

# iQuHACK 2026 - Superquantum Track

## Team: The Q-Factor

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### Overview

The goal was to compile quantum unitaries into efficient Clifford+T circuits. Non-Clifford gates (T gates) are expensive in fault-tolerant quantum computing, so minimizing T-count while maintaining accuracy was the key challenge. We used a mix of algebraic insight, KAK decomposition, and gridsynth approximation to achieve competitive results across all 11 challenges.

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### Challenge 1: Controlled-Y Gate

This was the warm-up to verify our submission pipeline worked. We used the identity  $Y = SXS^\dagger$  to express Controlled-Y in terms of Controlled-X (CNOT) with S gates on the target qubit. Since  $S = T^2$ , this gives an exact Clifford+T implementation with just a few T gates.

### Challenge 2: Controlled-Ry( $\pi/7$ )

A controlled rotation by an irrational angle. We decomposed it as a controlled-Rz sandwiched between basis changes. The key was isolating the control structure so only one rotation needed gridsynth approximation. We searched for epsilon sweet spots to minimize T-count while hitting the error target.

### Challenge 3: $\exp(i\pi/7 \cdot ZZ)$

The ZZ interaction is diagonal in the computational basis. We used the standard CNOT to compute parity, apply Rz on the parity qubit, then CNOT to uncompute. This "CNOT-phase-CNOT" pattern is compact and only requires synthesizing one Rz rotation.

### Challenge 4: $\exp(i\pi/7 \cdot (XX + YY))$

The XY interaction has a known structure related to partial SWAP. We decomposed it as CNOT → Controlled-Rz → CNOT → single-qubit corrections. Recognizing this algebraic structure meant we only needed to synthesize one non-trivial angle ( $2\pi/7$ ) rather than treating it as a generic 2-qubit gate.

### Challenge 5: $\exp(i\pi/4 \cdot (XX + YY + ZZ))$

The full Heisenberg interaction with a special angle. The key insight is  $XX + YY + ZZ = 2 \cdot \text{SWAP} - I$ . With the  $\pi/4$  coefficient, this becomes related to  $\sqrt{\text{SWAP}}$ , which is nearly Clifford. This gave us a very low T-count since the structure is almost exact.

### **Challenge 6: $\exp(i\pi/7 \cdot (XX + ZI + IZ))$**

The transverse field Ising model. We avoided Trotter decomposition (which adds discretization error) and used exact KAK decomposition instead. This gave us 10 non-Clifford rotations. We then searched epsilon values systematically and found spots where gridsynth errors across rotations canceled out. The result was T=1140 with error  $3 \times 10^{-11}$ , beating the competition by 10,000× on error.

### **Challenge 7: State Preparation**

Prepare a random 2-qubit state from  $|00\rangle$ . We used Qiskit's state preparation decomposition which gives 1 CNOT + 6 rotations. The key insight is we only need  $U|00\rangle = \text{target}$ , not a full unitary. With the 10,000 gate budget, we pushed epsilon to  $2 \times 10^{-9}$  and achieved precise results with only 1,600 gates.

### **Challenge 8: 2-Qubit QFT**

This was an exact synthesis problem, not an approximation problem.  $\text{QFT}_2$  decomposes as  $H \rightarrow \text{Controlled-S} \rightarrow H \rightarrow \text{SWAP}$ . The Controlled-S gate needs just 3 T gates:  $T(\text{ctrl}) \rightarrow \text{CNOT} \rightarrow T^\dagger(\text{tgt}) \rightarrow \text{CNOT} \rightarrow T(\text{tgt})$ . Total: 3 T gates with zero error.

### **Challenge 9: Structured Unitary**

The "figure out the structure" challenge. We identified this matrix as a controlled operation conjugated by Hadamard:  $(H^{\otimes 2}) \cdot \text{Controlled-U} \cdot (H^{\otimes 2})$ . Recognizing this structure helped us decompose the inner controlled operation efficiently.

### **Challenge 10: Random Unitary**

No exploitable structure here since the unitary is randomly generated. We tried several approaches: naive transpilation left generic single-qubit gates (not true Clifford+T), Solovay-Kitaev worked but produced very deep T-heavy circuits, and manual Weyl/KAK + gridsynth was accurate but overly complex. Our final approach used the Qiskit gridsynth plugin which provides built-in optimal Clifford+T synthesis with error control. The result was 2043 T-gates with 1e-11 norm distance.

### **Challenge 11: 4-Qubit Diagonal**

All phases were multiples of  $\pi/4$ , which means exact Clifford+T synthesis is possible. We used phase polynomial decomposition from the workshop, ending up with 3 T-gates in total. We used RMSynth for this challenge, to reduce the number of T-gates in our circuit!