Tutorial 7.2

Simulated a circuit for 9 cases of connection matrices 3 seconds. For each circuit, added 20 units of current pulse during 1s - 2s, and tried initial firing rate: 0 Hz and 50 Hz for each unit.

Q1: Mono-stability

Time Series: Both units increase during the current pulse and, after the pulse ends, stabilize at firing rates of approximately 5 Hz and 15 Hz, regardless of the initial state.

Phase Plane: Both trajectories converge to a single stable fixed point, indicating a mono-stable system.

Interpretation: The system is mono-stable, meaning it has only one stable equilibrium state. No oscillations or switching occur. The network demonstrates robustness to initial conditions and input perturbations, always converging to the same steady-state behavior.

Q2: Non-responsive Network

Time Series: Both units remain at 0 Hz throughout the simulation, as the applied pulse is insufficient to activate the system.

Phase Plane: The system is stuck at the origin, indicating that no dynamics are occurring.

Interpretation: The system fails to respond due to either overly high thresholds or weak connection weights. This non-responsiveness means that the network remains inactive under the given stimulus. For activation, stronger or more suitable input conditions would be required.

Q3: Bistability

Time Series: Depending on initial conditions, one unit saturates at 100 Hz while the other stays at 0 Hz.

Phase Plane: The trajectories diverge, each heading toward one of the system's stable fixed points.

Interpretation: This system demonstrates bistability. The network has two stable states—one with high firing rate (100 Hz) and one with low firing rate (0 Hz). These stable states are separated by an unstable fixed point, with the system's final state being dependent on initial conditions. The strong recurrent excitation and inhibition lead to competition between the two states.

Q4: Weak Feedback and Partial Bistability

Time Series: The units may remain at 0 Hz or slightly increase and then decay, depending on pulse strength.

Phase Plane: Trajectories either converge to the origin or move slightly before returning to their previous state.

Interpretation: The system shows weak feedback with a soft threshold. The weak recurrent structure leads to partial bistability: although the system can settle in one of two states, perturbations may lead to slight fluctuations rather than strong oscillations or stable states.

Q5: High Threshold and No Activity

Time Series: All units stay at 0 Hz due to high thresholds and lack of feedback, resulting in zero output.

Phase Plane: The system remains fixed at the origin (0, 0).

Interpretation: The system is effectively inactive due to high thresholds and weak drive, preventing any activity. Oscillations or any meaningful dynamics only occur when the system is initially at high firing rates, indicating that strong input and feedback are required for the network to respond.

Q6: Asymmetric Convergence

Time Series: One or two units activate and remain stable while the third unit is suppressed or decays.

Interpretation: This system exhibits asymmetric convergence, where some units remain active and others consistently stay off. Although this behavior does not appear to be bistable in practice, it suggests the possibility of hidden attractors that could emerge under slight perturbations or different input conditions.

Q7: Sequential Pattern Generation

Time Series: Units activate in sequence, each inhibiting the previous one.

Interpretation: This pattern is a sequential pattern generator, where the system exhibits heteroclinic chain behavior. The network alternates between different states, never truly settling into one, suggesting a non-stationary pattern of activity.

Q8: Strong Attractor

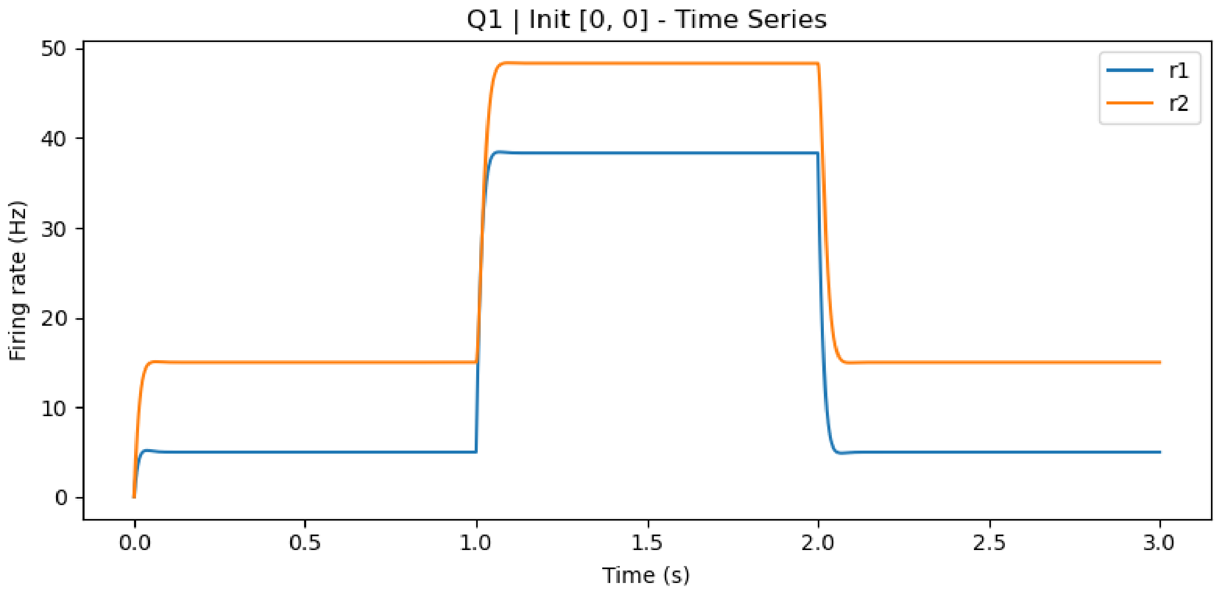
Time Series: Units 1 and 2 rise to high firing rates and remain stable, while unit 3 stays inactive.

Interpretation: The system exhibits a strong attractor, where the output pattern is stable and largely independent of initial conditions. The system tends toward one dominant state, demonstrating stability and predictability in its behavior.

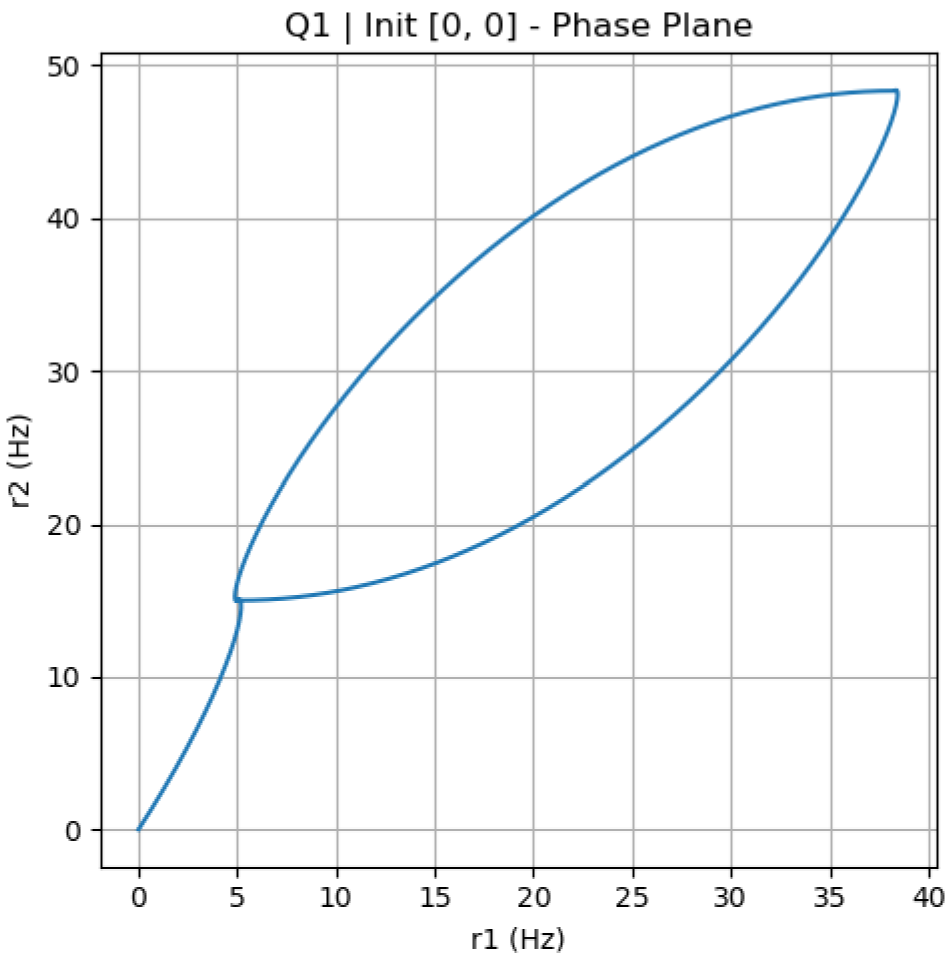
Q9: Metastable System

Time Series: Some units spike or climb slowly, while others jump to higher firing rates. The system behavior varies depending on the initial state.

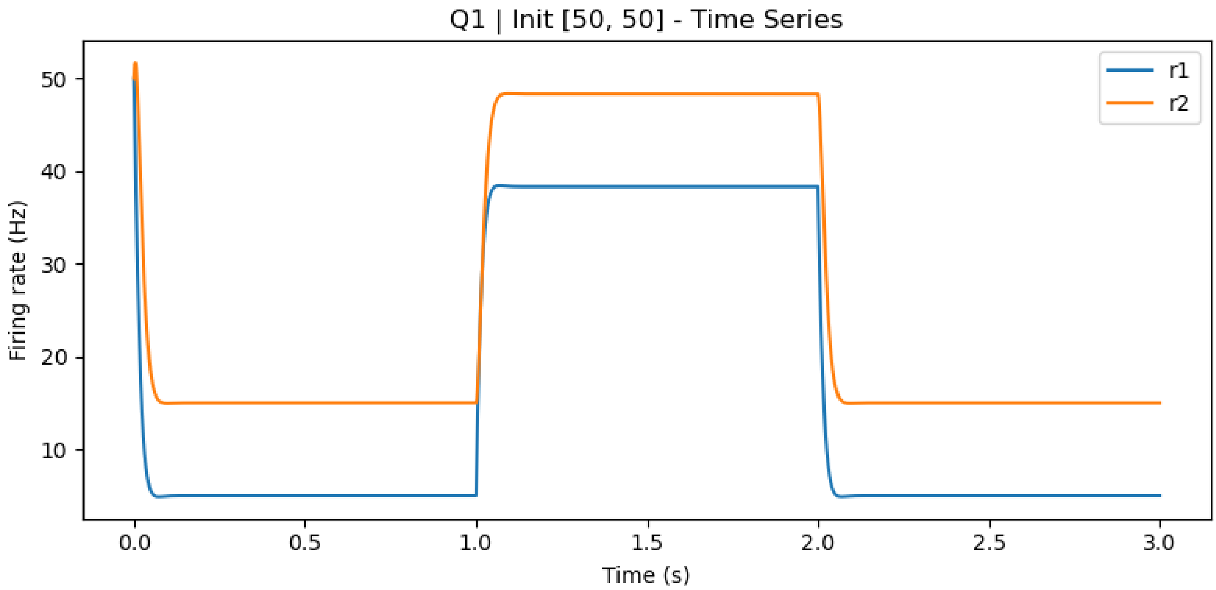
Interpretation: This system is metastable, with small perturbations potentially causing transitions to different final states. The network's behavior exhibits signs of borderline chaotic dynamics, where the system is sensitive to initial conditions, leading to different outcomes under similar conditions. The system's behavior is governed by high-dimensional attractor surfaces that enable this sensitivity.



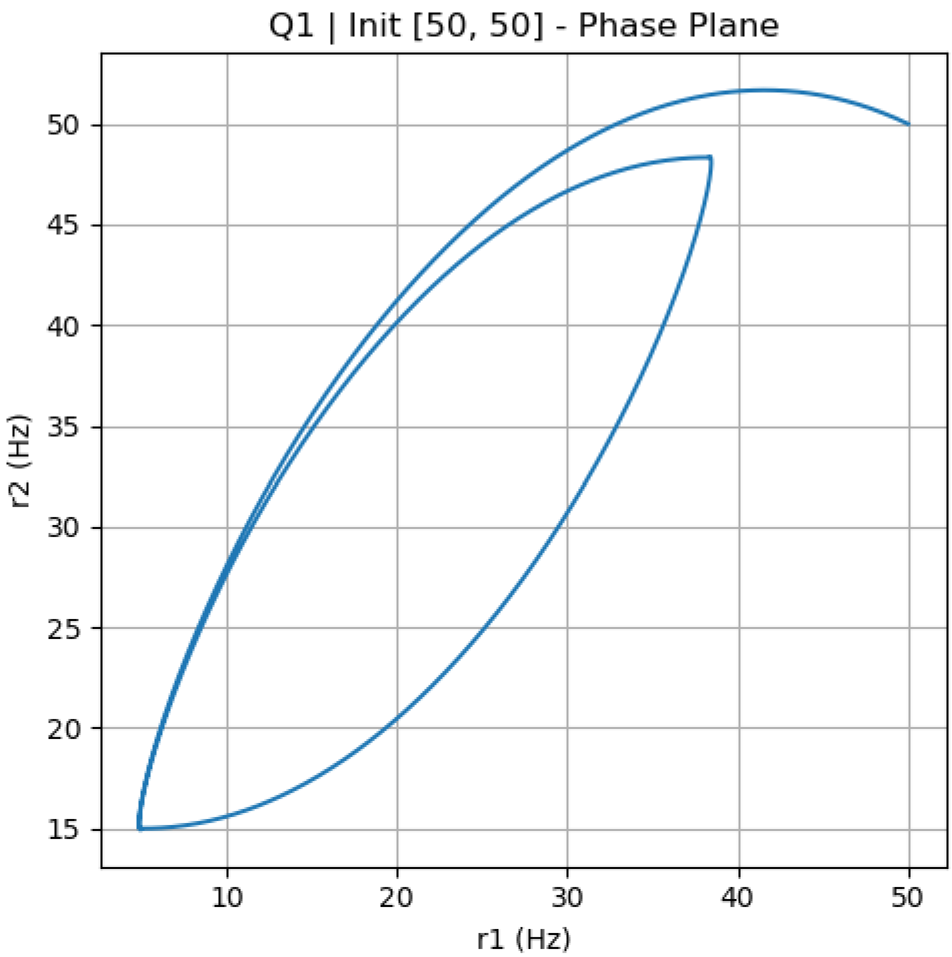
Q1 | Init [0, 0] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0
10
20
30
40
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0



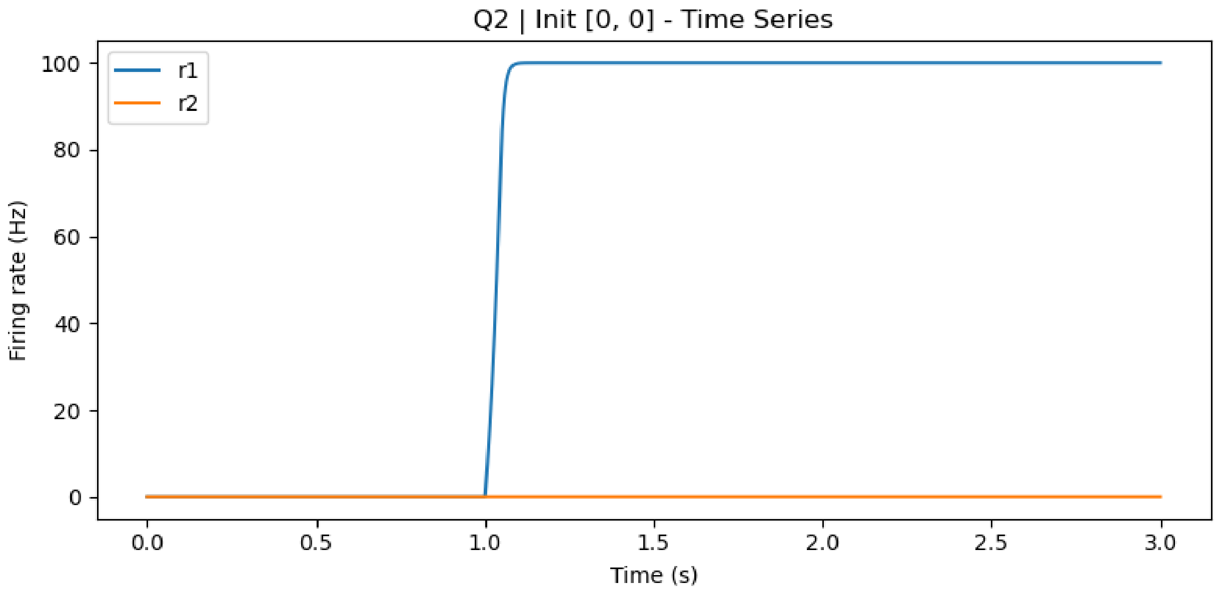
Q1 | Init [0, 0] - Phase Plane
r2 (Hz)
r1 (Hz)
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40

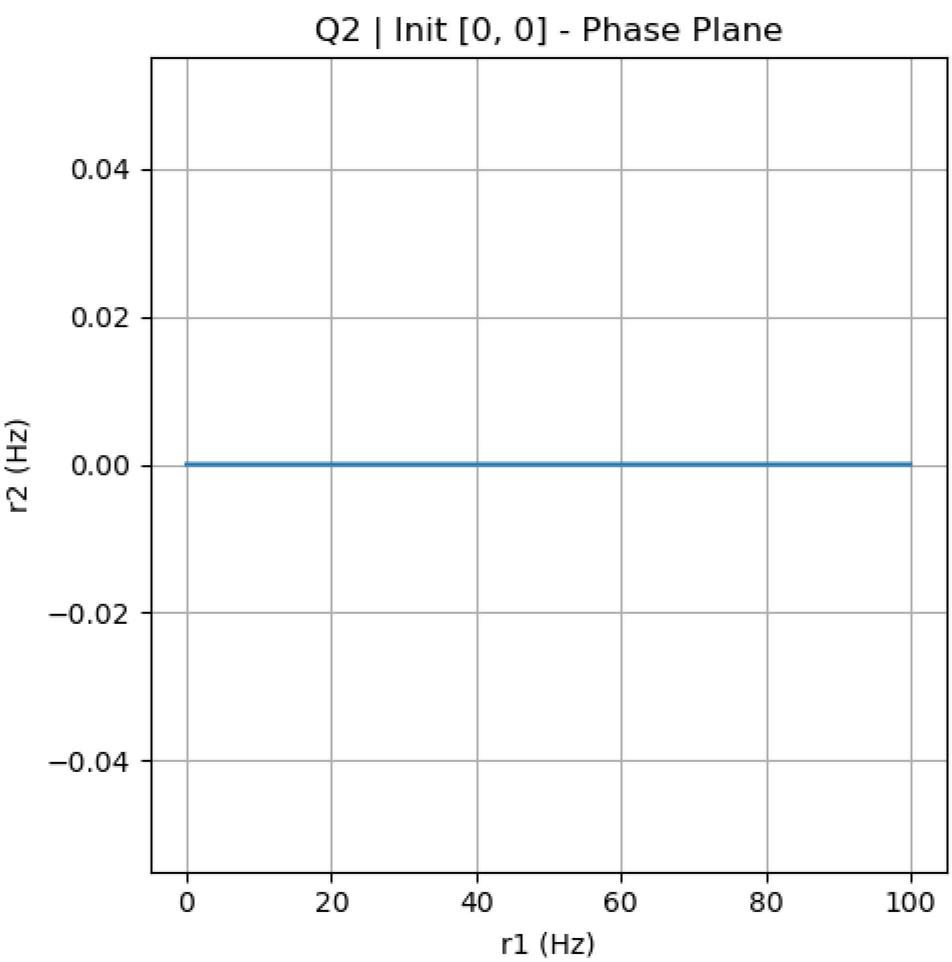


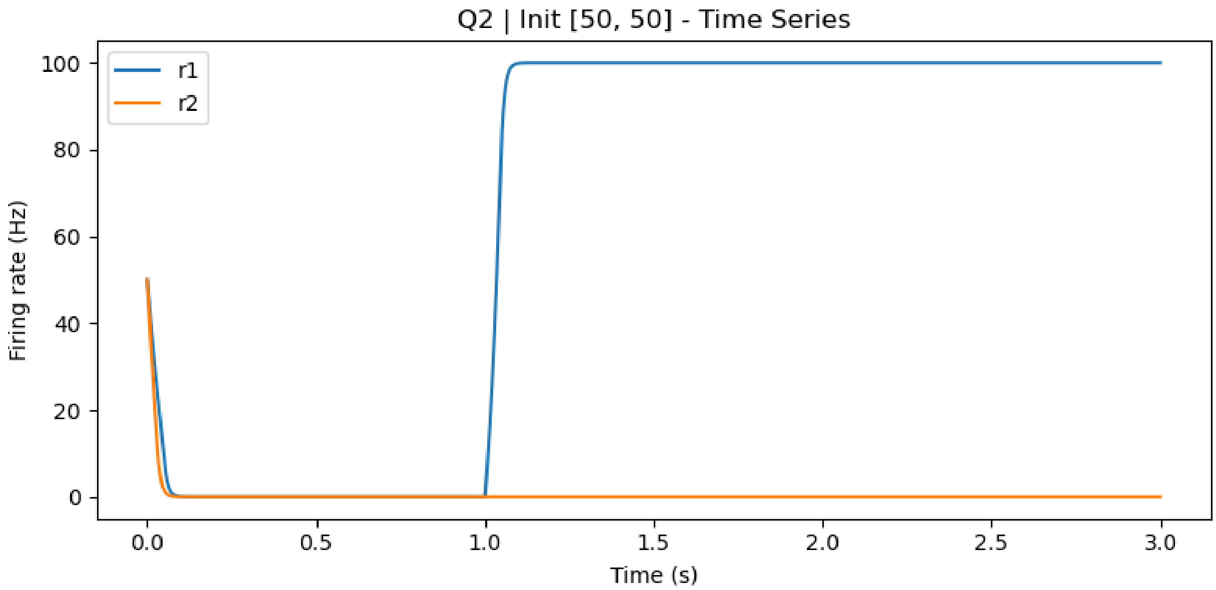
Q1 | Init [50, 50] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
50
40
30
20
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0

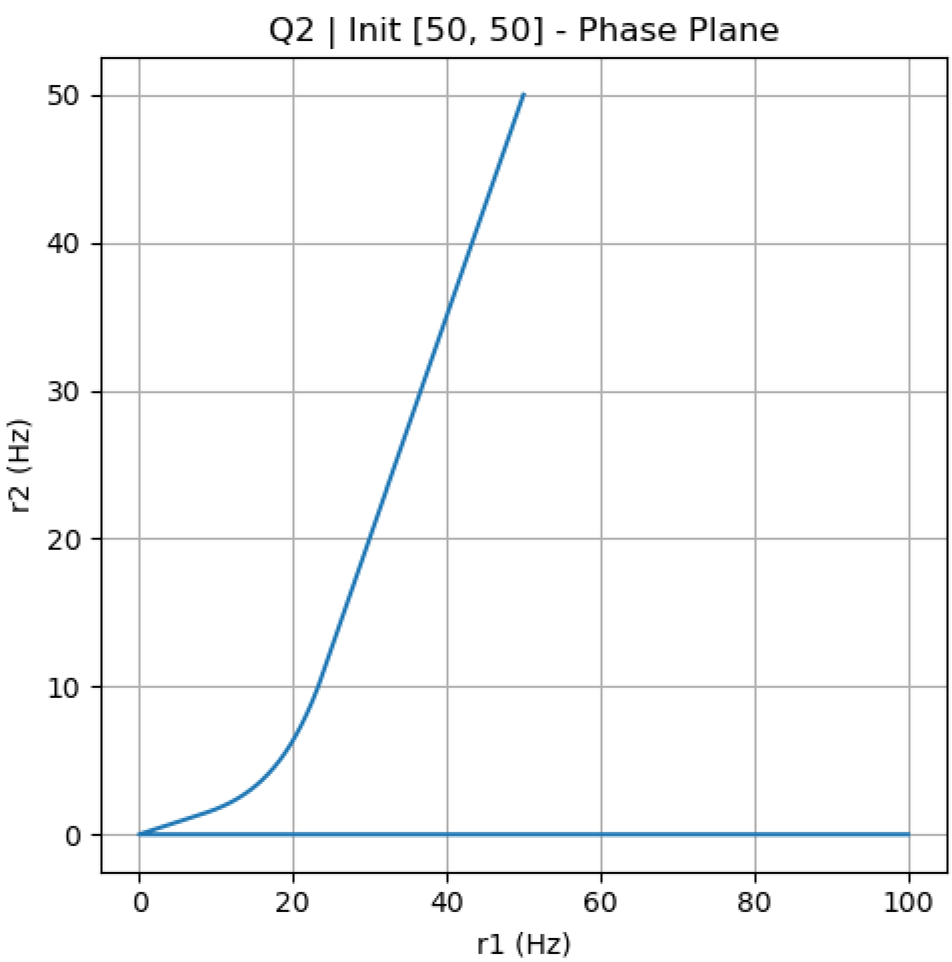


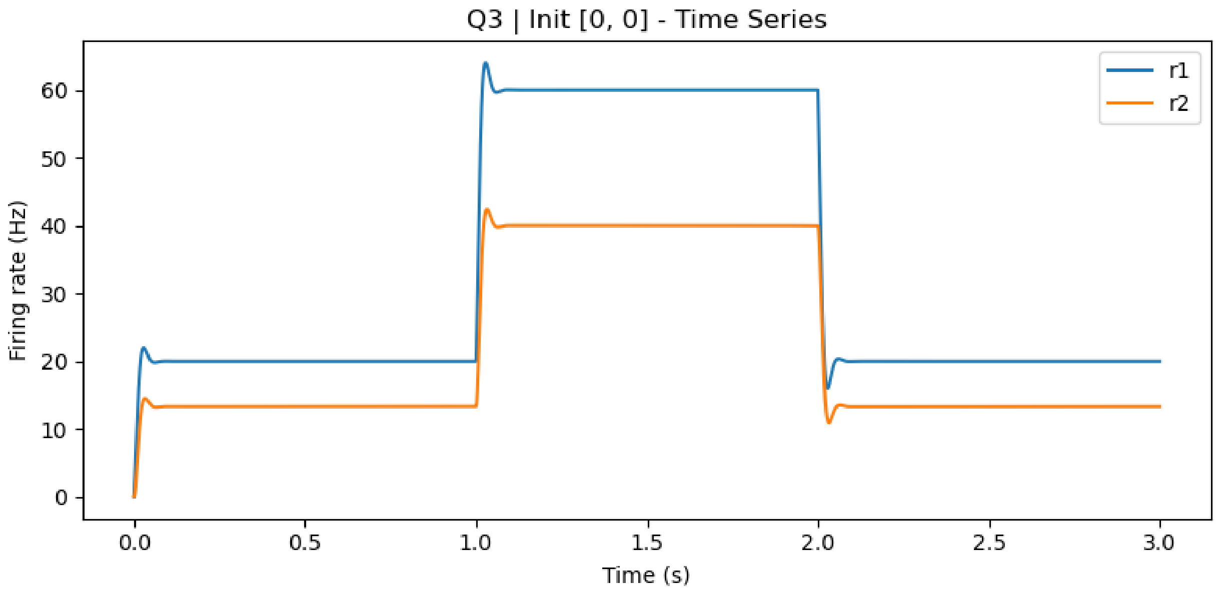
Q1 | Init [50, 50] - Phase Plane
r2 (Hz)
r1 (Hz)
50
45
40
35
30
25
20
15
10
20
30
40
50

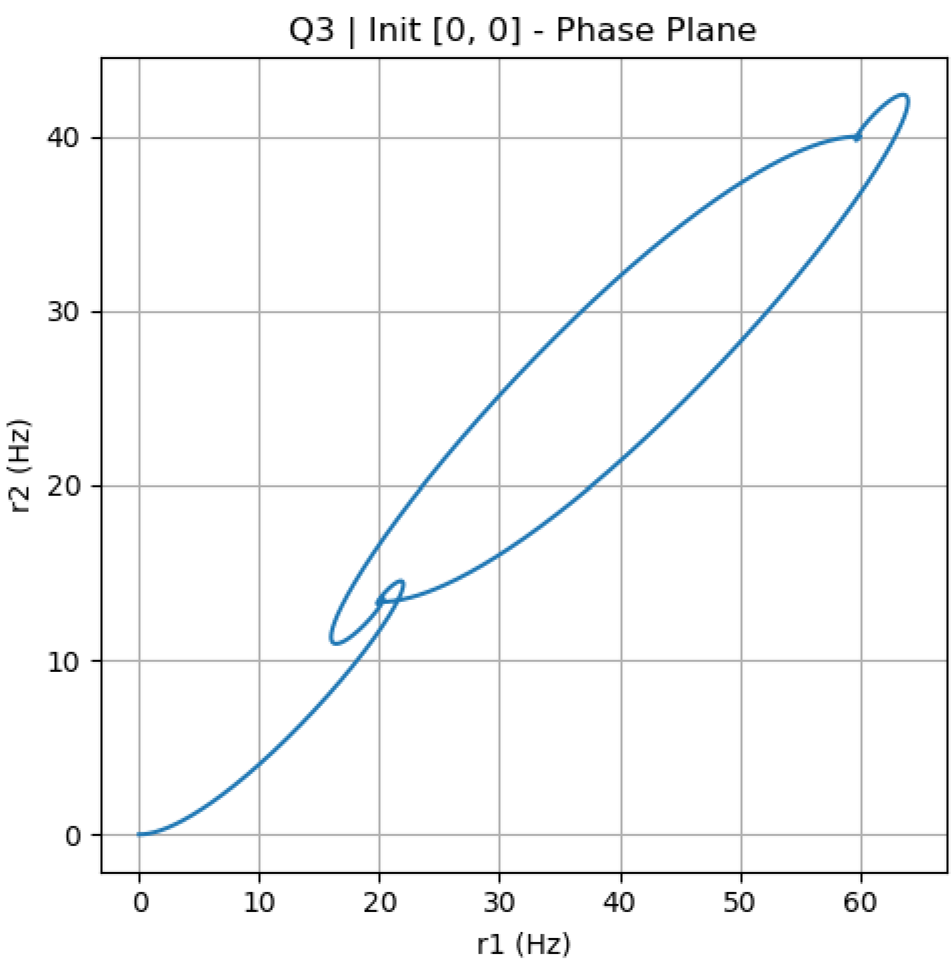

Q2 | Init [0, 0] - Time Series
r1
r2
Firing rate (Hz)
Time (s)

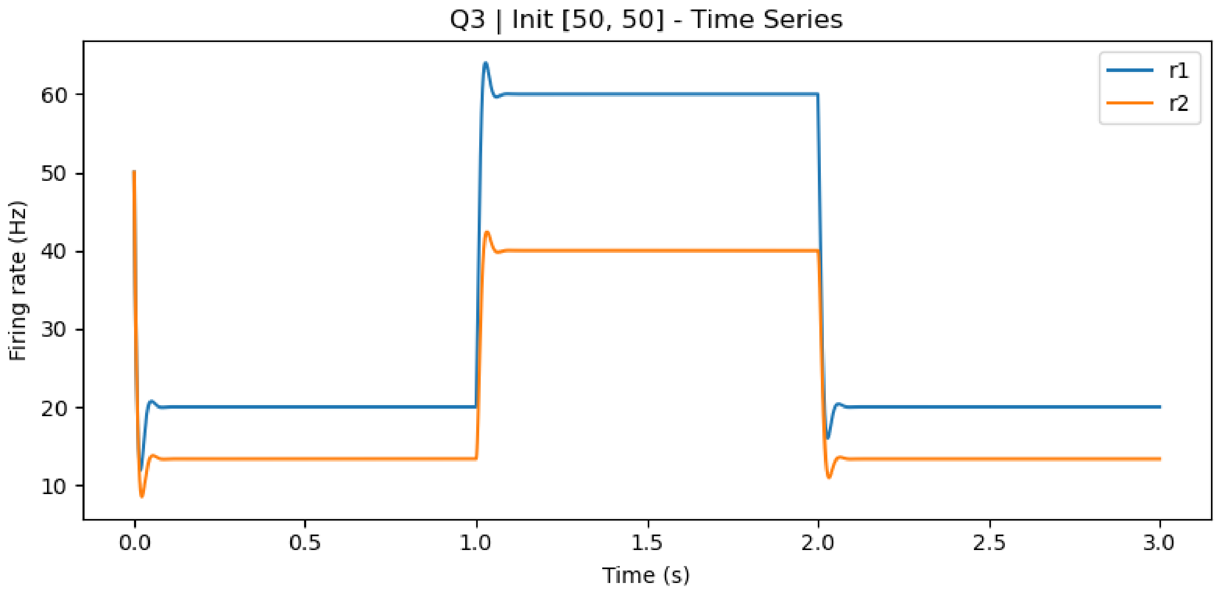

Q2 | Init [0, 0] - Phase Plane
r2 (Hz)
r1 (Hz)

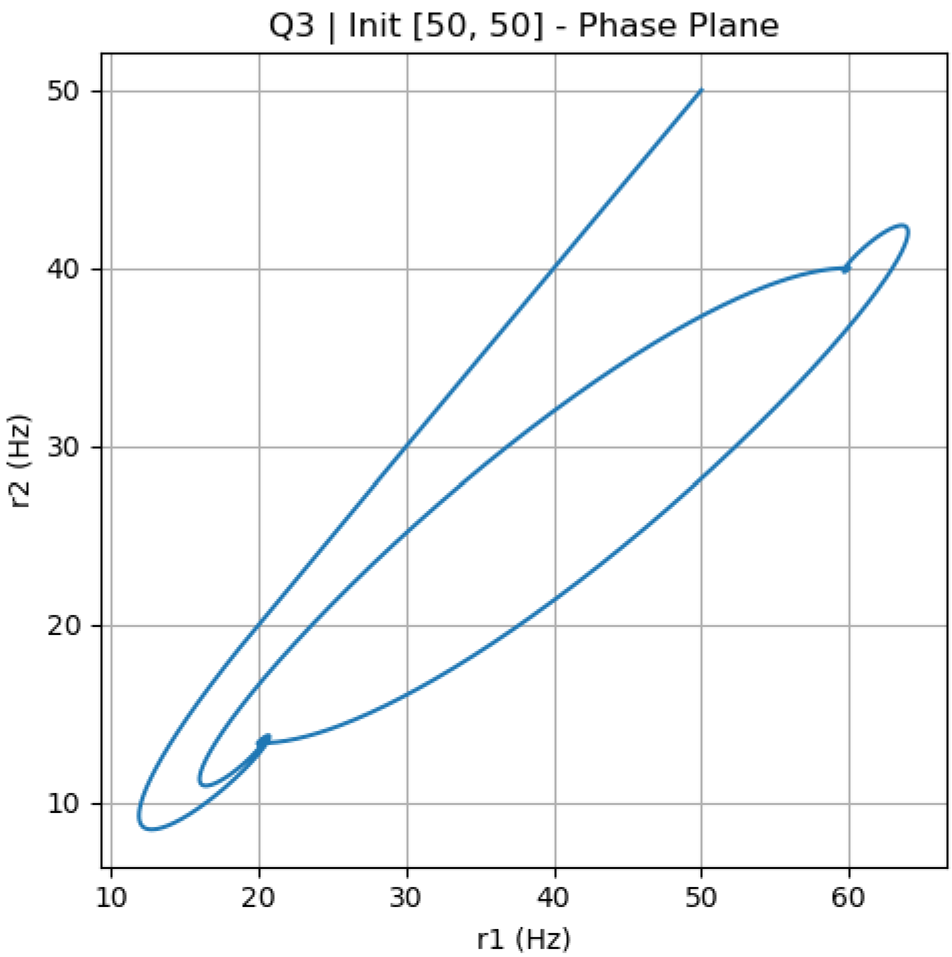

Q2 | Init [50, 50] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100

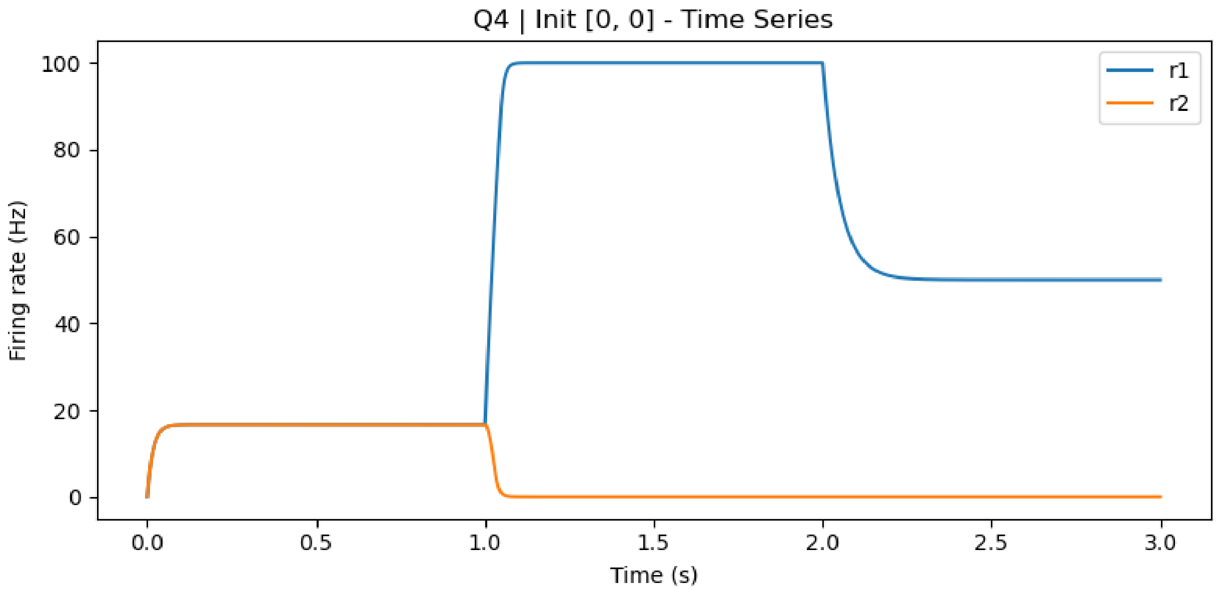

Q2 | Init [50, 50] - Phase Plane
r2 (Hz)
r1 (Hz)
0
20
40
60
80
100
0
10
20
30
40
50

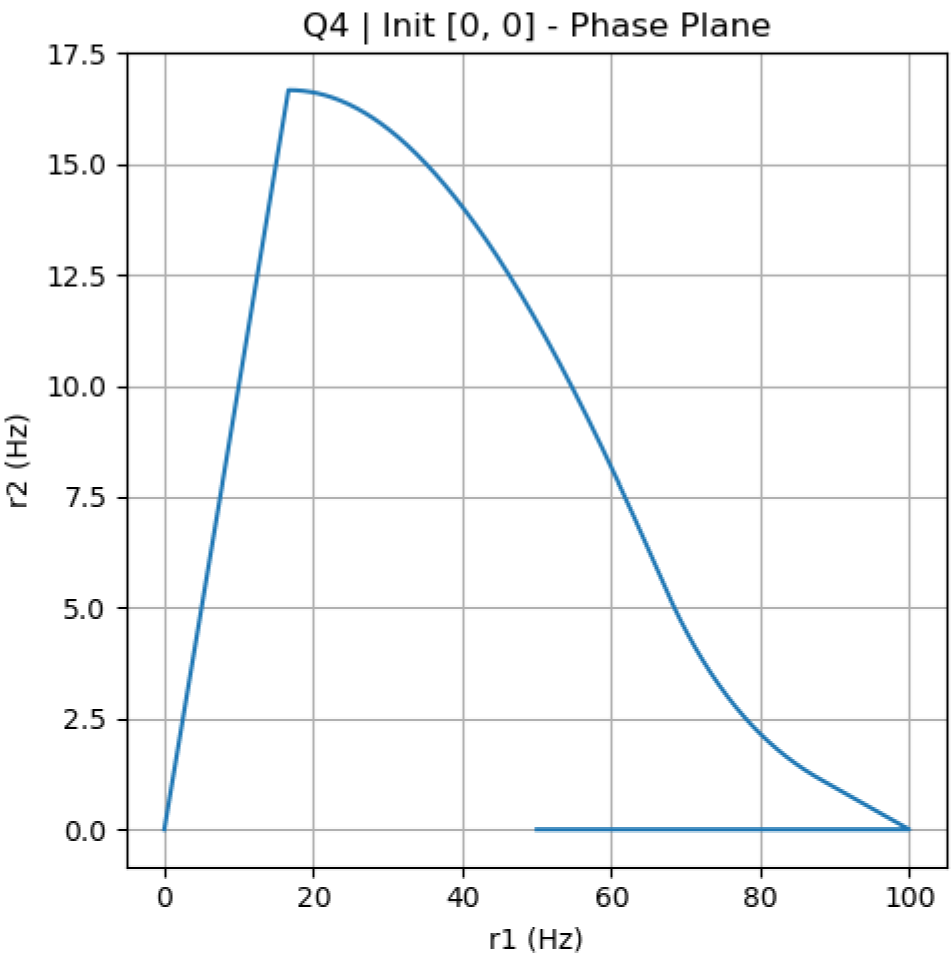

Q3 | Init [0, 0] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0
10
20
30
40
50
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0

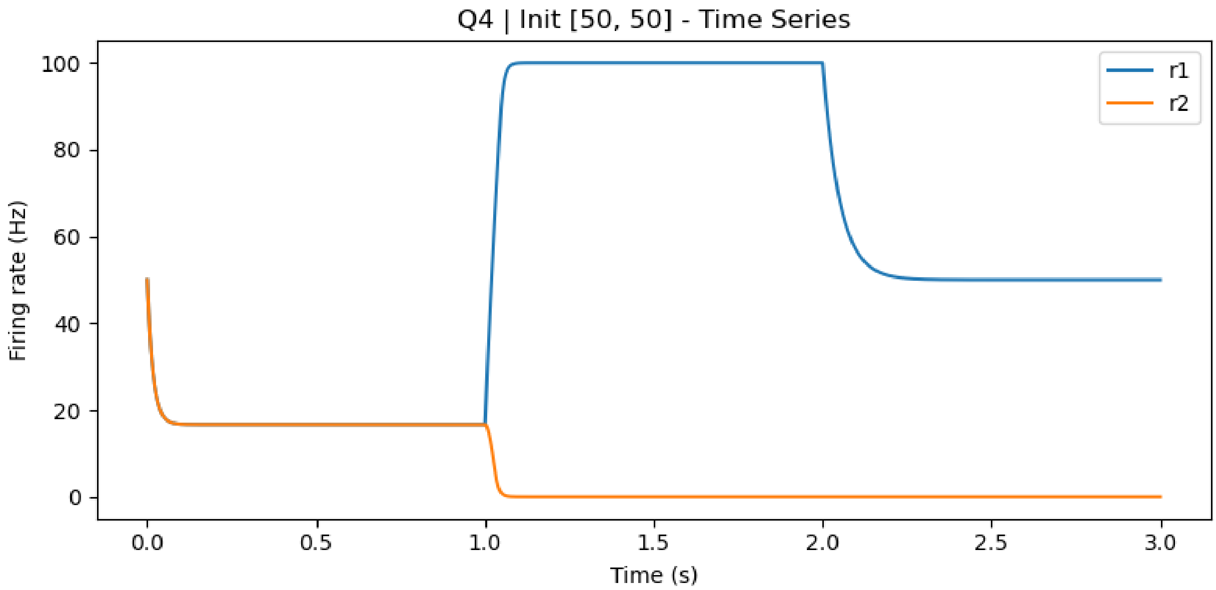

Q3 | Init [0, 0] - Phase Plane
r2 (Hz)
r1 (Hz)
0
10
20
30
40
0
10
20
30
40
50
60

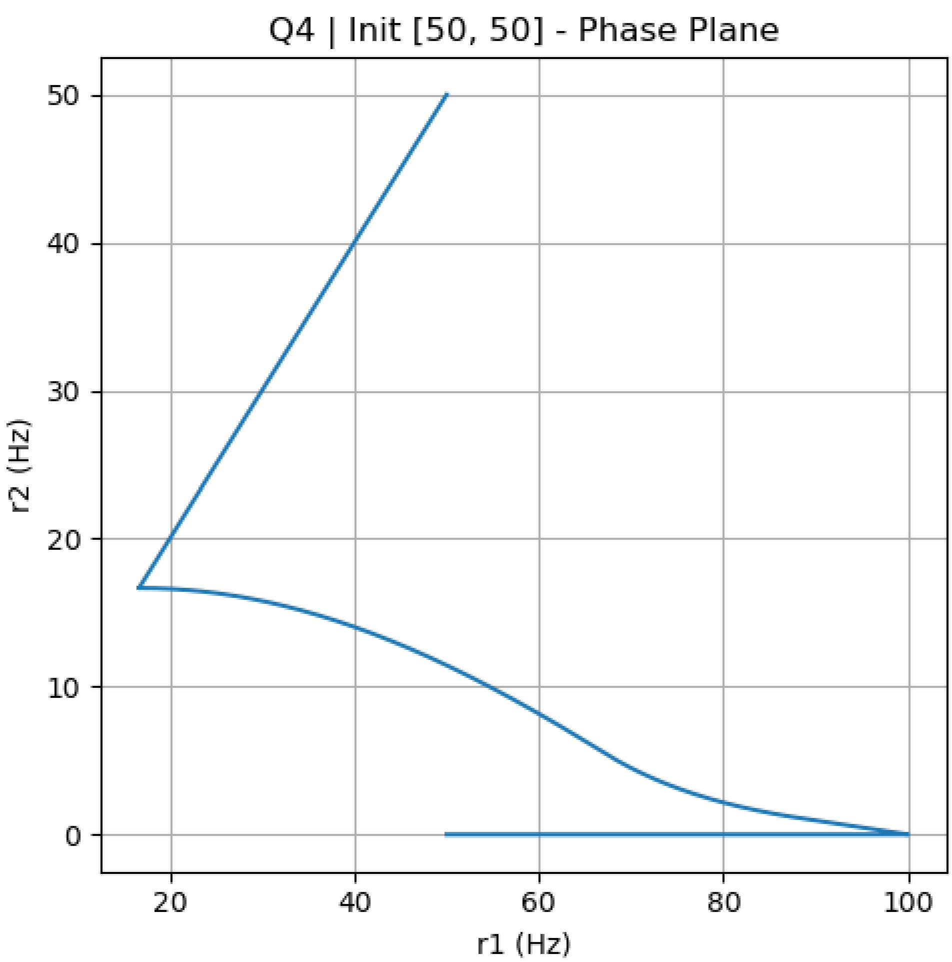

Q3 | Init [50, 50] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
60
50
40
30
20
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0

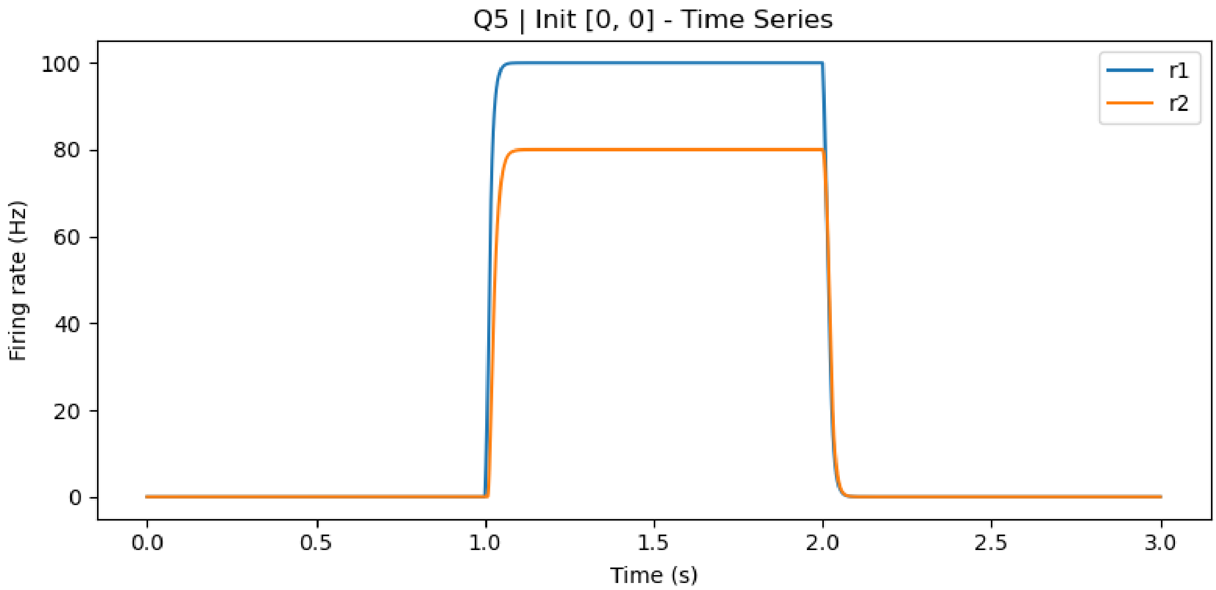

Q3 | Init [50, 50] - Phase Plane
r2 (Hz)
r1 (Hz)
50
40
30
20
10
10
20
30
40
50
60

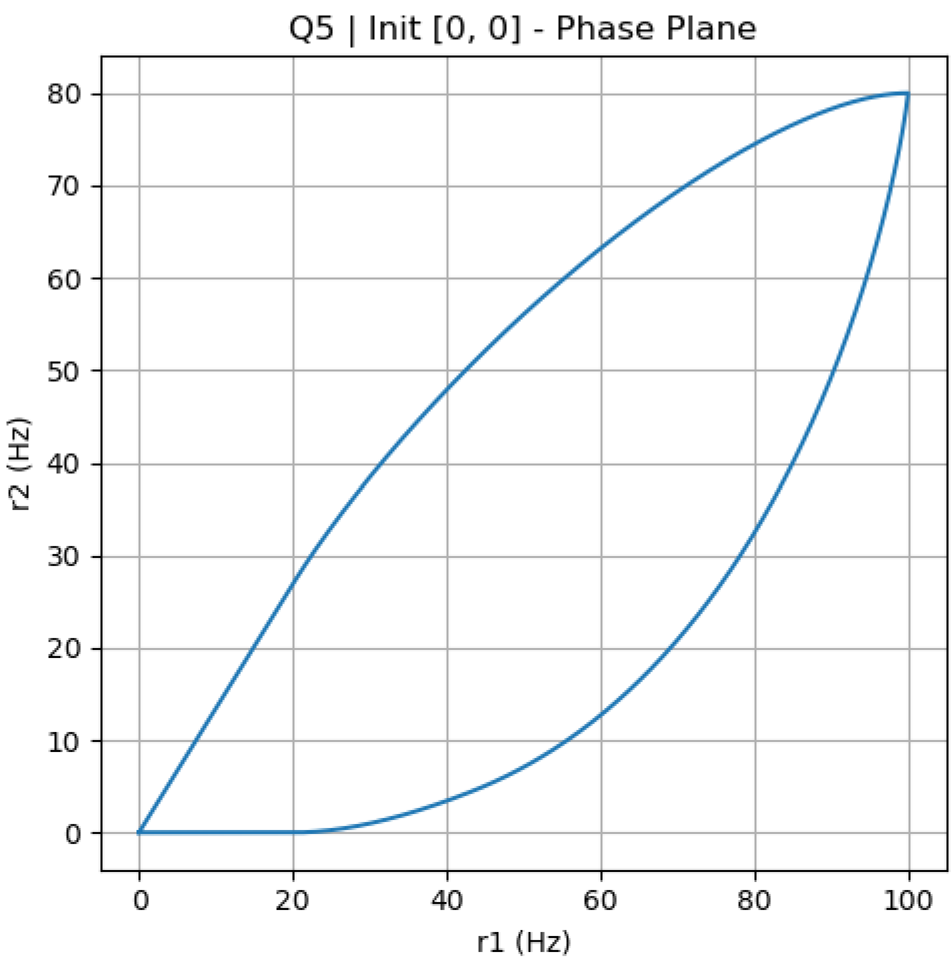

Q4 | Init [0, 0] - Time Series
Firing rate (Hz)
Time (s)
r1
r2
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0

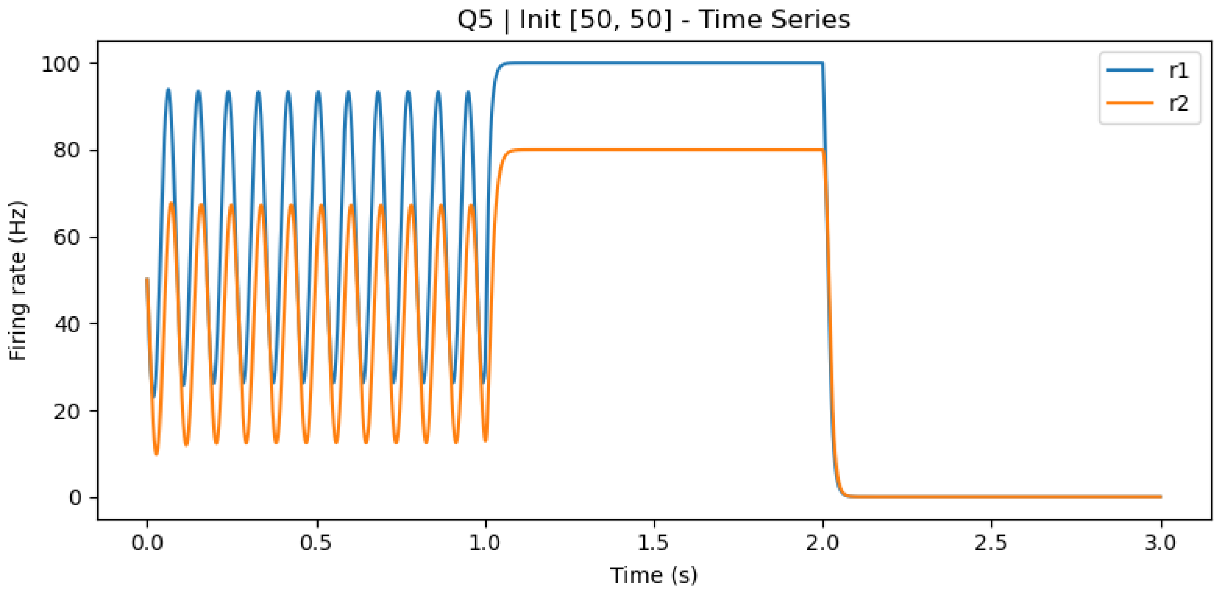

Q4 | Init [0, 0] - Phase Plane
r2 (Hz)
r1 (Hz)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
20
40
60
80
100

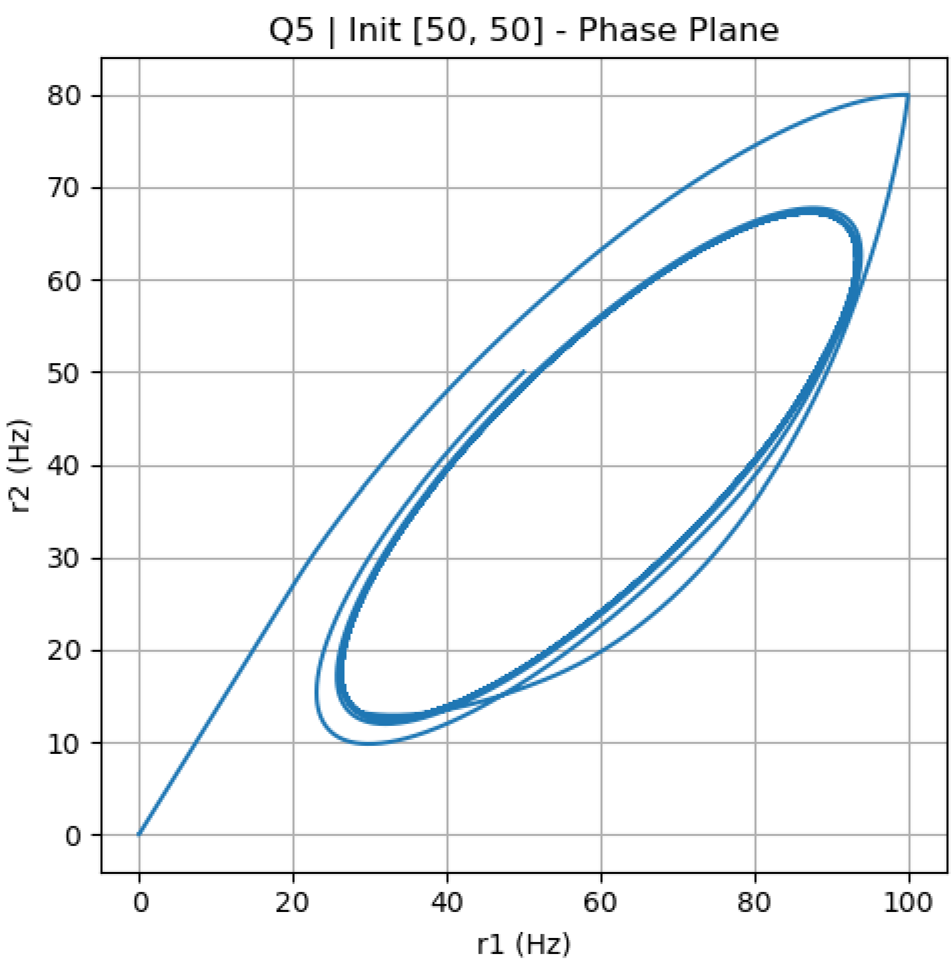

Q4 | Init [50, 50] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0

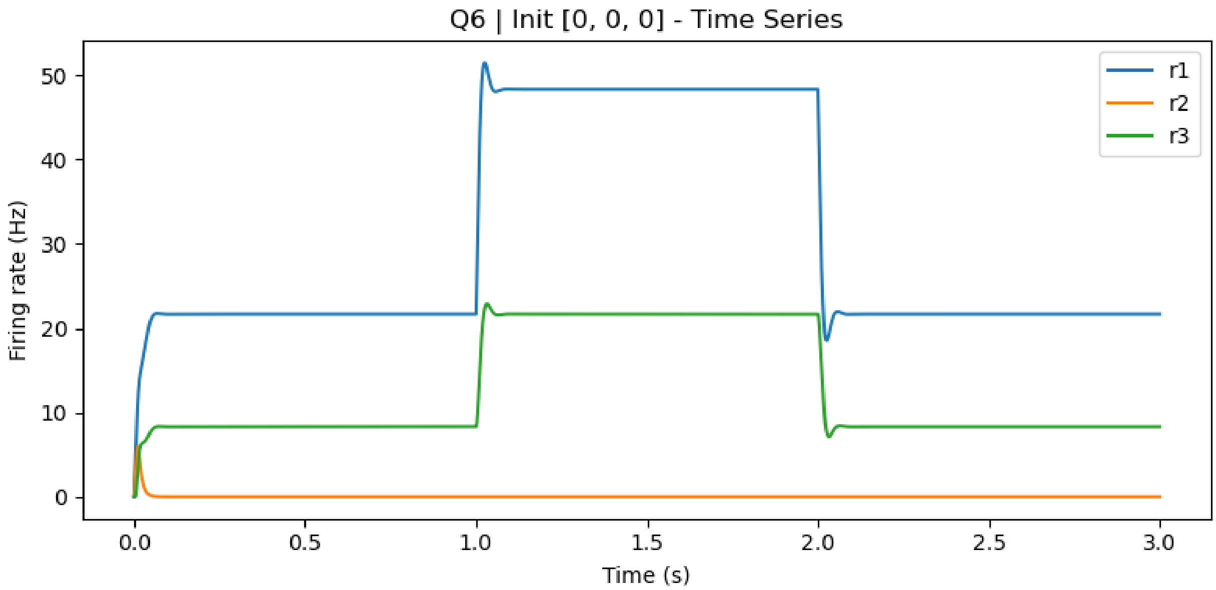

Q4 | Init [50, 50] - Phase Plane
r2 (Hz)
r1 (Hz)
0
10
20
30
40
50
20
40
60
80
100

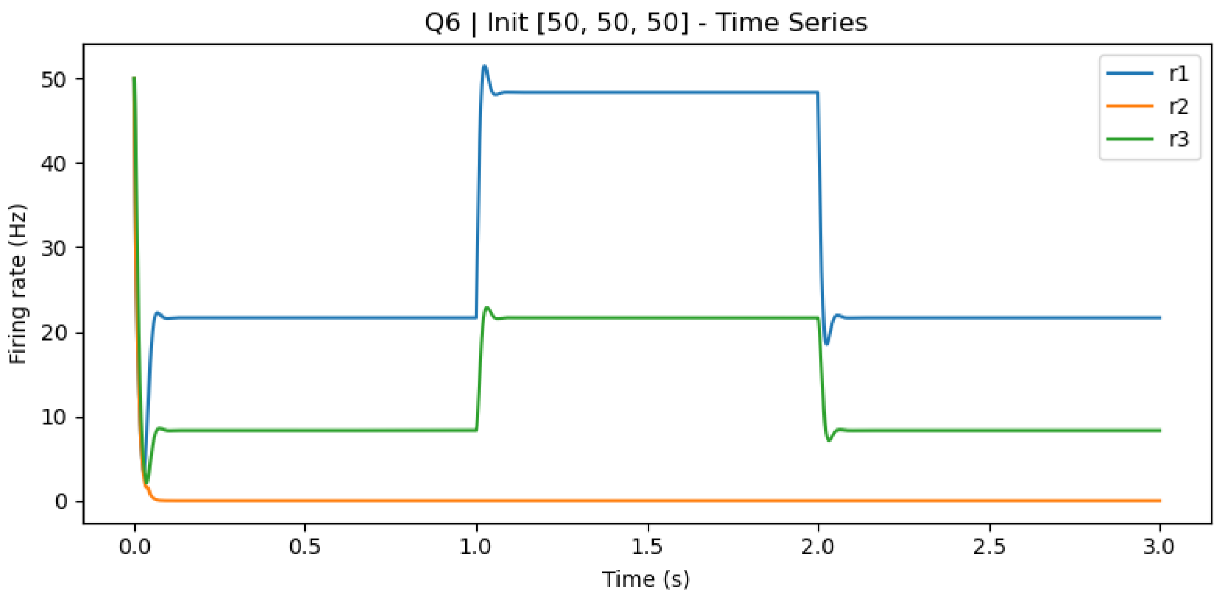

Q5 | Init [0, 0] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100

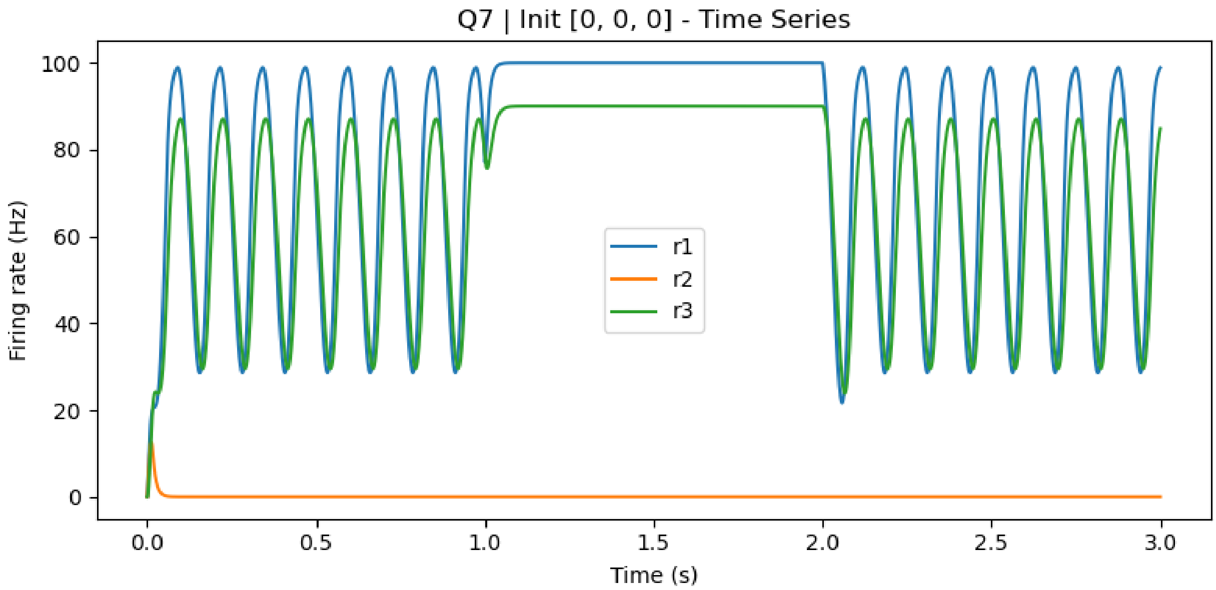

Q5 | Init [0, 0] - Phase Plane
r2 (Hz)
r1 (Hz)
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80


Q5 | Init [50, 50] - Time Series
r1
r2
Firing rate (Hz)
Time (s)
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0

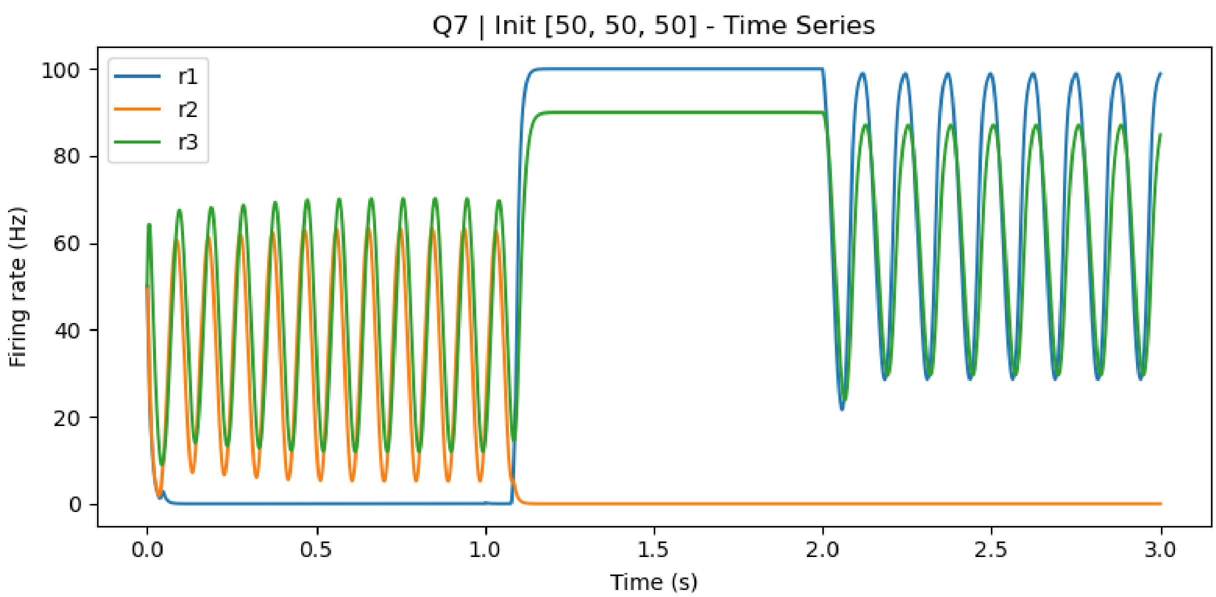

Q5 | Init [50, 50] - Phase Plane
r2 (Hz)
r1 (Hz)
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100


Q6 | Init [0, 0, 0] - Time Series
Firing rate (Hz)
Time (s)
r1
r2
r3
0
10
20
30
40
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0

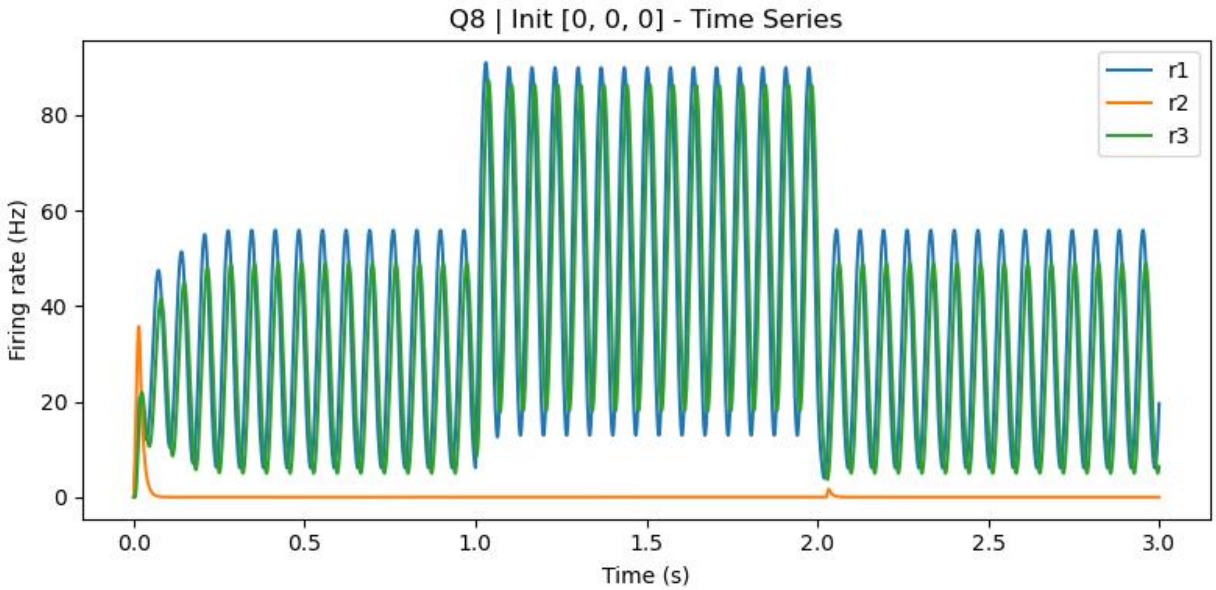

Q6 | Init [50, 50, 50] - Time Series
Firing rate (Hz)
Time (s)
r1
r2
r3
0
10
20
30
40
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0

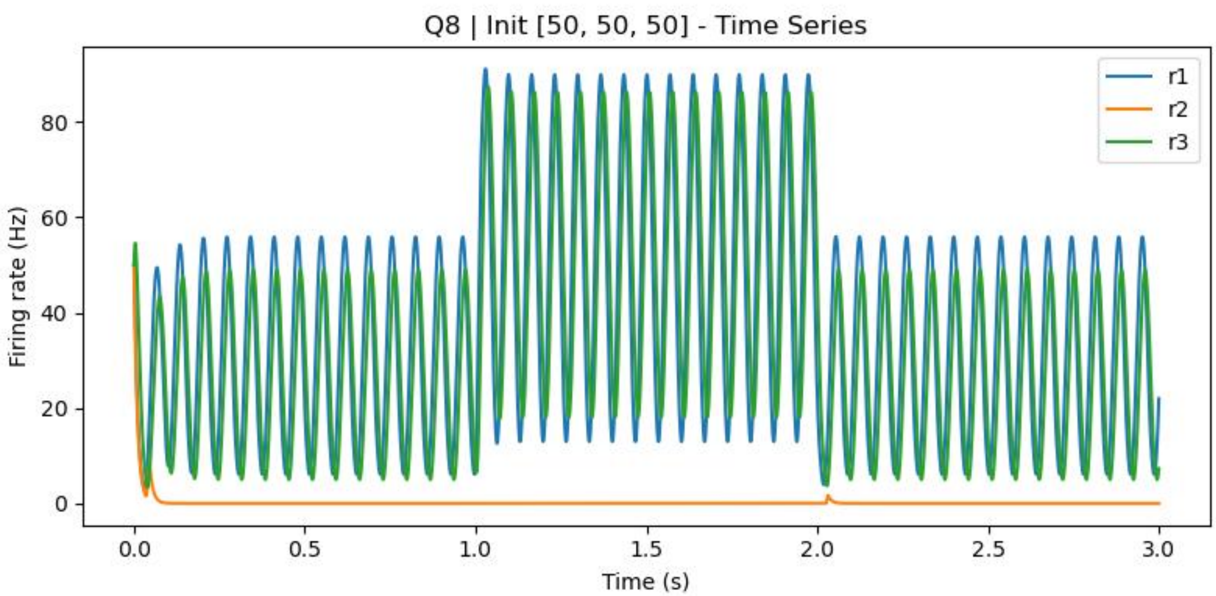


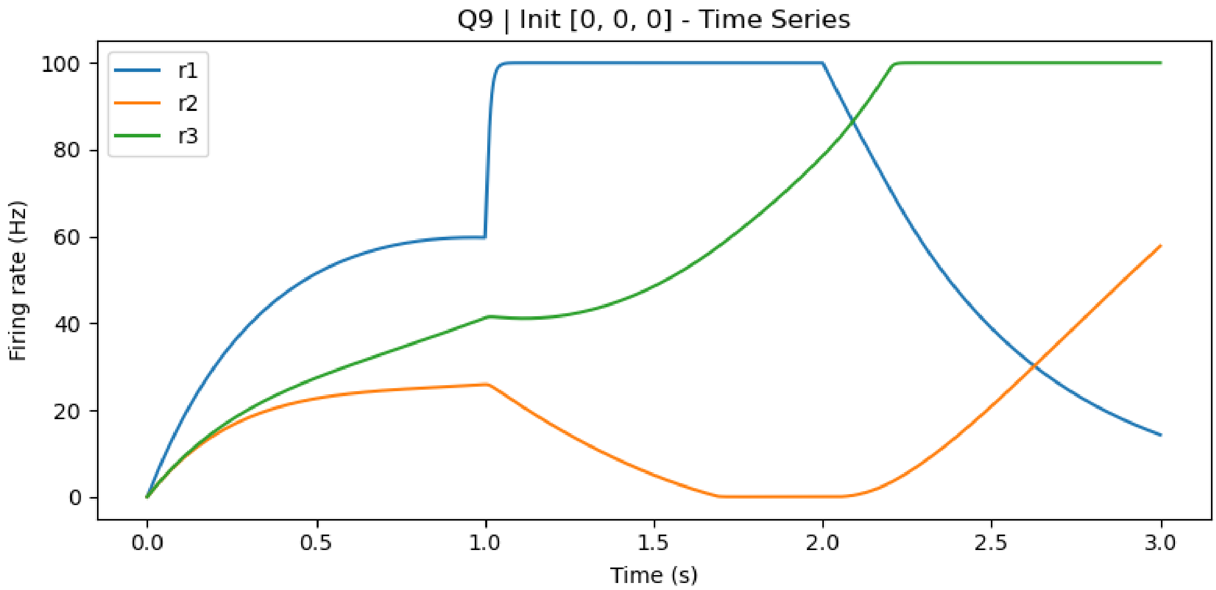
Q7 | Init [0, 0, 0] - Time Series
Firing rate (Hz)
Time (s)
r1
r2
r3

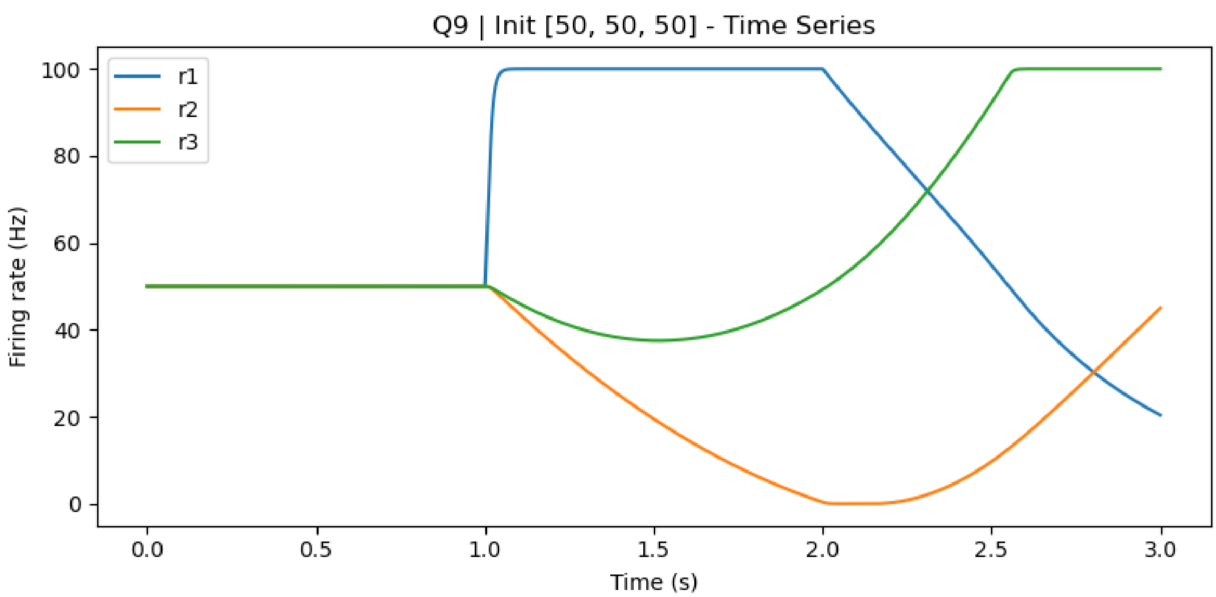


Q7 | Init [50, 50, 50] - Time Series
Firing rate (Hz)
Time (s)
r1
r2
r3


Q8 | Init [0, 0, 0] - Time Series
r1
r2
r3
Firing rate (Hz)
0
20
40
60
80
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time (s)


Q8 | Init [50, 50, 50] - Time Series
r1
r2
r3
Firing rate (Hz)
0
20
40
60
80
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time (s)


Q9 | Init [0, 0, 0] - Time Series
r1
r2
r3
Firing rate (Hz)
Time (s)


Q9 | Init [50, 50, 50] - Time Series
r1
r2
r3
Firing rate (Hz)
Time (s)