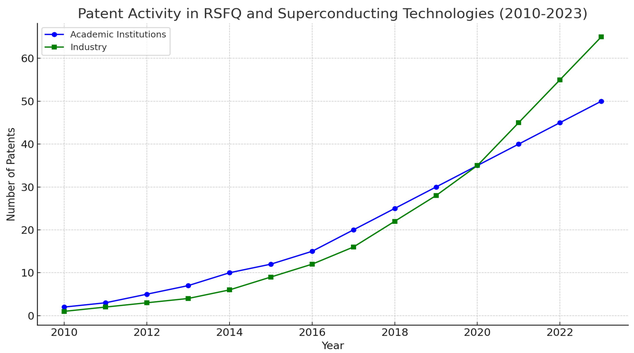
SFQ based quantum control and readout will greatly improve latency,
reduce the I/O counts, cost and scalability.

Hybrid Classical-Quantum Integration

Advantages of Superconducting Technology:

- Compatibility in operating temperature
- Compatibility in energy level
- Compatibility in materials and devices

Patent activity indicates a surge in RSFQ and TFF innovations:



- **Velocity:** Increasing filings globally since 2018, focused on scalability and power efficiency.
- **Actors:** Led by research institutions (Berkeley, MIT) and corporations (IBM, Northrop Grumman).
- **Technology Maturity:** Early-stage, with proof-of-concept demonstrated.

Paving the Way for Power-Efficient, Low-Latency Superconducting Solutions of Tomorrow

Adoption Timeline:

- **1–3 Years:** AI/ML accelerators
- **2–5 years**: Niche applications in quantum computing and cryo-sensors.
- **5–10 years**: Expansion into datacenters and HPC.
- **10+ years**: Mainstream adoption as RSFQ matures further.