The future development of quantum information using superconducting circuits requires Josephson qubits with long coherence times combined with a high-fidelity readout. Significant progress in the control of coherence has recently been achieved using circuit quantum electrodynamics architectures, where the qubit is embedded in a coplanar waveguide resonator, which both provides a well-controlled electromagnetic environment and serves as qubit readout. In particular, a new qubit design, the so-called transmon, yields reproducibly long coherence times. However, a high-fidelity single-shot readout of the transmon, desirable for running simple quantum algorithms or measuring quantum correlations in multi-qubit experiments, is still lacking. Here, we demonstrate a new transmon circuit where the waveguide resonator is turned into a sample-and-hold detector—more specifically, a Josephson bifurcation amplifier—which allows both fast measurement and single-shot discrimination of the qubit states. We report Rabi oscillations with a high visibility of 94%, together with dephasing and relaxation times longer than 0.5 μs. By carrying out two measurements in series, we also demonstrate that this new readout does not induce extra qubit relaxation.
device and setup:
- superconducting qubit (transmon)
- coplanar waveguide resonator (CPWR) with Josephson junction in the middle (Josephson bifurcation amplifier)
- qubit driving source $V_Q$
- variable microwave source $V_R$
- homodyne detection circuit (with filtering and cryogenic amplification)

$t_R = 30 \text{ns}, \ t_S = t_H = 250 \text{ns}$
best single-shot visibility:

- bifurcation for different qubit states
- shift of the ’S-curve’ ($P_B$ vs $P_s$)
- readout contrast 86% ($f_{01}$) and 92% ($f_{12}$)
- Rabi oscillations with ‘composite readout’
  exp. damping time ~ 500ns
preparation errors 2% and 6.5%
backaction of the readout on Qubit?

- Rabi oscillation for delay and double-readout:
  no additional decoherence
- Stark-shift of the qubit frequency:
  bifurcation shows up as a sudden jump in the photon number
- qubit relaxation time T1 with applied auxiliary field:
  no change of coherence
**high fidelity window:**

- readout contrast of bifurcation probability highest for strong coupling: small detuning!
- qubit coherence time highest for weak coupling: larger detuning!

**best operating range:**

contrast 92%, $T_1 = 0.5$ μs

detuning $\Delta = 0.38$ GHz