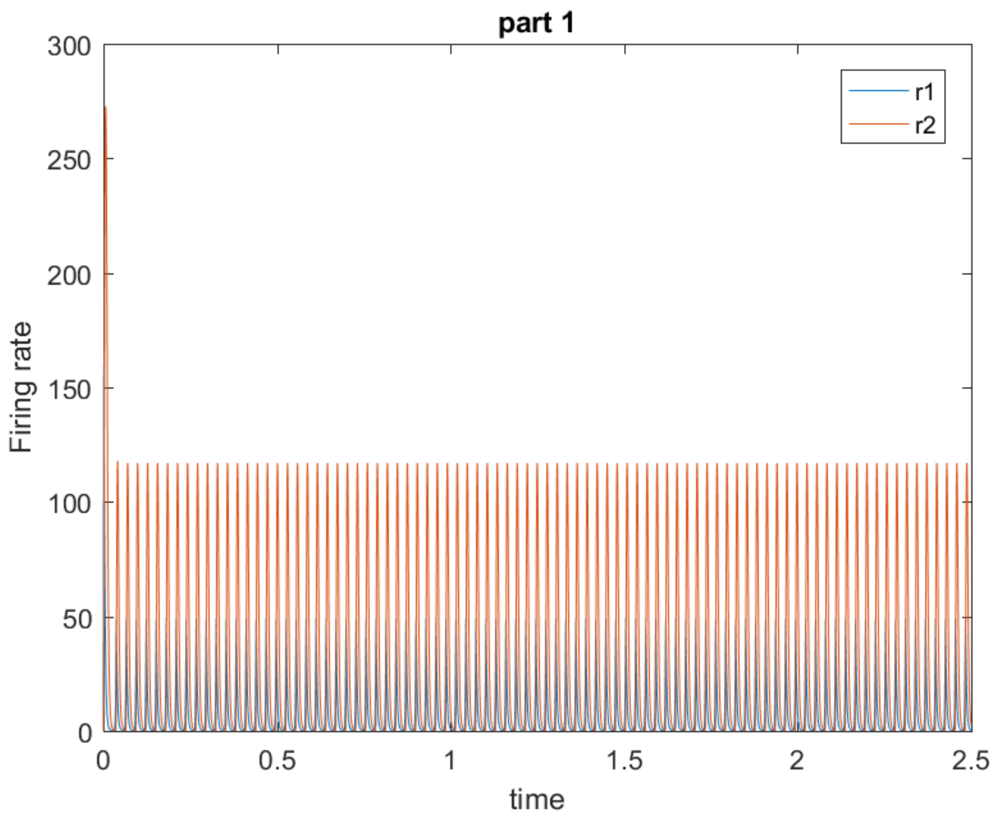
```
close all
clear
clc
Vth=-50e-3;
Vreset=-80e-3;
sigv=1e-3;
tau=3e-3;
E_L=-70e-3;
E_I=-65e-3;
E_E=0;
G_L=50e-12;
W_EE=25e-9;
W_EI=4e-9;
W_IE=800e-9;
G_in1=1e-9;
G_in2=0;
dt=0.1e-3;
t=0:dt:2.5;
tau_E=2e-3;
tau_I=5e-3;
alpha=0.2;
G_E1(1)=0;
G_E2(1)=0;
G_I1(1)=0;
G_I2(1)=0;
r_1(1)=0;
r_2(1)=0;
s_E1(1)=0;
s_I2(1)=0;
for n = 2:length(t)
     G_E1(n) = W_EE*s_E1(n-1) + G_in1;
      G_E2(n) = W_EI*s_E1(n-1) + G_in2;
      G_I1(n) = W_IE*s_I2(n-1);
      G_I2(n) = 0;
      V_ss1(n) = (G_L*E_L + G_I1(n)*E_I + G_E1(n)*E_E)/(G_L + G_I1(n) +
G_E1(n));
      V_ss2(n) = (G_L*E_L + G_I2(n)*E_I + G_E2(n)*E_E)/(G_L + G_I2(n) +
G_E2(n));
      %update diff eqs vie Euler's method
      r_1(n) =  r_1(n-1)+(dt/tau)*(-r_1(n-1)+fin(V_ss1(n)));
      r_2(n) =  r_2(n-1)+(dt/tau)*(-r_2(n-1)+fin(V_ss2(n)));
      s_E1(n) =  s_E1(n-1)+dt*((-s_E1(n-1)/tau_E)+alpha*r_1(n)*(1-s_E1(n-
1)));
      s_I2(n) =  s_I2(n-1)+dt*((-s_I2(n-1)/tau_I)+alpha*r_2(n)*(1-s_I2(n-
1)));
end
f1=figure(1);
plot(t,r_1)

hold on
plot(t,r_2)
xlabel('time');
ylabel('Firing rate');
title('part 1');
legend('r1','r2')
saveas(f1, sprintf('1.png'));
peaks_r1 = findPeaks(r_1);
```

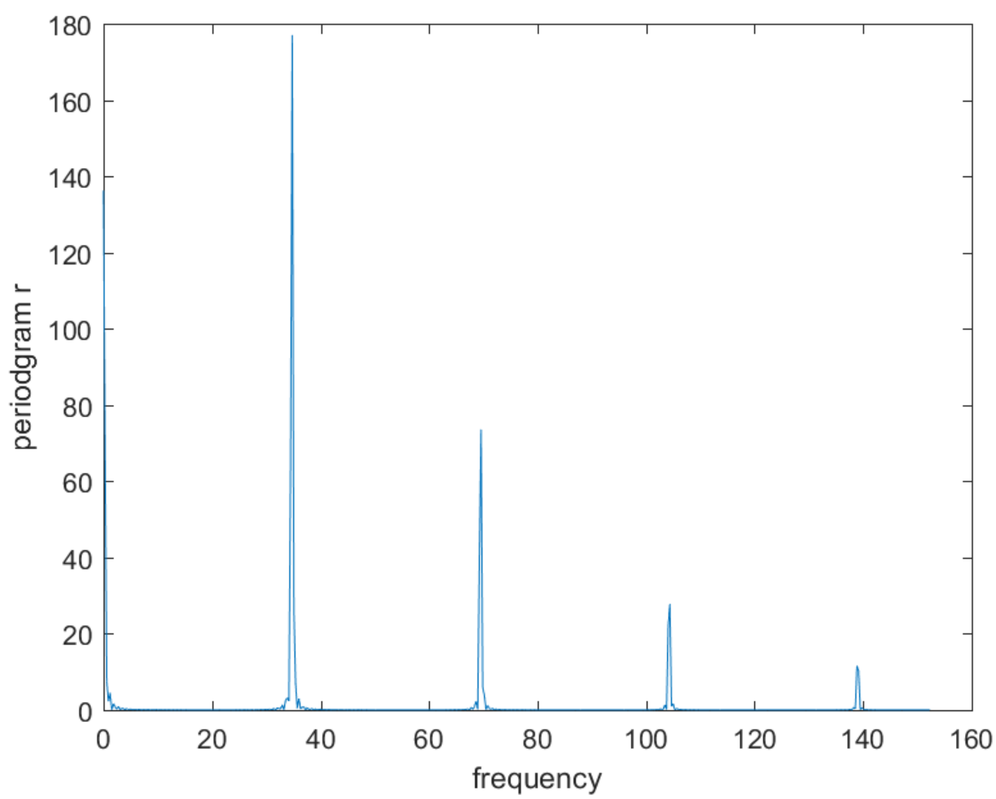
```
peaks_r2 = findPeaks(r_2);

spike_times1 = find(peaks_r1)*dt;
spike_times2 = find(peaks_r2)*dt;
frequency_r1 = 1/mean(diff(spike_times1));
frequency_r2 = 1/mean(diff(spike_times2));
% Display the oscillation frequencies
message = sprintf('Firing rate 1 oscillation frequency: %.2f Hz',
frequency_r1);
disp(message);
%Firing rate 1 oscillation frequency: 7270.65 Hz
message = sprintf('Firing rate 1 oscillation frequency: %.2f Hz',
frequency_r2);
disp(message);
%Firing rate 1 oscillation frequency: 8100.11 Hz

%% Part 3
new_r1=r_1(find(t>=0.5));

[p,F]=periodogram(new_r1,[],[],1/dt);


f2=figure(2);
plot(F(1:500),p(1:500))
xlabel('frequency')
ylabel('periodgram r')
[peak loc]=max(p)
disp(F(loc))
saveas(f2, sprintf('2.png'));
%The f=0 component represents the mean or DC offset of the signal and has the
greatest amplitude.Even if the signal oscillates around this mean, the
amplitude of the oscillations is typically smaller than the mean value
itself.
%we truncate the r1 signal to remove the non-oscilatory part of
signal.multiple peaks are representing a frequency at which there is
significant power in the firing rate data.The number and location of the
peaks are depend on the intrinsic dynamics of the coupled oscillator system

%% part 4

% Define parameters
G_in2 = 0; % Input to inhibitory cells (constant)
G_in1_range = 0:0.1e-9:10e-9; % Range of input to excitatory cells
G_E1(1)=0;
G_E2(1)=0;
G_I1(1)=0;
G_I2(1)=0;
r_1(1)=0;
r_2(1)=0;
s_E1(1)=0;
s_I2(1)=0;
i=1;
G_in1_range= 0:0.1e-9:10e-9;
% Simulation loop
for i=1:length(G_in1_range)
```

```
    G_in1=G_in1_range(i);
    % Simulate network dynamics
    for n = 2:length(t)
        G_E1(n) = W_EE*s_E1(n-1) + G_in1;
        G_E2(n) = W_EI*s_E1(n-1) + G_in2;
        G_I1(n) = W_IE*s_I2(n-1);
        G_I2(n) = 0;
        V_ss1(n) = (G_L*E_L + G_I1(n)*E_I + G_E1(n)*E_E)./(G_L + G_I1(n) +
G_E1(n));


        V_ss2(n) = (G_L*E_L + G_I2(n)*E_I + G_E2(n)*E_E)./(G_L + G_I2(n) +
G_E2(n));
        %update diff eqs vie Euler's method

        r_1(n) =  r_1(n-1)+(dt/tau)*(-r_1(n-1)+fin(V_ss1(n)));
        r_2(n) =  r_2(n-1)+(dt/tau)*(-r_2(n-1)+fin(V_ss2(n)));
        s_E1(n) =  s_E1(n-1)+dt*((-s_E1(n-1)/tau_E)+alpha*r_1(n)*(1-s_E1(n-
1)));
        s_I2(n) =  s_I2(n-1)+dt*((-s_I2(n-1)/tau_I)+alpha*r_2(n)*(1-s_I2(n-
1)));
    end
    new_r1=r_1(find(t>=0.5));
    new_r2=r_2(find(t>=0.5));
    new_r1=new_r1-mean(new_r1);
    new_r2=new_r2-mean(new_r2);
    [p1,F1]=periodogram(new_r1,[],[],1/dt);
    [p2,F2]=periodogram(new_r2,[],[],1/dt);

    [max_power, max_index] = max(p1);

% Extract the frequency corresponding to the maximum power
    frequency_at_max_power = F1(max_index);

    oscillation_frequency1(i)=frequency_at_max_power;
    [max_power2, max_index2] = max(p2);
    frequency_at_max_power2 = F2(max_index2);
    oscillation_frequency2(i)=frequency_at_max_power2;
    peaks_r1 = max(p1)-min(p1);
    peaks_r2 =  max(p2)-min(p2);
    excitatory_amplitude1(i) = peaks_r1;
    inhibitory_amplitude2(i) = peaks_r2;

    mean_excitatory(i) = mean(p1);     % Mean firing rate of cell 1
    mean_inhibitory(i) = mean(p2);     % Mean firing rate of cell 2


end

% Plot figures
f3=figure;

subplot(2,2,1);
plot(G_in1_range, oscillation_frequency1);
hold on
```

```
plot(G_in1_range, oscillation_frequency2);
xlabel('stimulus amplitude');
ylabel('Oscillation Frequency (Hz)');
legend('E', 'I');
title('Oscillation Frequency vs. G_{in1}');

subplot(2,2,2);
plot(G_in1_range*1e9, excitatory_amplitude1);
hold on;
plot(G_in1_range*1e9, inhibitory_amplitude2);
xlabel('stimulus amplitude');
ylabel('Oscillation Amplitude');
legend('E', 'I');
title('Oscillation Amplitude vs. G_{in1}');

subplot(2,2,3);
plot(G_in1_range*1e9, mean_excitatory);
hold on;
plot(G_in1_range*1e9, mean_inhibitory);
xlabel('stimulus amplitude');
ylabel('Mean Firing Rate');
legend('E', 'I');
title('Mean Firing Rate vs. G_{in1}');
saveas(f3, sprintf('3.png'));

function fout = fin(V_ss)
Vth=-50e-3;
Vreset=-80e-3;%-0.08
sigv=1e-3;
tau=3e-3;
if V_ss==Vth;
fout=sigv/(tau*(V_ss-Vreset));
else
fout=(V_ss-Vth)/(tau*(Vth-Vreset)*(1-exp(-(V_ss-Vth)/sigv)));
end
```



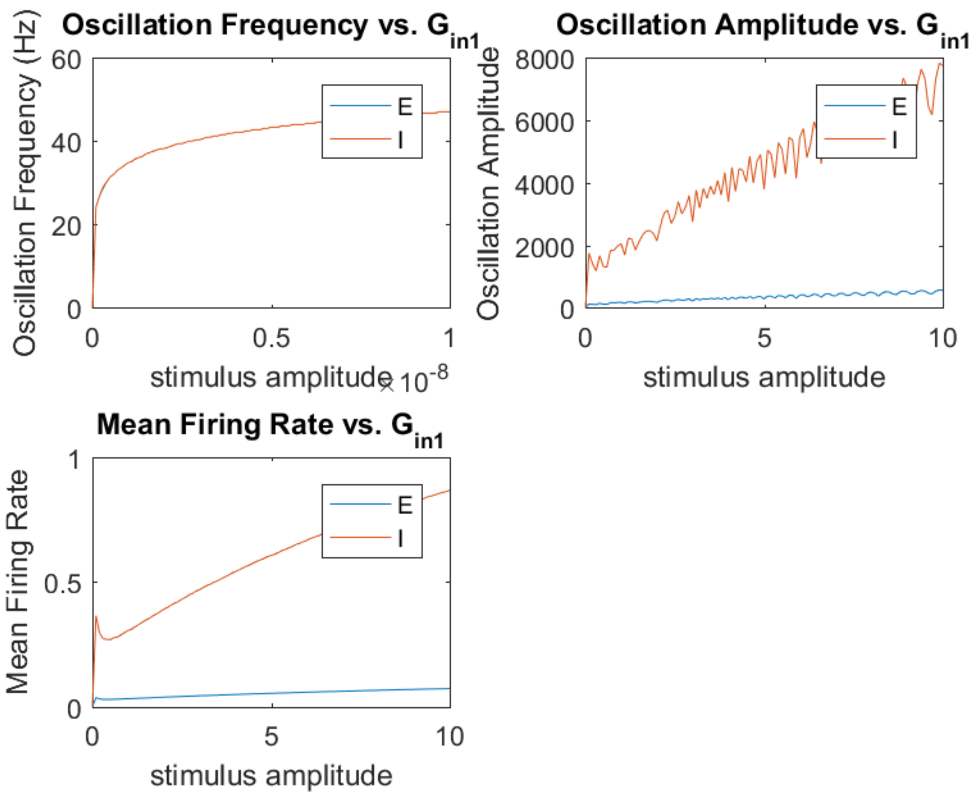
part 1
Firing rate
time
r1
r2
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5



periodgram r
frequency
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160

Firing rate 1 oscillation frequency: 34.79 Hz
Firing rate 2 oscillation frequency: 47 Hz

The f=0 component represents the mean or DC offset of the signal and has the greatest amplitude. Even if the signal oscillates around this mean, the amplitude of the oscillations is typically smaller than the mean value itself.
We truncate the r1 signal to remove the non-oscillatory part of the signal. Multiple peaks represent frequencies at which there is significant power in the firing rate data. Based on the graph, I can see that these presenting frequencies are multiples of each other. It seems that these multiple peaks are harmonics of a fundamental frequency; firing rate signals exhibit harmonics due to the inherent periodicity of neural firing patterns.



The frequency of oscillation increases within the gamma range, from below 30 Hz to 50 Hz, as excitatory

input to the excitatory unit is increased. As the excitatory input to the E-unit increases, it requires a stronger inhibitory response from the I-unit to maintain the oscillation balance. To achieve this, the amplitude (strength) of the inhibitory signal from the I-unit needs to be larger to effectively counter the stronger excitation. This results in a rise in the amplitude of the inhibitory cell's oscillation. The mean firing rates of both units increase as the oscillation amplitude increases, though mean firing rate of the E-unit remains below the oscillation frequency, an indication that individual cells fire spikes on intermittent gamma cycles.