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Master Thesis for a double degree program in:
Nanotechnologies for ICTs and Quantum Devices

Superconducting circuit for parametric coupling: development and characterization of a Josephson Parametric Converter

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This thesis presents the design, fabrication and experimental validation of a supercodnucting device, enabling parametric coupling between bosonic modes, with potential applications in Quantum Neural Networks. The central objective is to realize tunable interactions, resembling the weight tunability of synapses, by leveraging three-wave mixing in superconducting Josephson circuits. The main focus of this work was on improving the quality factor of coplanar waveguide resonators, achinving longer coherence time and so enhanced memory devices, addressing a wider range of harmonics to have a higher number of available bosonic states (resembling the neurons) for coupling and demonstrating parametric coupling. The project progressed through three generations of device development. The first samples, integrating a Josephson Parametric Converter, suffered from undercoupling and mode mismatch but achived high quality factor thanks to holes in the ground. The second generation of samples achived high quality factors and controllable harmonic spectra thanks to a meandered resonators design. The final generation implemented a full Jospehson Parametric Converter (JPC) integrating previous design improvements, allowing to successfully demonstarte flux-tunability, Kerr nonlinearity and parametric amplification via three-wave mixing process. These results highlight the potential of superconducting circuits as scalable hardware for programmable quantum neuromorphic computing. Future works will focus on training these kind of system implementing learning and training protocols by dynamically controlling the coupling strength, as well as the integration with transmon qubit for a non dispersive readout.