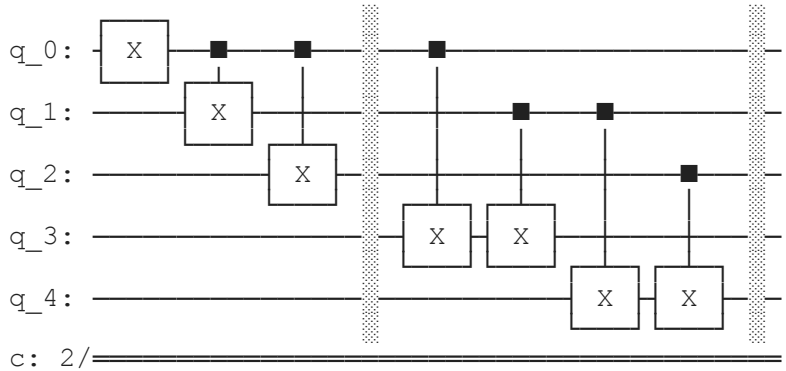
```
!pip install qiskit
!pip install git+https://github.com/qiskit-community/qiskit-textbook.git#subdirectory
!pip install numexpr
!pip install pylatexenc

# Do the necessary imports
import numpy as np
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit import IBMQ, Aer, transpile, assemble, execute
from qiskit.visualization import plot_histogram, plot_bloch_multivector
from qiskit.extensions import Initialize
from qiskit_textbook.tools import random_state, array_to_latex
from math import sqrt, pi
from qiskit.quantum_info import *
from qiskit.visualization import *
from qiskit.result import *
```

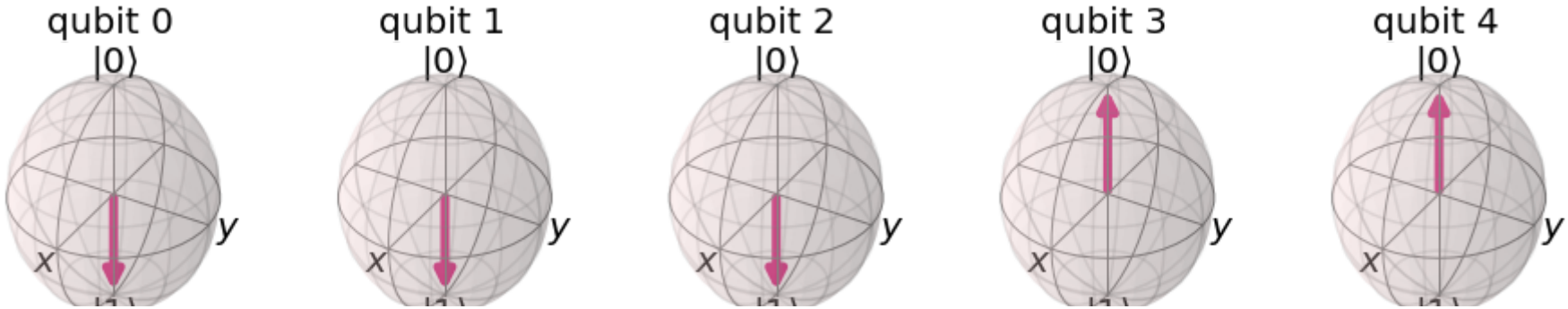
1.- CREATING THE 3 BIT FLIP-CODE CIRCUIT

```
def encoding(qc, d0, d1, d2):

    #### your code goes here
    qc.x(d0)
    qc.cnot(d0,d1)
    qc.cnot(d0,d2)
    qc.barrier()


def detection(qc, d0, d1, d2, a0, a1):

     #### your code goes here

    qc.cnot(d0,a0)
```

```
    qc.cnot(d1,a0)
    qc.cnot(d1,a1)
    qc.cnot(d2,a1)

    qc.barrier()

    #measurement ancilla qubits
    #### your code goes here

## SETUP
bitflip_circuit = QuantumCircuit(5,2)

## STEP 1: encoding
encoding(bitflip_circuit, 0,1,2)


## STEP 2:detection
detection(bitflip_circuit,0,1,2,3,4)

bitflip_circuit.draw()
```




```
sv_sim = Aer.get_backend('statevector_simulator')
qobj = assemble(bitflip_circuit)
out_vector = sv_sim.run(qobj).result().get_statevector()
plot_bloch_multivector(out_vector)
```



CHECKING THE RESULTS:

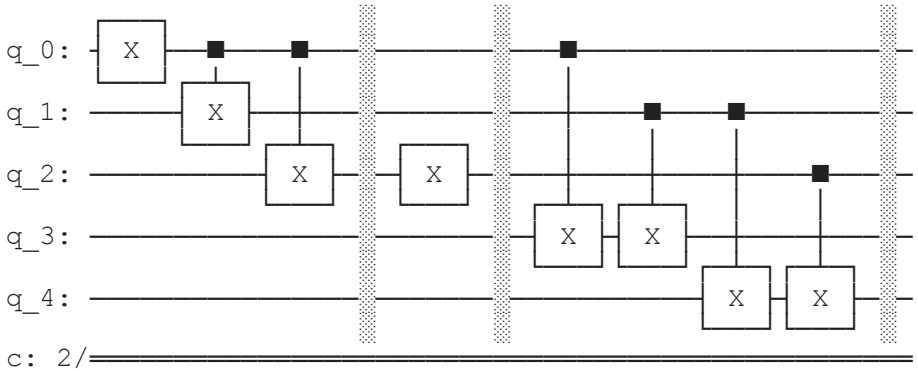
a) What are the states of q3 and q4 (ancilla qubits) and why?

b) What are the states of $|q_0\rangle$, $|q_1\rangle$ and $|q_2\rangle$? Or in other words, what is the state of the logical qubit $|\psi_L\rangle = |q_2 q_1 q_0\rangle$?

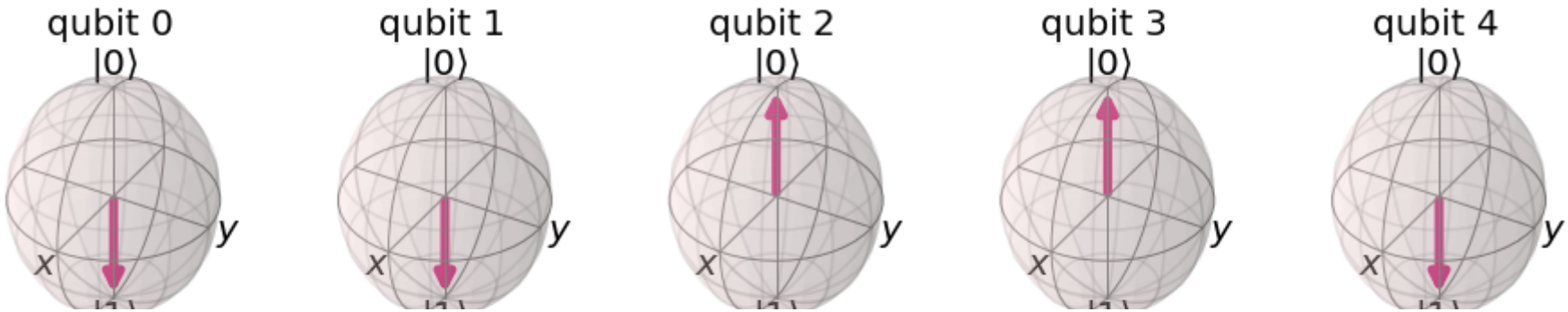
2.- INJECTING BIT-FLIP ERRORS AND DECODING THEM

```
import random

def error_injection(qc, d0, d1, d2):
    #function for injecting a bit-flip on q0, or on q1 or on q2
    rand = random.randint(1,3)
    #### your code goes here
    if rand == 1: qc.x(d0)
    if rand == 2: qc.x(d1)
    if rand == 3: qc.x(d2)
    qc.barrier()


## SETUP

bitflip_circuit = QuantumCircuit(5,2)
```

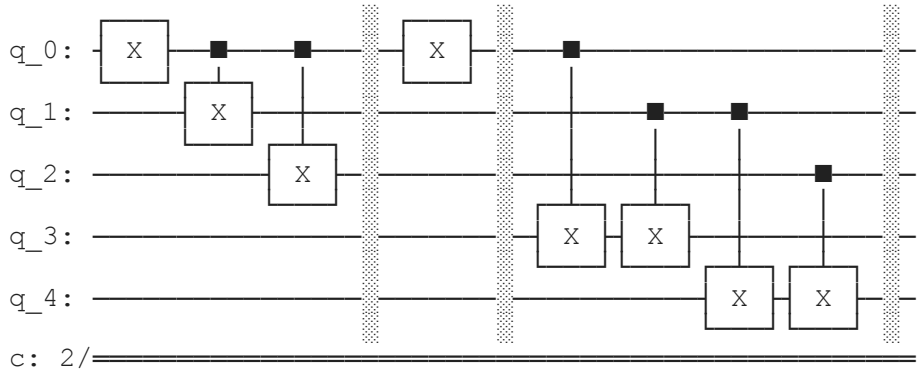
```
## STEP 1: encoding
encoding(bitflip_circuit, 0,1,2)

## STEP 2: inserting errors
error_injection(bitflip_circuit, 0,1,2)

## STEP 3:detection
detection(bitflip_circuit,0,1,2,3,4)

bitflip_circuit.draw()
```




```
sv_sim = Aer.get_backend('statevector_simulator')
qobj = assemble(bitflip_circuit)
out_vector = sv_sim.run(qobj).result().get_statevector()
plot_bloch_multivector(out_vector)
```

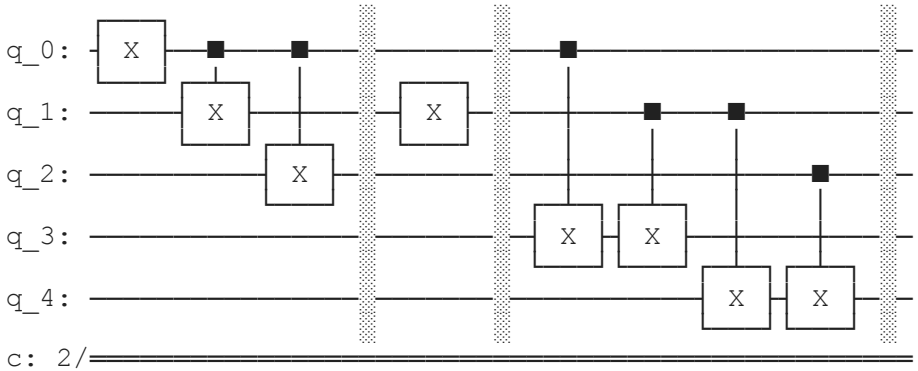


```
## SETUP

bitflip_circuit = QuantumCircuit(5,2)

## STEP 1: encoding
encoding(bitflip_circuit, 0,1,2)

## STEP 2: inserting errors
error_injection(bitflip_circuit, 0,1,2)

## STEP 3:detection
detection(bitflip_circuit,0,1,2,3,4)

bitflip_circuit.draw()
```

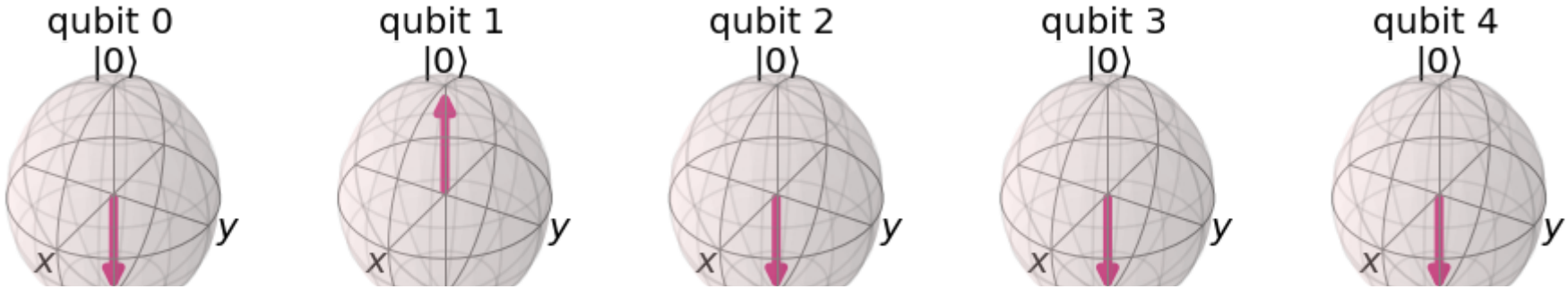



```
sv_sim = Aer.get_backend('statevector_simulator')
qobj = assemble(bitflip_circuit)
out_vector = sv_sim.run(qobj).result().get_statevector()
plot_bloch_multivector(out_vector)
```


```
## SETUP

bitflip_circuit = QuantumCircuit(5,2)

## STEP 1: encoding
encoding(bitflip_circuit, 0,1,2)

## STEP 2: inserting errors
error_injection(bitflip_circuit, 0,1,2)

## STEP 3:detection
detection(bitflip_circuit,0,1,2,3,4)

bitflip_circuit.draw()
```




```
sv_sim = Aer.get_backend('statevector_simulator')
qobj = assemble(bitflip_circuit)
out_vector = sv_sim.run(qobj).result().get_statevector()
plot_bloch_multivector(out_vector)
```

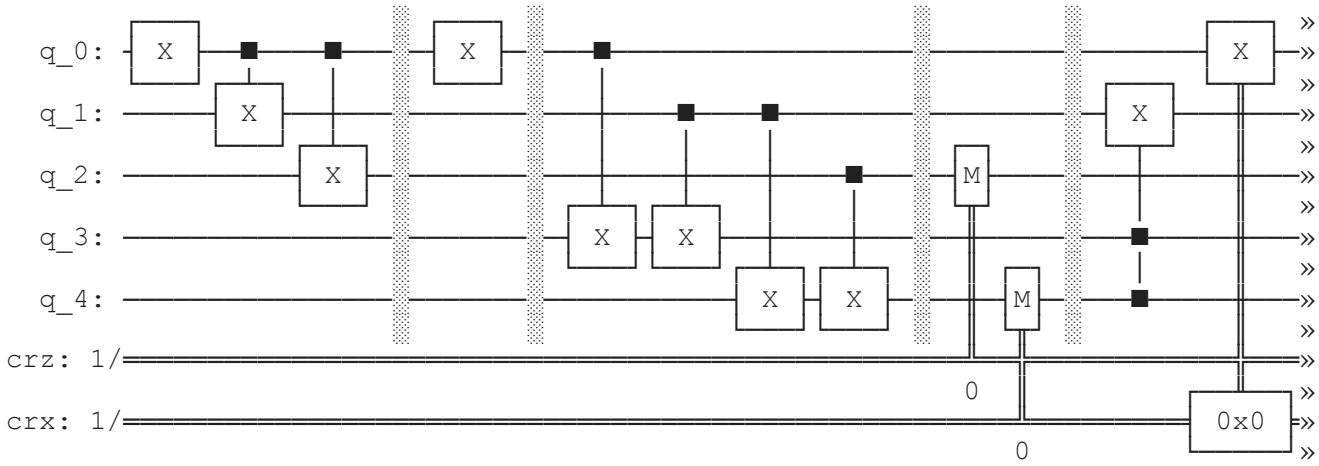


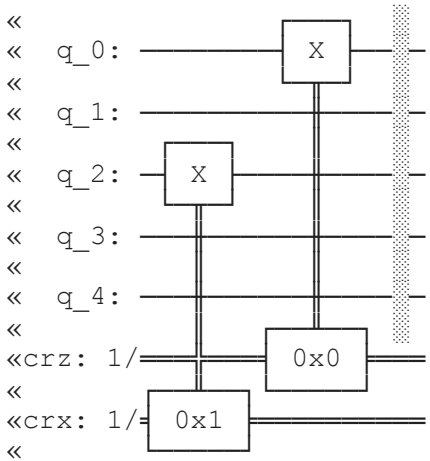
Error (Bit-flip)	Logical state $\|\psi_L\rangle = \|q_2 q_1 q_0\rangle$	Syndrome $\|q_4 q_3\rangle$
q0	|110⟩	|01⟩
q1	|001⟩	|11⟩
q2	|011⟩	|10⟩

3.- CORRECTING BIT-FLIP ERRORS

```
import random

def error_injection(qc, d0, d1, d2):
    #function for injecting a bit-flip on q0, or on q1 or on q2
    rand = random.randint(1,3)
    #### your code goes here
    if rand == 1: qc.x(d0)
    if rand == 2: qc.x(d1)
    if rand == 3: qc.x(d2)
    qc.barrier()
```

```
def correction(qc, d0, d1, d2, d3, d4, a0, a1):
     #### your code goes here

    qc.measure(d3,a0)
    qc.measure(d4,a1)

    qc.barrier()

    #correction d1
    qc.ccx(d3,d4,d1)

    #correction do y d2
    qc.x(d0).c_if(a1,0)
    qc.x(d2).c_if(a1,1)
    qc.x(d0).c_if(a0,0)

    qc.barrier()

## SETUP
qr = QuantumRegister(5, name="q")
crz, crx = ClassicalRegister(1, name="crz"), ClassicalRegister(1, name="crx")
bitflip_circuit = QuantumCircuit(qr,crz,crx)

## STEP 1: encoding
encoding(bitflip_circuit, 0,1,2)

## STEP 2: inserting errors
error_injection(bitflip_circuit, 0,1,2)

## STEP 3:detection
detection(bitflip_circuit,0,1,2,3,4)

## STEP 4:correction
correction(bitflip_circuit,0,1,2,3,4,crz,crx)


bitflip_circuit.draw()
```



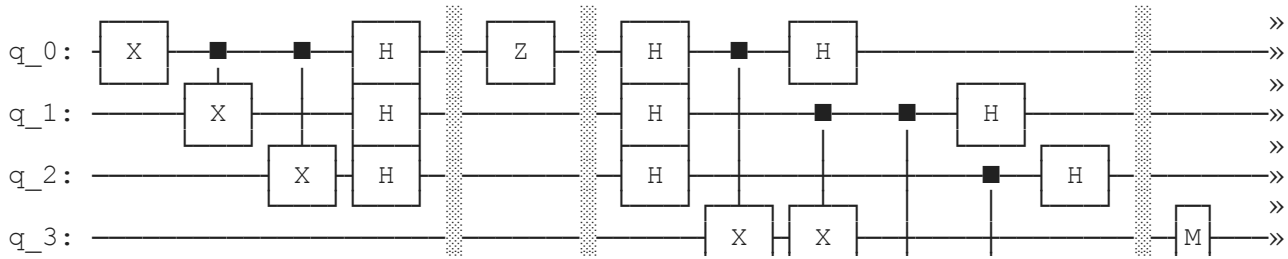


THE 3 QUBIT PHASE-FLIP CODE

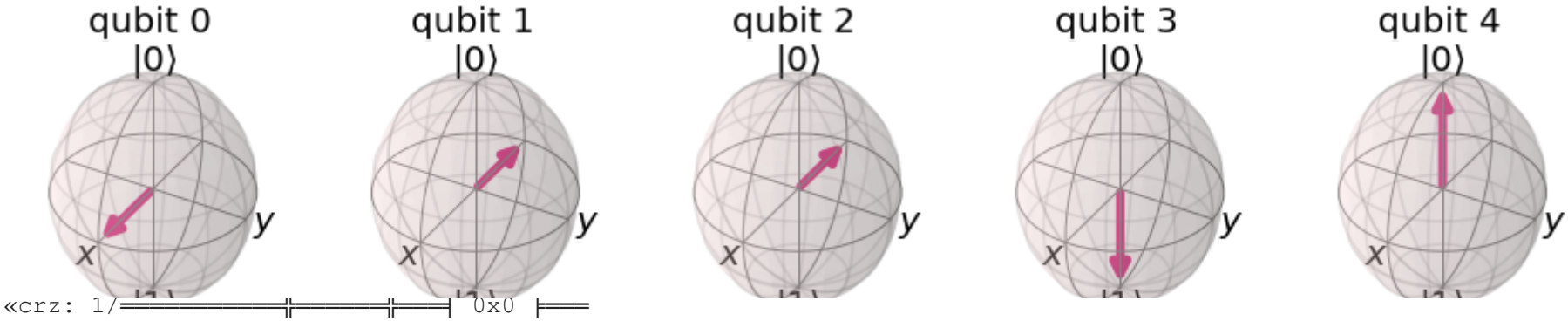
```
def encoding(qc, d0, d1, d2):

    #### your code goes here
    qc.x(d0)
    qc.cnot(d0,d1)
    qc.cnot(d0,d2)
    qc.h(d0)
```

```
    qc.h(d1)
    qc.h(d2)
    qc.barrier()


import random

def error_injection(qc, d0, d1, d2):
    #function for injecting a bit-flip on q0, or on q1 or on q2
    rand = random.randint(1,3)
    #### your code goes here
    if rand == 1: qc.z(d0)
    if rand == 2: qc.z(d1)
    if rand == 3: qc.z(d2)
    qc.barrier()


def detection(qc, d0, d1, d2,a0,a1):

     #### your code goes here
    qc.h(d0)
    qc.h(d1)
    qc.h(d2)
    qc.cnot(d0,a0)
    qc.cnot(d1,a0)
    qc.cnot(d1,a1)
    qc.cnot(d2,a1)
    qc.h(d0)
    qc.h(d1)
    qc.h(d2)

    qc.barrier()

    #measurement ancilla qubit



## SETUP
```

```
qr = QuantumRegister(5, name="q")
crz, crx = ClassicalRegister(1, name="crz"), ClassicalRegister(1, name="crx")
phaseflip_circuit = QuantumCircuit(qr,crz,crx)

## STEP 1: encoding
encoding(phaseflip_circuit, 0,1,2)

## STEP 2: inserting errors
error_injection(phaseflip_circuit, 0,1,2)

## STEP 3:detection
detection(phaseflip_circuit,0,1,2,3,4)

## STEP 4:correction
correction(phaseflip_circuit,0,1,2,3,4,crz,crx)


phaseflip_circuit.draw()
```




```
sv_sim = Aer.get_backend('statevector_simulator')
qobj = assemble(phaseflip_circuit)
out_vector = sv_sim.run(qobj).result().get_statevector()
plot_bloch_multivector(out_vector)
```



THE 7 QUBIT STEANE CODE

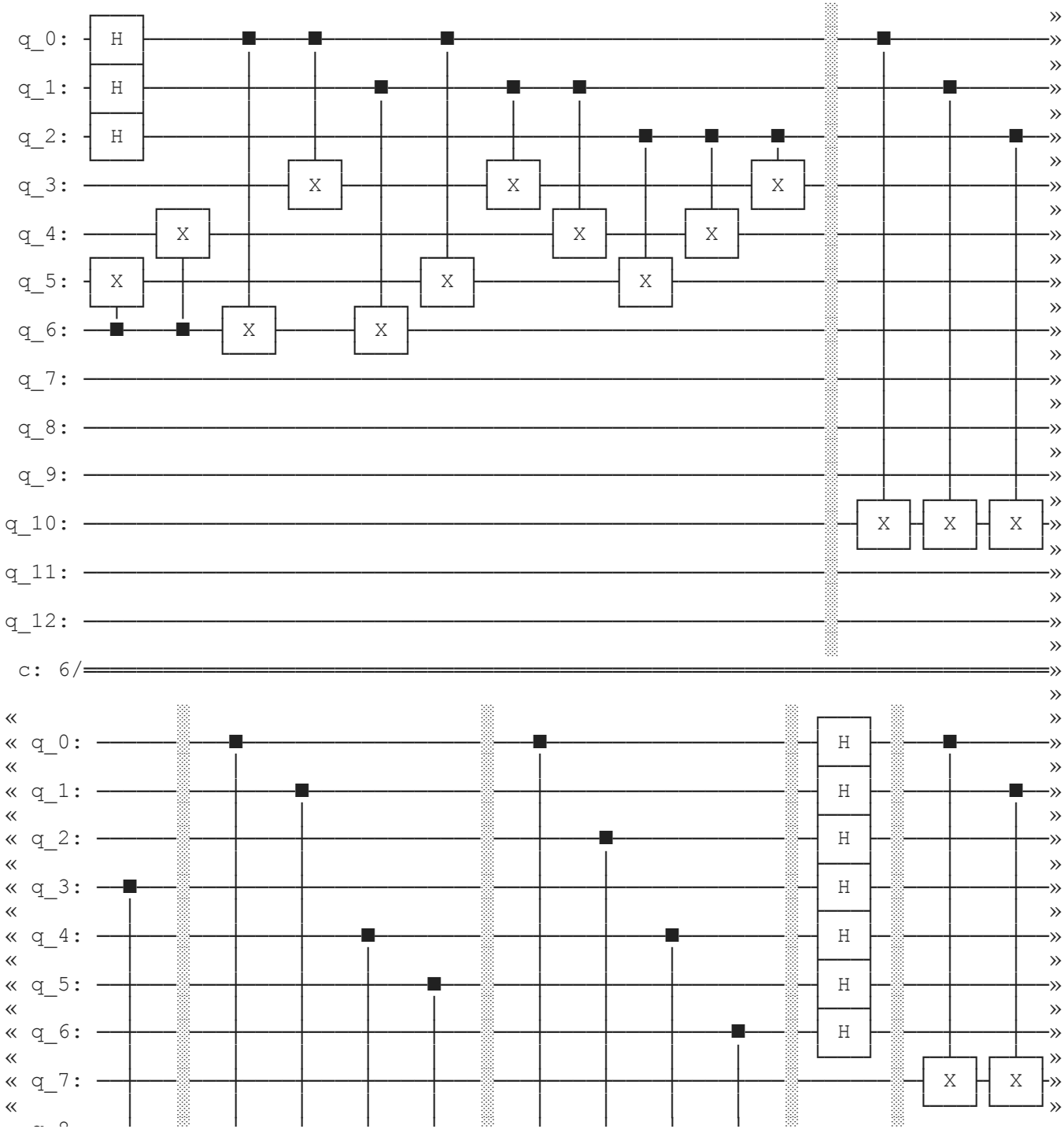
```
def encoding(qc, d0, d1, d2, d3, d4, d5, d6):
  qc.h(d0)
  qc.h(d1)
  qc.h(d2)
  qc.cnot(d6,d5)
  qc.cnot(d6,d4)
  qc.cnot(d0,d6)
  qc.cnot(d0,d3)
  qc.cnot(d0,d5)
  qc.cnot(d1,d6)
```

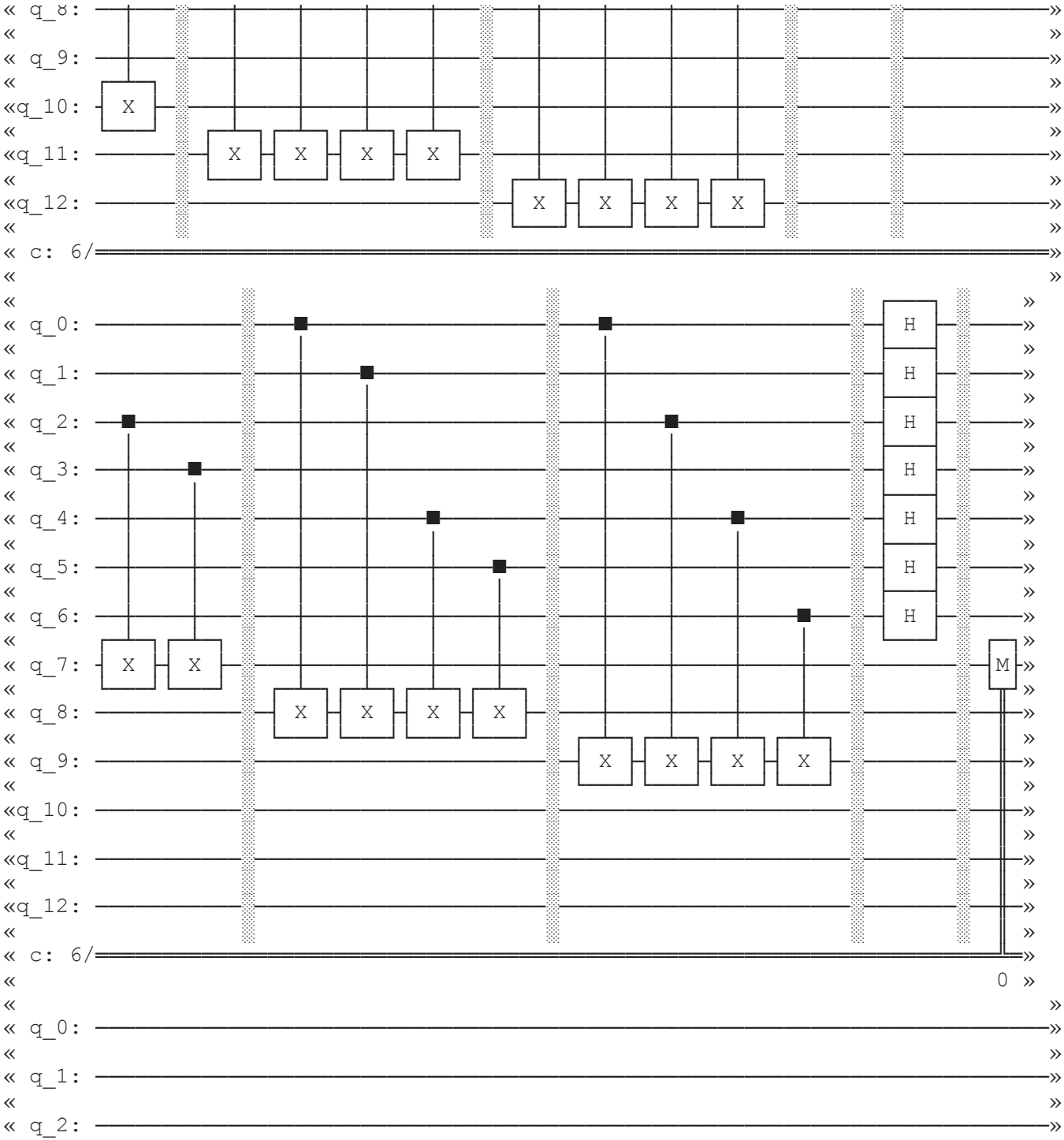
```
    qc.cnot(d1,d3)
    qc.cnot(d1,d4)
    qc.cnot(d2,d5)
    qc.cnot(d2,d4)
    qc.cnot(d2,d3)
    qc.barrier()

import random

def error_injection(qc, d0, d1, d2, d3, d4, d5, d6):
#function for injecting  phase-flip  and bit-flip errors
    rand = random.randint(1,7)
    rand2 = random.randint(1,2)
    #### your code goes here
    if rand == 1 and rand2 == 1: qc.x(d0)
    if rand == 1 and rand2 == 2: qc.z(d0)

    if rand == 2 and rand2 == 1: qc.x(d1)
    if rand == 2 and rand2 == 2: qc.z(d1)

    if rand == 3 and rand2 == 1: qc.x(d2)
    if rand == 3 and rand2 == 2: qc.z(d2)

    if rand == 4 and rand2 == 1: qc.x(d3)
    if rand == 4 and rand2 == 2: qc.z(d3)

    if rand == 5 and rand2 == 1: qc.x(d4)
    if rand == 5 and rand2 == 2: qc.z(d4)

    if rand == 6 and rand2 == 1: qc.x(d5)
    if rand == 6 and rand2 == 2: qc.z(d5)

    if rand == 7 and rand2 == 1: qc.x(d6)
    if rand == 7 and rand2 == 2: qc.z(d6)


    qc.barrier()
```

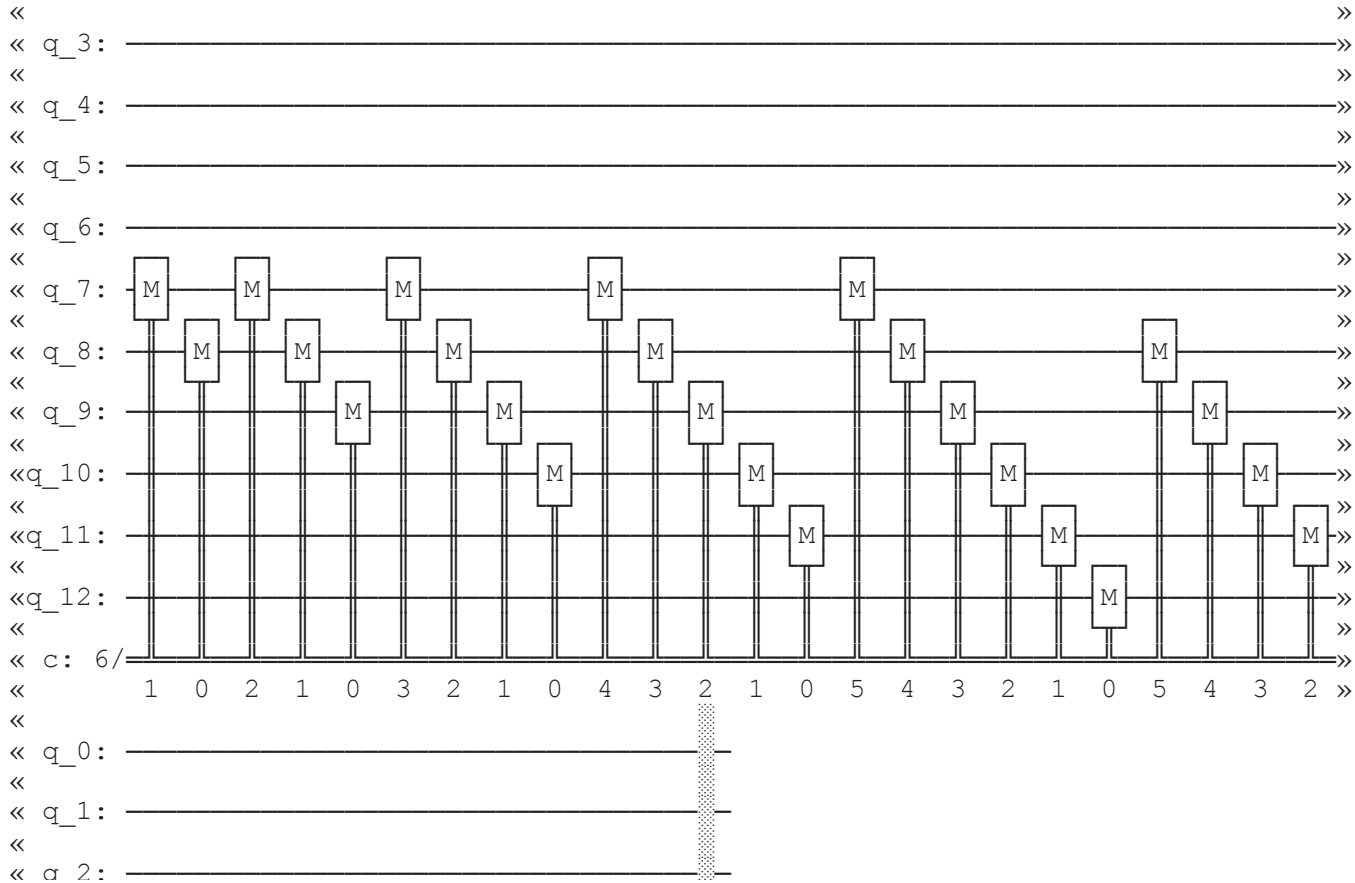
```
def detection(qc,d0,d1,d2,d3,d4,d5,d6,a1,a2,a3,a4,a5,a6,c):
  #ancilla 1
  qc.cnot(d0,a4)
  qc.cnot(d1,a4)
  qc.cnot(d2,a4)
  qc.cnot(d3,a4)
  qc.barrier()

  #ancilla 2
  qc.cnot(d0,a5)
  qc.cnot(d1,a5)
  qc.cnot(d4,a5)
  qc.cnot(d5,a5)
  qc.barrier()

  #ancilla 3
  qc.cnot(d0,a6)
  qc.cnot(d2,a6)
  qc.cnot(d4,a6)
  qc.cnot(d6,a6)
  qc.barrier()

  #hadamard
  qc.h(d0)
  qc.h(d1)
  qc.h(d2)
  qc.h(d3)
  qc.h(d4)
  qc.h(d5)
  qc.h(d6)
  qc.barrier()

  #ancilla 4
  qc.cnot(d0,a1)
  qc.cnot(d1,a1)
  qc.cnot(d2,a1)
  qc.cnot(d3,a1)
```

```
qc.barrier()

#ancilla 5
qc.cnot(d0,a2)
qc.cnot(d1,a2)
qc.cnot(d4,a2)
qc.cnot(d5,a2)
qc.barrier()

#ancilla 6
qc.cnot(d0,a3)
qc.cnot(d2,a3)
qc.cnot(d4,a3)
qc.cnot(d6,a3)
qc.barrier()

#hadamard
qc.h(d0)
qc.h(d1)
qc.h(d2)
qc.h(d3)
qc.h(d4)
qc.h(d5)
qc.h(d6)
qc.barrier()


#MEASUREMENT

qc.measure(a1,c)
qc.measure(a2,c)
qc.measure(a3,c)
qc.measure(a4,c)
qc.measure(a5,c)
qc.measure(a6,c)
qc.barrier()
```

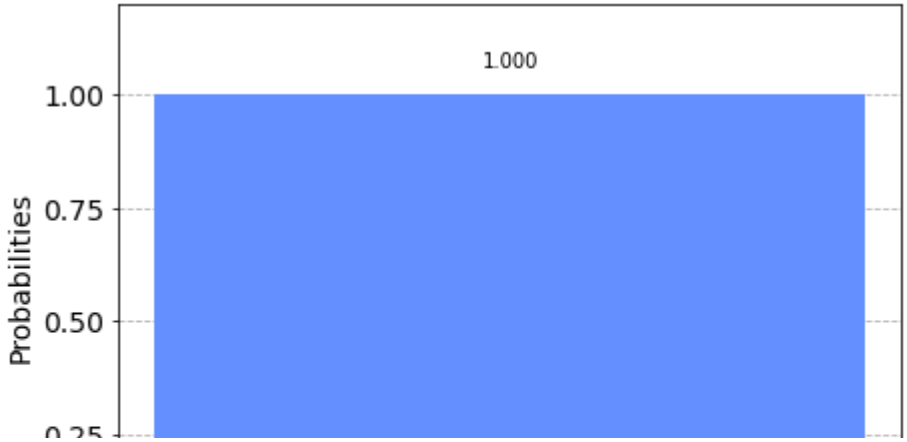
```
qr = QuantumRegister(13, name="q")
cr = ClassicalRegister(6, name="c")
## SETUP
steane_circuit = QuantumCircuit(qr,cr)

## STEP 1: encoding
encoding(steane_circuit,0,1,2,3,4,5,6)

## STEP 2: inserting errors
#error_injection(steane_circuit,0,1,2,3,4,5,6)

## STEP 3:detection
detection(steane_circuit,0,1,2,3,4,5,6,7,8,9,10,11,12,cr)

steane_circuit.draw()
```


q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
H
X


« q_8:
« q_9:
«q_10:
«q_11:
«q_12:
« c: 6/
« q_0:
« q_1:
« q_2:
« q_3:
« q_4:
« q_5:
« q_6:
« q_7:
« q_8:
« q_9:
«q_10:
«q_11:
«q_12:
« c: 6/
0
« q_0:
« q_1:
« q_2:
X
H
M

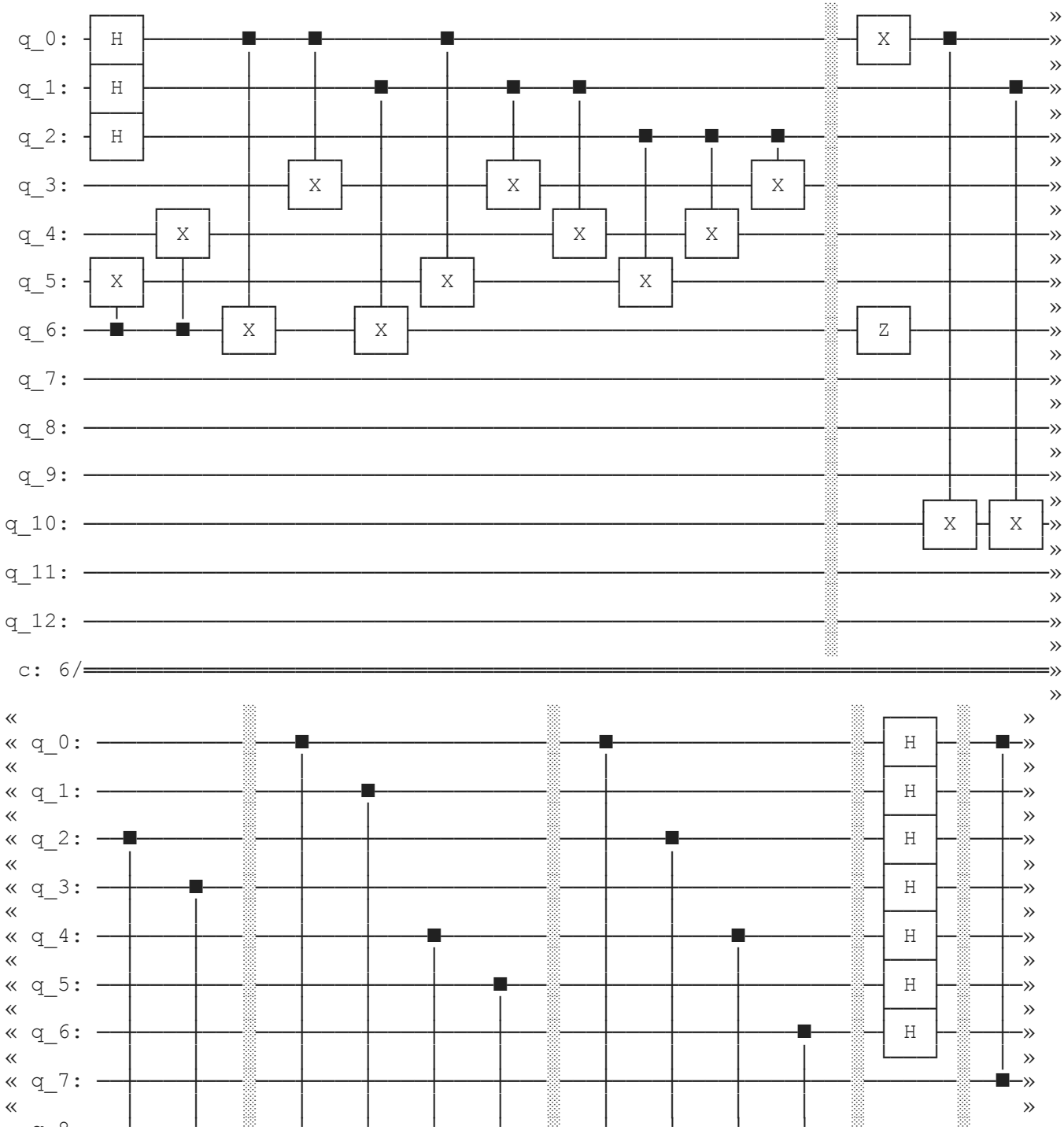



```
qasm_sim = Aer.get_backend('qasm_simulator')
t_qc = transpile(steane_circuit, qasm_sim)
qobj = assemble(t_qc)
results = qasm_sim.run(qobj).result()
counts = results.get_counts()
plot_histogram(counts)
```

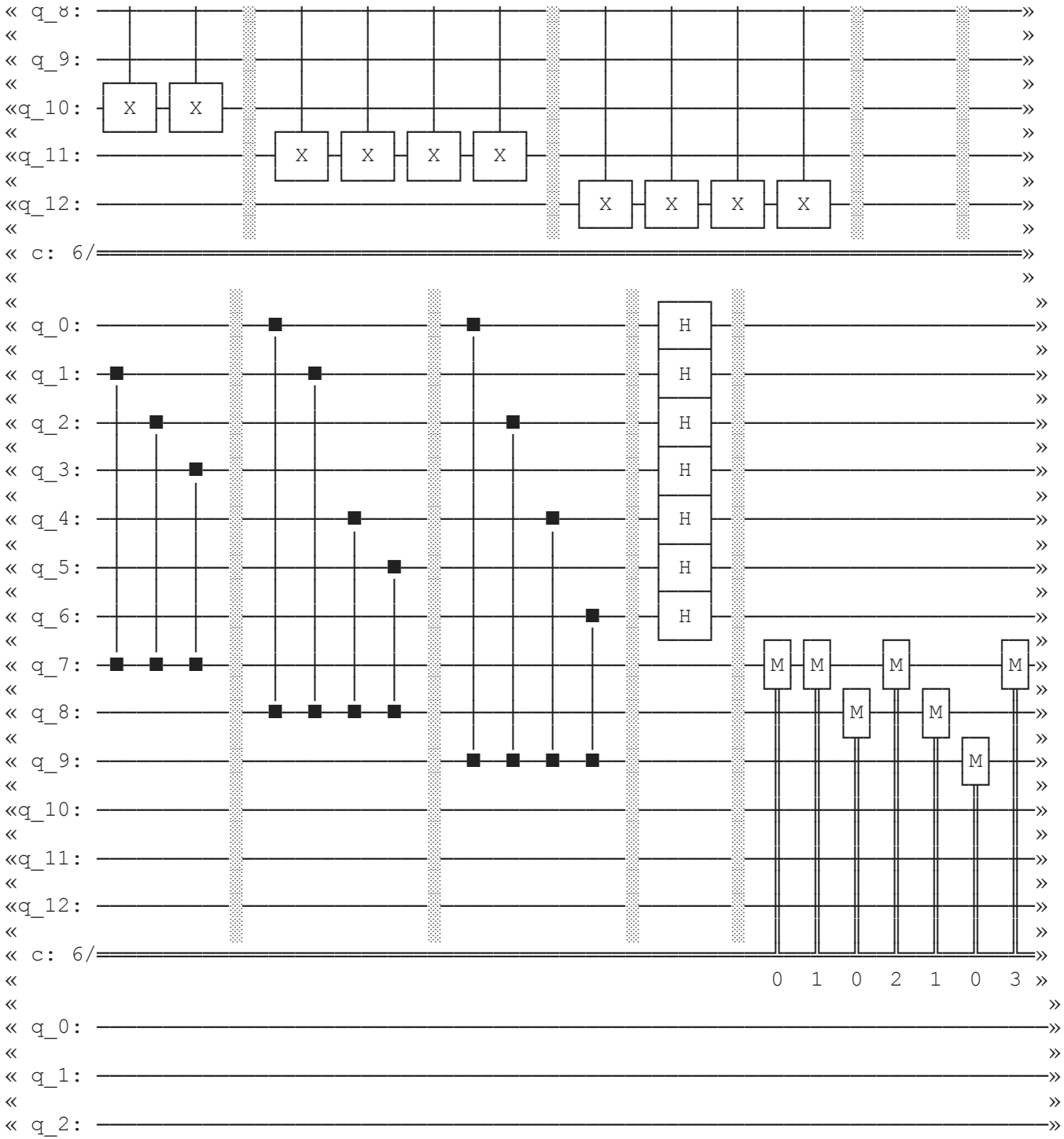


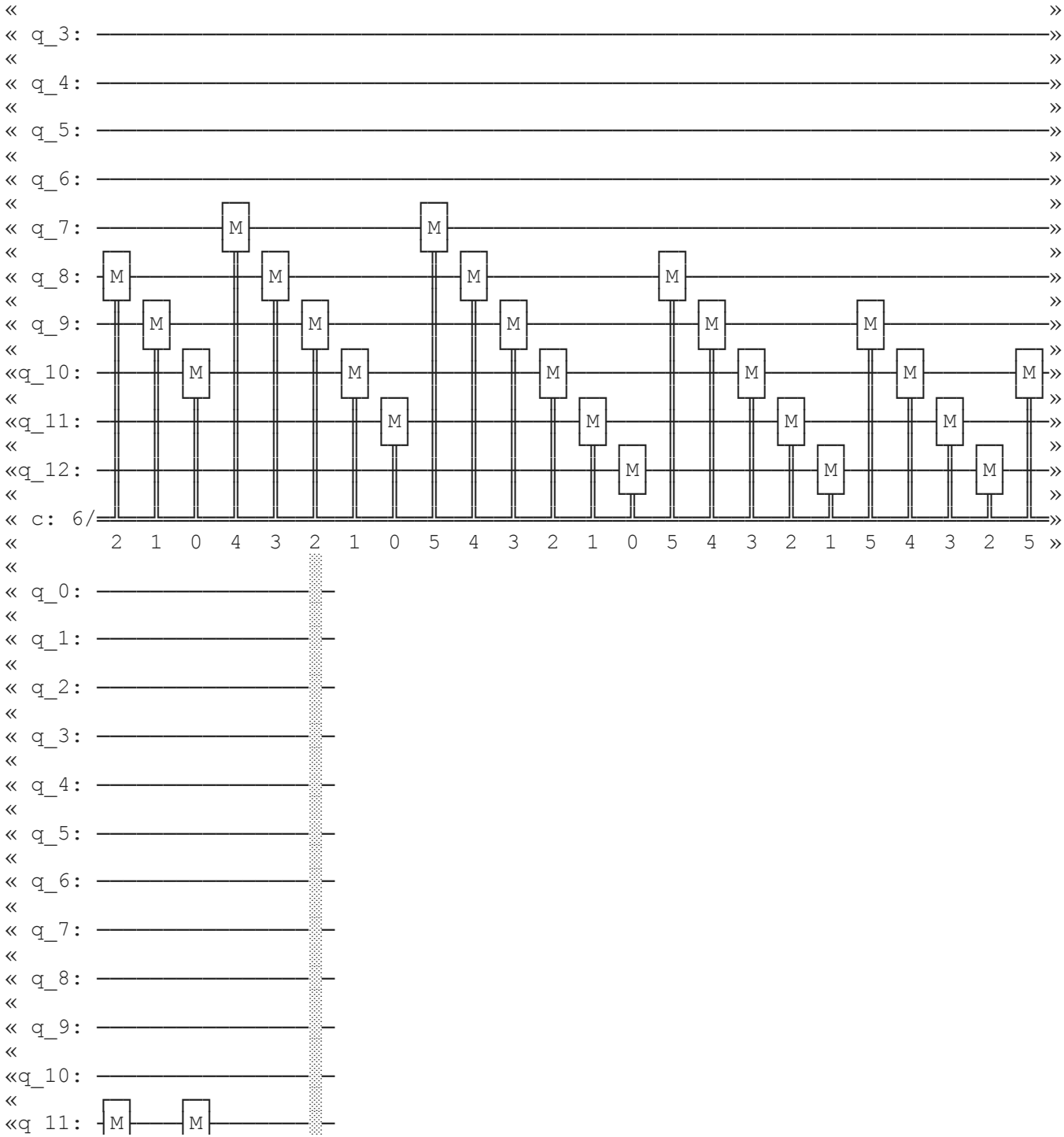
What is the error syndrome if we inject a bit-flip error on q0 and a phase flip error on q6? Are these errors detectable and correctable?

```
def error_injection(qc, d0, d1, d2, d3, d4, d5, d6):
  qc.x(d0)
  qc.z(d6)


qr = QuantumRegister(13, name="q")
cr = ClassicalRegister(6, name="c")
## SETUP
steane_circuit = QuantumCircuit(qr,cr)

## STEP 1: encoding
encoding(steane_circuit,0,1,2,3,4,5,6)

## STEP 2: inserting errors
error_injection(steane_circuit,0,1,2,3,4,5,6)

## STEP 3:detection
detection(steane_circuit,0,1,2,3,4,5,6,7,8,9,10,11,12,cr)

steane_circuit.draw()
```


q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
H
X
Z

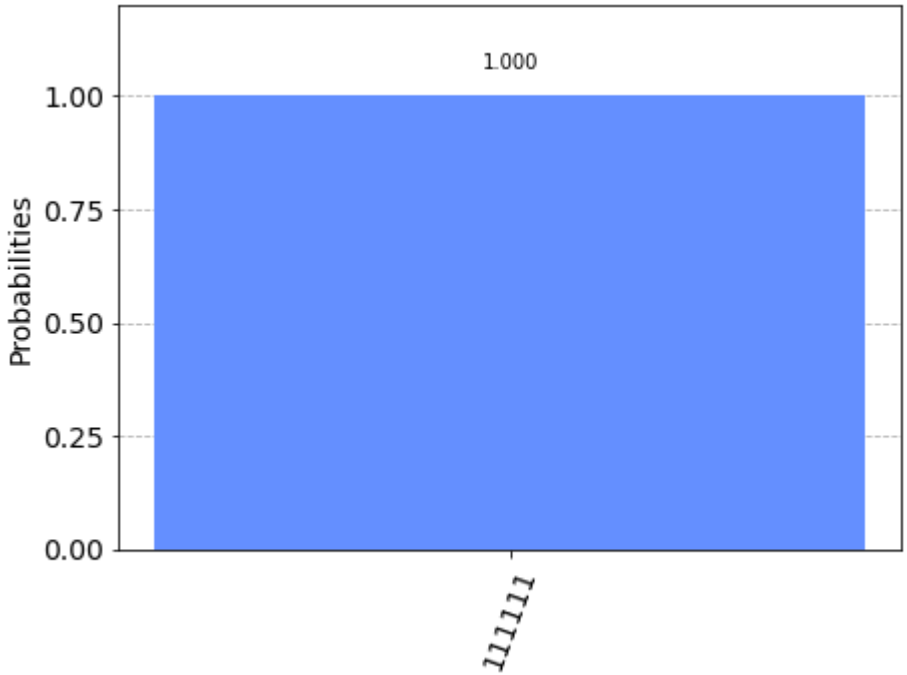
q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
H


« q_8:
« q_9:
«q_10:
«q_11:
«q_12:
« c: 6/
X
« q_0:
« q_1:
« q_2:
« q_3:
« q_4:
« q_5:
« q_6:
« q_7:
« q_8:
« q_9:
«q_10:
«q_11:
«q_12:
« c: 6/
H
M
0 1 0 2 1 0 3
« q_0:
« q_1:
« q_2:


q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
2 1 0 4 3 2 1 0 5 4 3 2 1 0 5 4 3 2 1 5 4 3 2 5
q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
M

```
«                 
«q_12: ─┤M├─┤M├─┤M├─
«                 
« c: 6/═══════════════
```

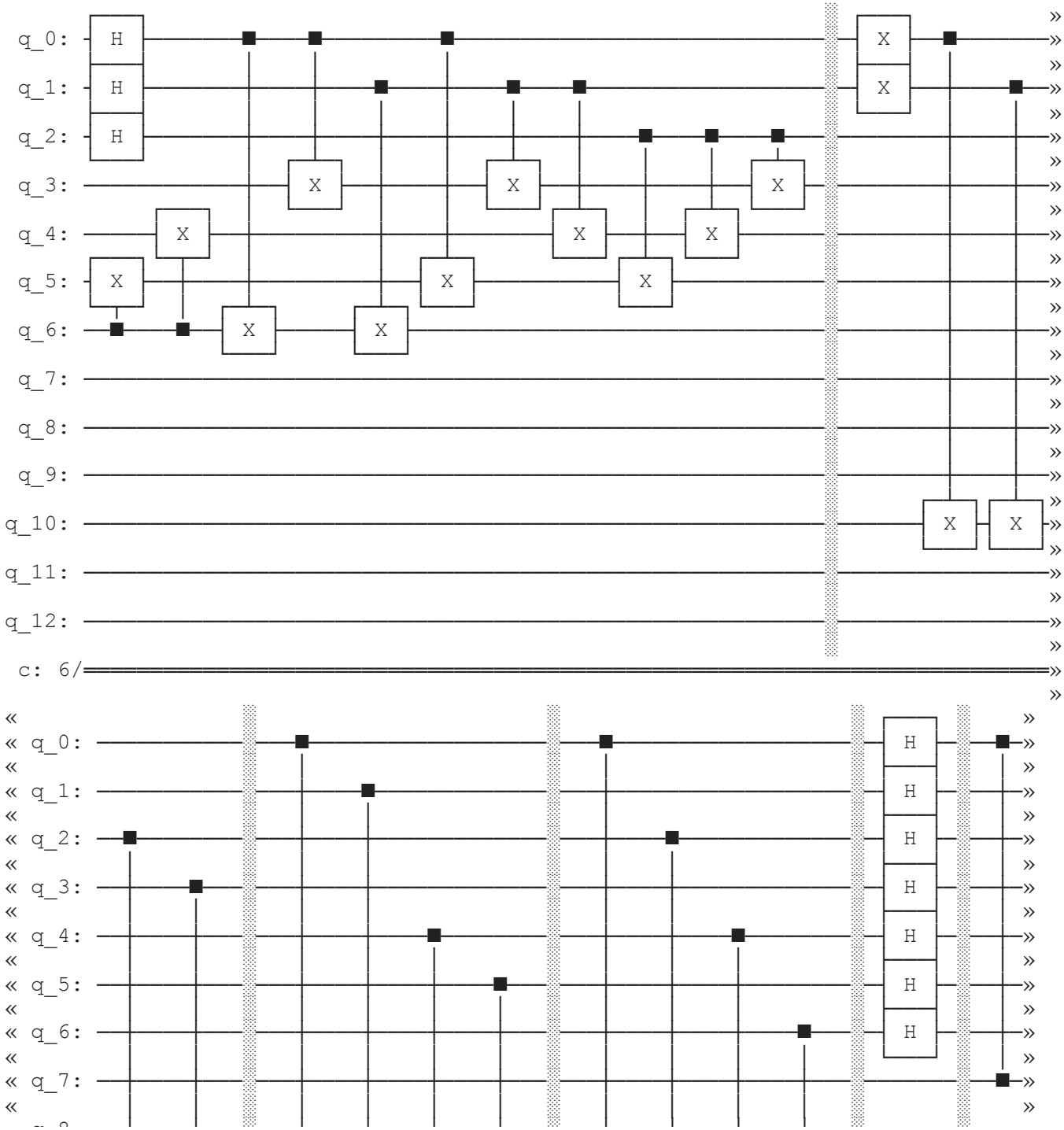
```
qasm_sim = Aer.get_backend('qasm_simulator')
t_qc = transpile(steane_circuit, qasm_sim)
qobj = assemble(t_qc)
results = qasm_sim.run(qobj).result()
counts = results.get_counts()
plot_histogram(counts)
```

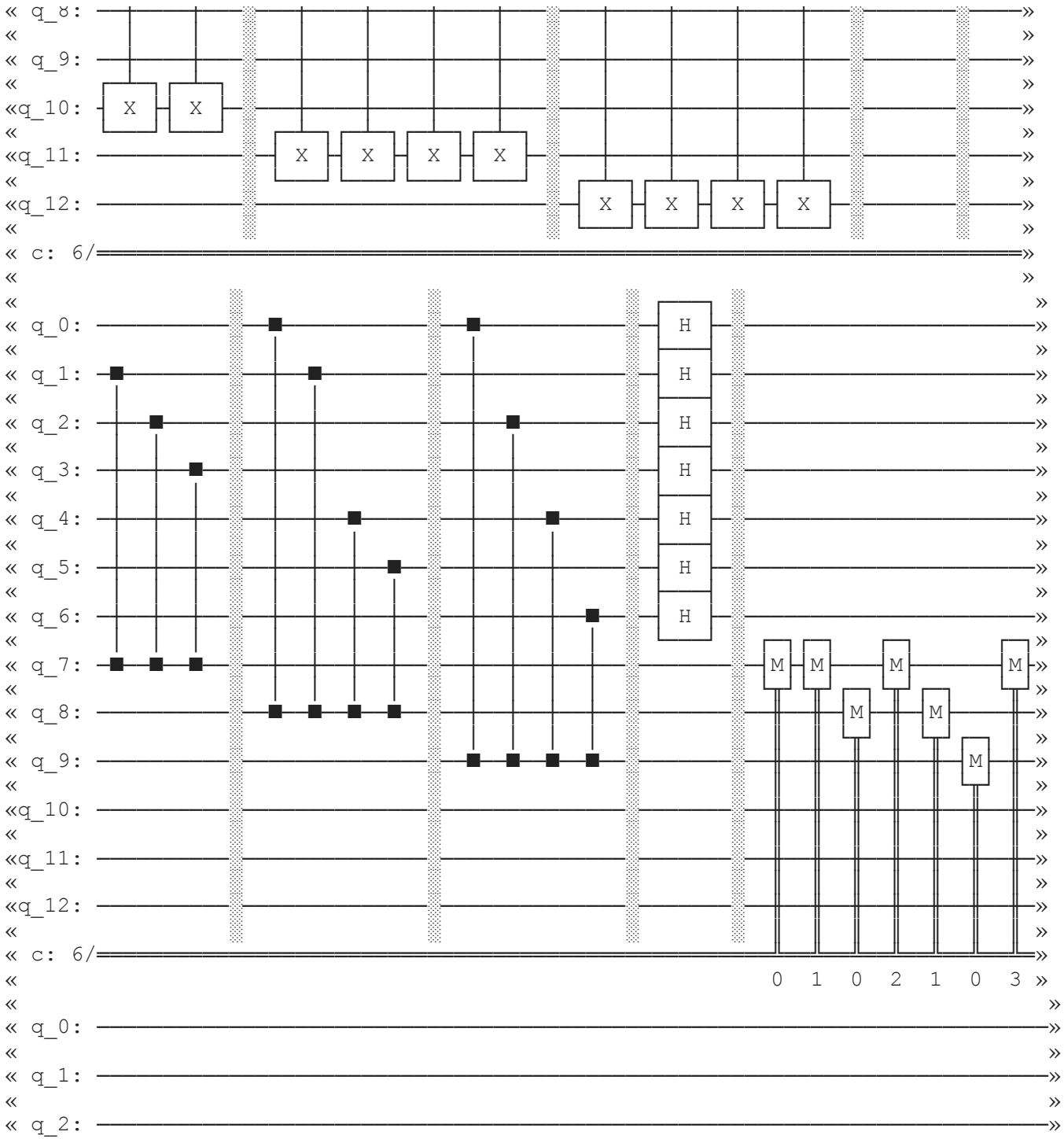


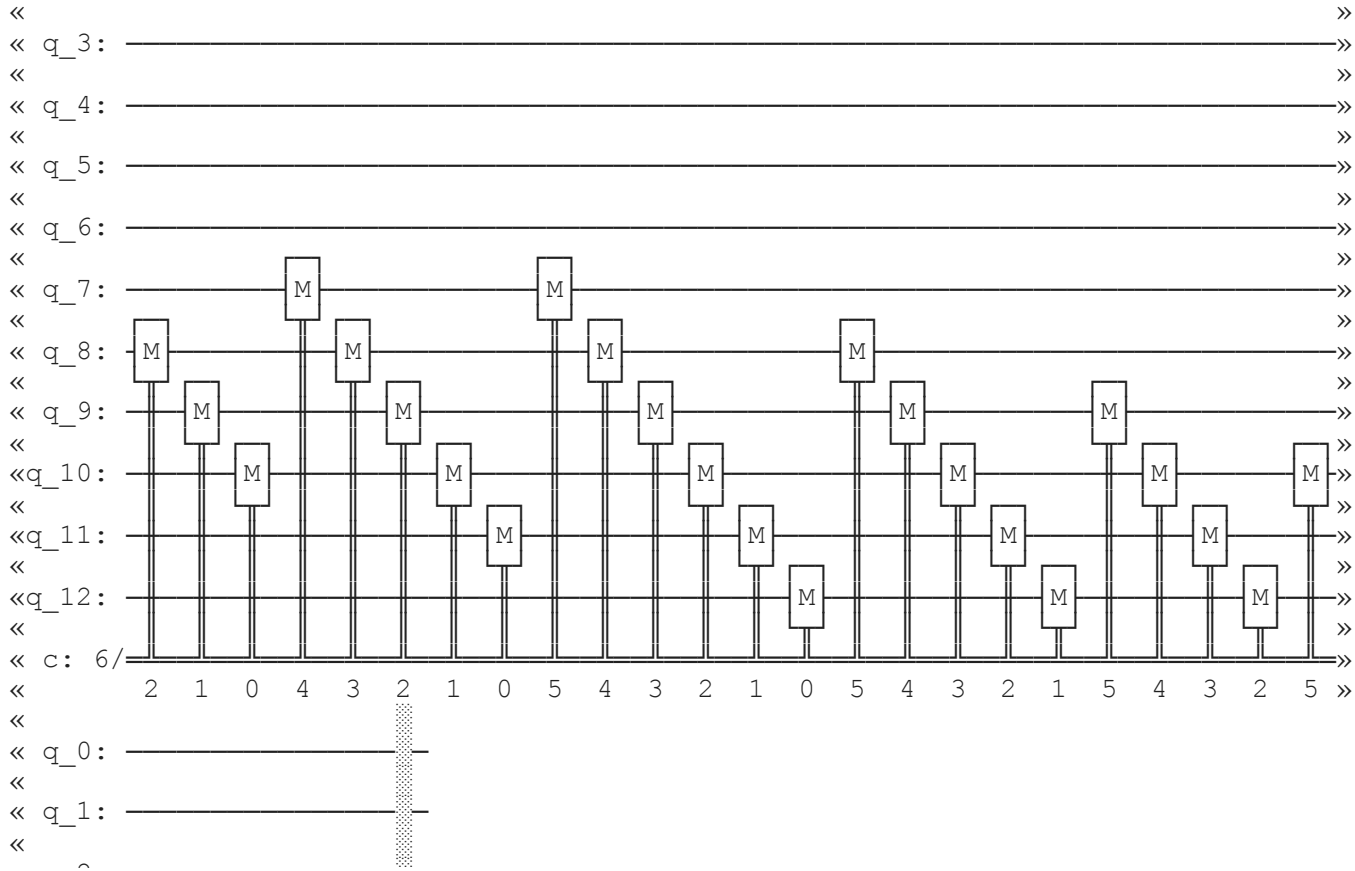
What is the error syndrome if we inject two bit-flip errors simultaneously, one on q0 and another on q1? Are these errors detectable and correctable? Why?

```
def error_injection(qc, d0, d1, d2, d3, d4, d5, d6):
  qc.x(d0)
```

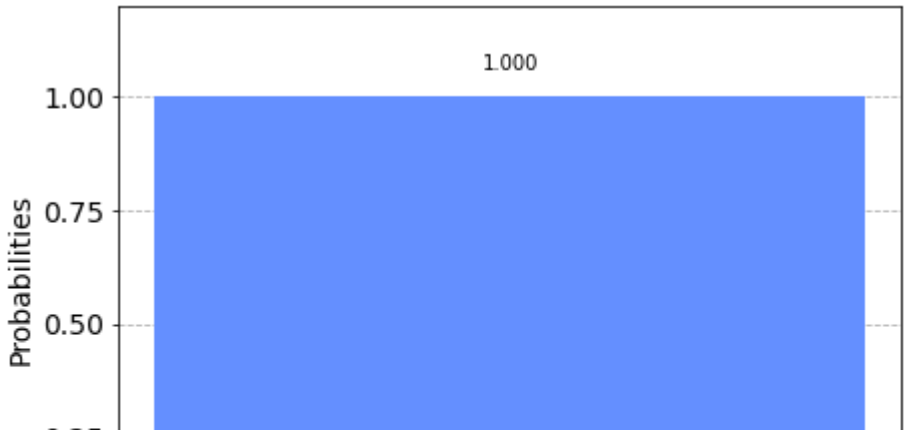
```
    qc.x(d1)

qr = QuantumRegister(13, name="q")
cr = ClassicalRegister(6, name="c")
## SETUP
steane_circuit = QuantumCircuit(qr,cr)

## STEP 1: encoding
encoding(steane_circuit,0,1,2,3,4,5,6)

## STEP 2: inserting errors
error_injection(steane_circuit,0,1,2,3,4,5,6)

## STEP 3:detection
detection(steane_circuit,0,1,2,3,4,5,6,7,8,9,10,11,12,cr)

steane_circuit.draw()
```


q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
H
X


q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
X
q_0:
q_1:
q_2:
q_3:
q_4:
q_5:
q_6:
q_7:
q_8:
q_9:
q_10:
q_11:
q_12:
c: 6/
H
M
0 1 0 2 1 0 3
q_0:
q_1:
q_2:




```
qasm_sim = Aer.get_backend('qasm_simulator')
t_qc = transpile(steane_circuit, qasm_sim)
qobj = assemble(t_qc)
results = qasm_sim.run(qobj).result()
counts = results.get_counts()
plot_histogram(counts)
```



NO ENTIENDO PORQUE ME DA ESTOS RESULTADOS EN LOS APARTADOS CUANDO HE COMPROBADO MIL VECES QUE EL CIRCUITO ESTUVIERA BIEN. NO ENTIENDO PORQUE CUANDO HAY UN ERROR CUALQUIERA TODO SE PONE A 1'S CUANDO HACEMOS EL HISTOGRAMA. HE ESTADO COMENTÁNDOLO CON ALGUNOS COMPAÑEROS Y EN LAS ÚLTIMAS DOS PREGUNTAS DEBERÍA HABER ERRORES Y SIN EMBARGO SE COMPORTA COMO LO HACE NORMALMENTE. POR ELLO NO HE PODIDO TERMINAR LA ÚLTIMA TABLA.

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✓ 0 s completado a las 19:49