digitalPIDStep

May 29, 2021

1 PID digital

[1]:
```
import numpy as np
import control as ct
import matplotlib.pyplot as plt
```

1.1 Simulation parameters

[2]:
```
# Time parameters
tsim = 0.1
dt = 0.001

# Time and reference signal
t = np.arange(0, tsim, dt)
R = 6*np.ones(len(t))
```

1.2 Simple step response (Ignoring saturation)

[3]:
```
# Plant
num1 = [29870]
den1 = [1, 414.7, 33610]
G = ct.tf(num1, den1)

# Controller
Kp = 3.84808815
Ti = 0.00711849
Td = 0
Gc = ct.tf([Kp*Ti*Td, Kp*Ti, Kp],[Ti, 0])



# Closed-loop system
sys = ct.feedback(Gc*G)
t1, C1 = ct.forced_response(sys,t,R)

print('Plant:', G)
```

```
Plant:
        2.987e+04
```

```
-------------------------
s^2 + 414.7 s + 3.361e+04
```

2 Digital PID: NO Anti-windup

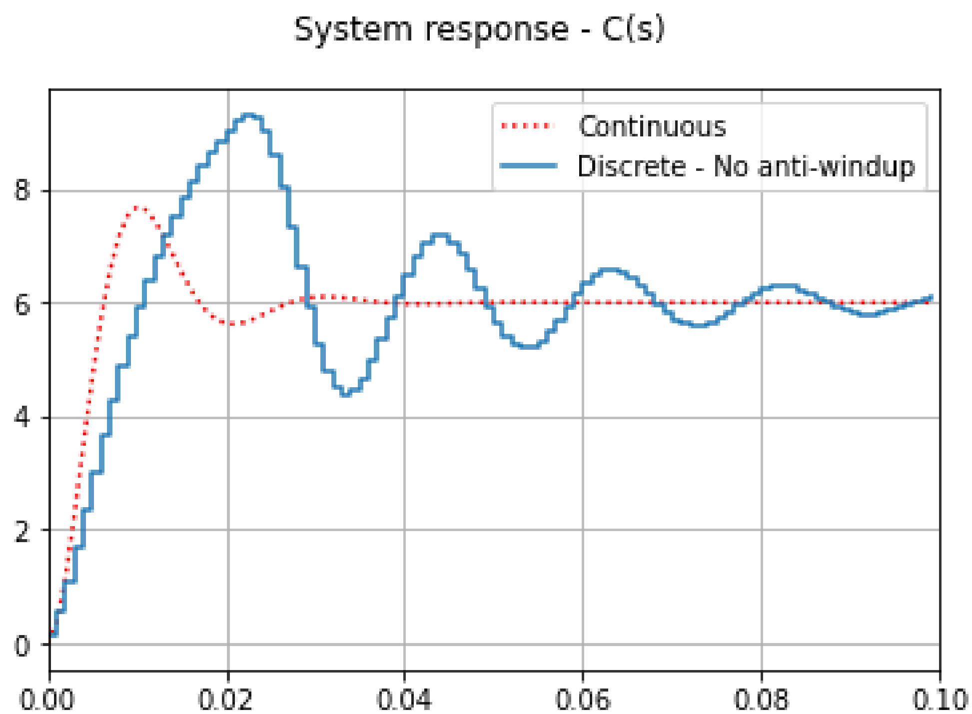
[4]:
```python
# Digital PID
ts = 0.002
b0 = Kp*(1 + (ts/(2*Ti)) + (Td/ts))
b1 = -Kp*(1 - (ts/(2*Ti)) + (2*Td/ts))
b2 = Kp*Td/ts

print('b0: {a:1.4f}, b1: {b:1.4f},b2: {c:1.4f} '.format(a=b0, b=b1, c=b2))
```

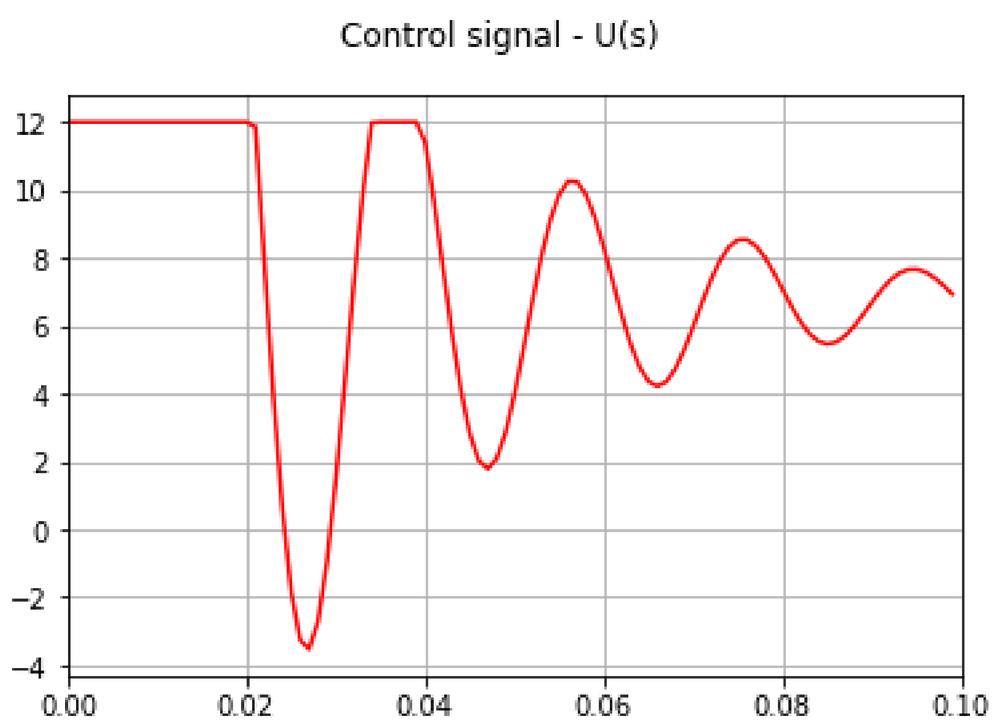
```
b0: 4.3887, b1: -3.3075,b2: 0.0000
```

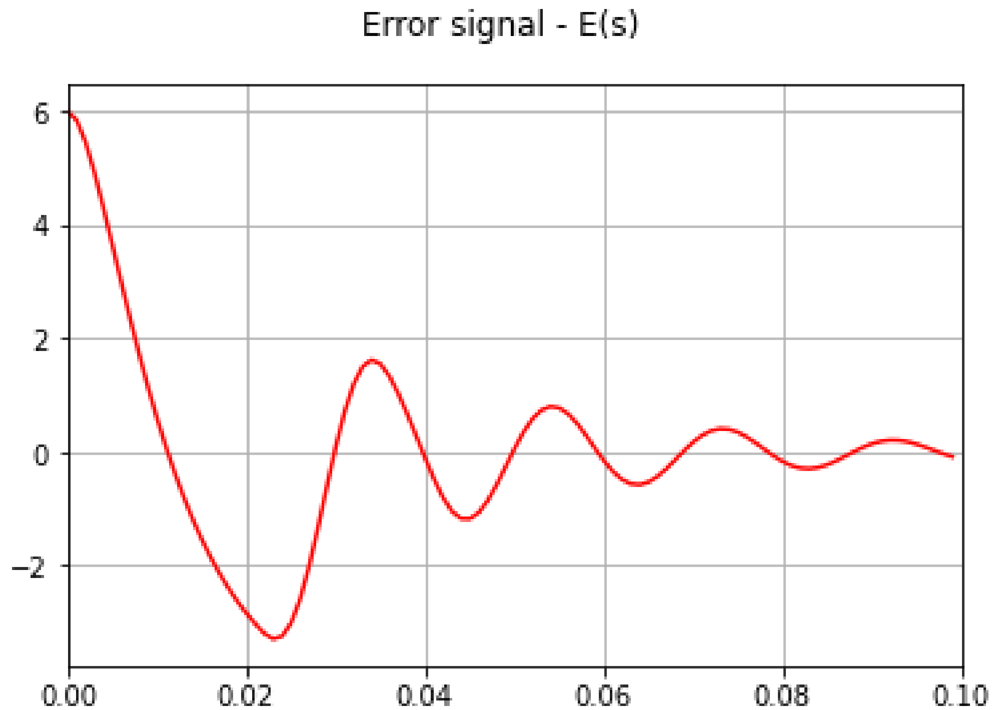
[5]:
```python
# Conver to space states to allow initial conditions
Gss = ct.tf2ss(G)

# Initial conditions
xPre = np.zeros(len(G.pole()))

# Accumulated system response
C2 = np.zeros(len(t))

# Accumulated control signal
Vacc = np.zeros(len(t))

# Accumulated control signal (saturated)
Uacc = np.zeros(len(t))

#Accumulated error
Eacc = np.zeros(len(t))

# Saturation limits
lUp = 12
lDo = -12

for i, ti in enumerate(t):
    # Error
    e = R[i] - C2[i-1]

    # Controller - ( Vacc[i] = U for antiWindup)
    V = b0*e + b1*Eacc[i-1] + b2*Eacc[i-2] + Vacc[i-1]
    U = max(min(V, lUp), lDo)

    # Plant response
```

```
    _, Ci, Xi = ct.forced_response(Gss, [ti-dt,ti], [U,U], X0 = xPre, return_x␣
↪= True)

    # Save results
    C2[i] = np.squeeze(Ci[-1])
    xPre = np.squeeze(Xi[:,-1])

    Eacc[i] = e
    Vacc[i] = V
    Uacc[i] = U
```

[6]:
```
# Compare
plt.plot(t1, C1, 'r:', label = "Continuous" )
plt.step(t, C2, where= "post", label = "Discrete - No anti-windup")
plt.xlim((0,tsim))
plt.suptitle("System response - C(s)")
plt.legend()
plt.grid()

#Controller
plt.figure()
plt.plot(t, Uacc, 'r');
plt.xlim((0, tsim))
plt.suptitle("Control signal - U(s)")
plt.grid()

#Error
plt.figure()
plt.plot(t, Eacc, 'r');
plt.xlim((0, tsim))
plt.suptitle("Error signal - E(s)")
plt.grid()
```


System response - C(s)
Continuous
Discrete - No anti-windup
0
2
4
6
8
0.00
0.02
0.04
0.06
0.08
0.10


Control signal - U(s)
−4
−2
0
2
4
6
8
10
12
0.00
0.02
0.04
0.06
0.08
0.10

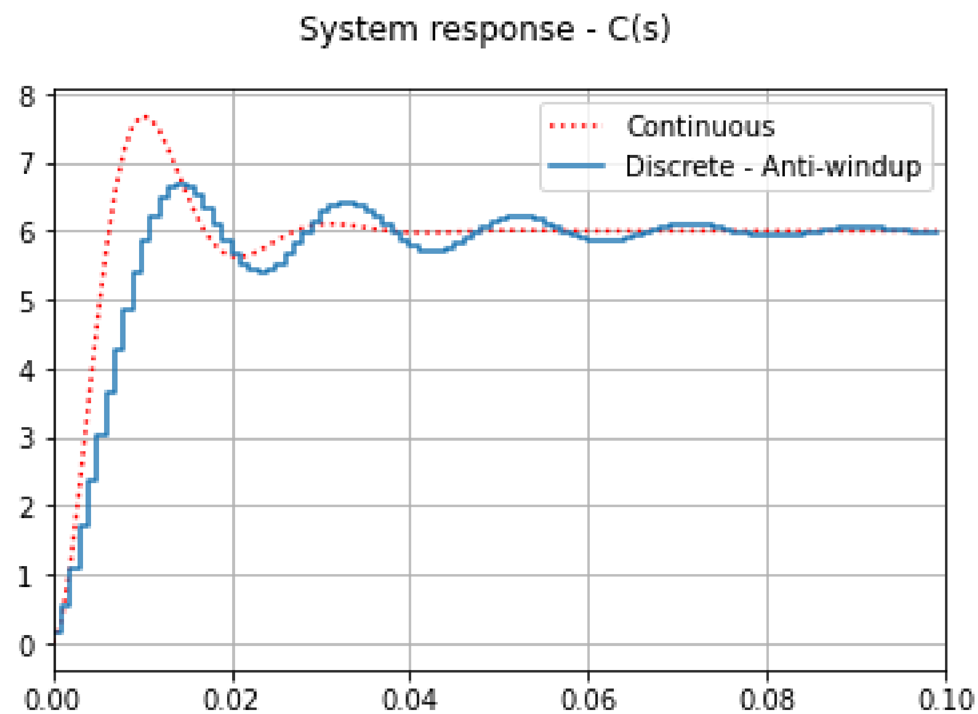


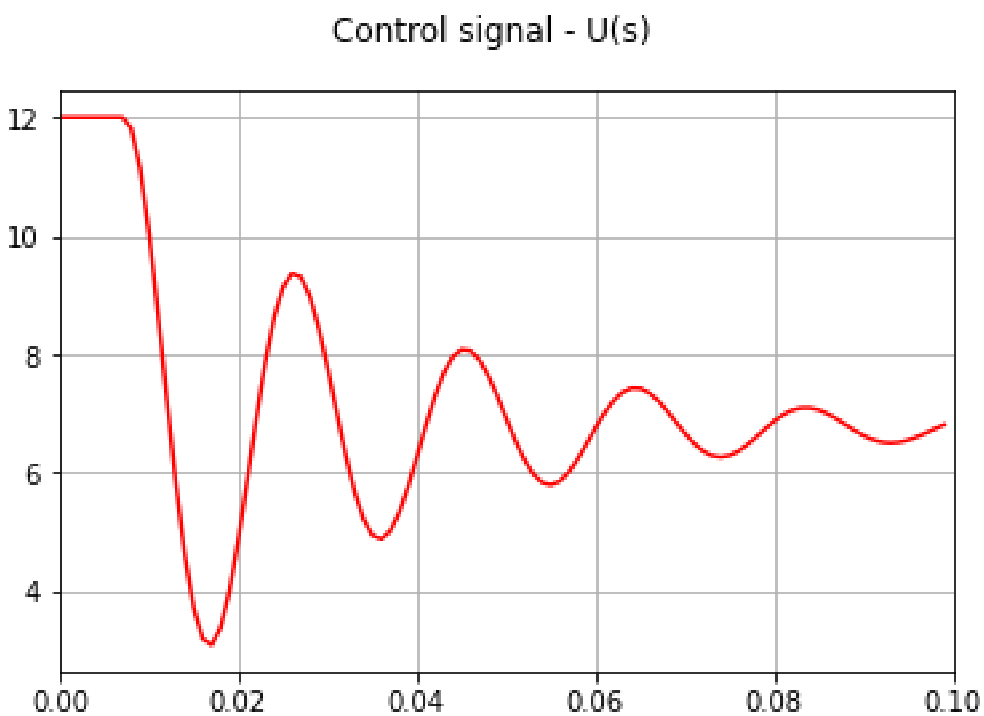
3 Digital PID: Anti-windup

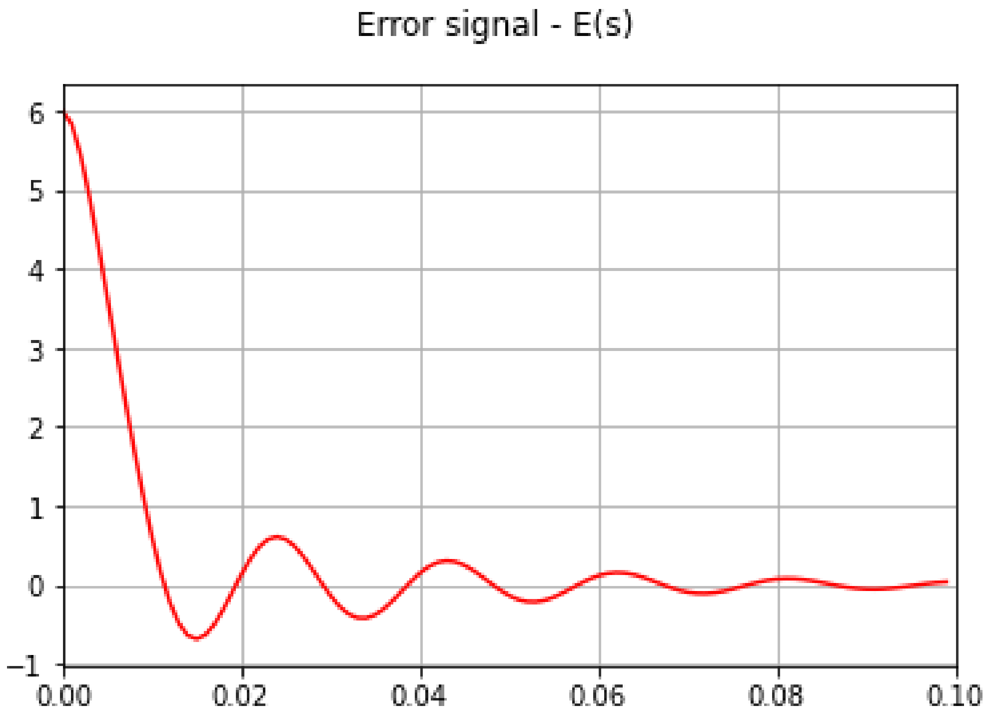
[7]:
```
# Conver to space states to allow initial conditions
Gss = ct.tf2ss(G)

# Initial conditions
xPre = np.zeros(len(G.pole()))

# Accumulated system response
C2 = np.zeros(len(t))

# Accumulated control signal
Vacc = np.zeros(len(t))

# Accumulated control signal (saturated)
Uacc = np.zeros(len(t))

#Accumulated error
Eacc = np.zeros(len(t))

# Saturation limits
lUp = 12
```

```python
lDo = -12

for i, ti in enumerate(t):
    # Error
    e = R[i] - C2[i-1]

    # Controller - ( Vacc[i] = U for antiWindup)
    V = b0*e + b1*Eacc[i-1] + b2*Eacc[i-2] + Vacc[i-1]
    U = max(min(V, lUp), lDo)

    # Plant response
    _, Ci, Xi = ct.forced_response(Gss, [ti-dt,ti], [U,U], X0 = xPre, return_x␣
↪= True)

    # Save results
    C2[i] = np.squeeze(Ci[-1])
    xPre = np.squeeze(Xi[:,-1])

    Eacc[i] = e
    Vacc[i] = U
    Uacc[i] = U
```

[8]:
```python
# Compare
plt.plot(t1, C1, 'r:', label = "Continuous" )
plt.step(t, C2, where= "post", label = "Discrete - Anti-windup")
plt.xlim((0,tsim))
plt.suptitle("System response - C(s)")
plt.legend()
plt.grid()

#Controller
plt.figure()
plt.plot(t, Uacc, 'r');
plt.xlim((0, tsim))
plt.suptitle("Control signal - U(s)")
plt.grid()

#Error
plt.figure()
plt.plot(t, Eacc, 'r');
plt.xlim((0, tsim))
plt.suptitle("Error signal - E(s)")
plt.grid()
```


System response - C(s)
Continuous
Discrete - Anti-windup
8
7
6
5
4
3
2
1
0
0.00
0.02
0.04
0.06
0.08
0.10


Control signal - U(s)
12
10
8
6
4
0.00
0.02
0.04
0.06
0.08
0.10


Error signal - E(s)
6
5
4
3
2
1
0
−1
0.00
0.02
0.04
0.06
0.08
0.10