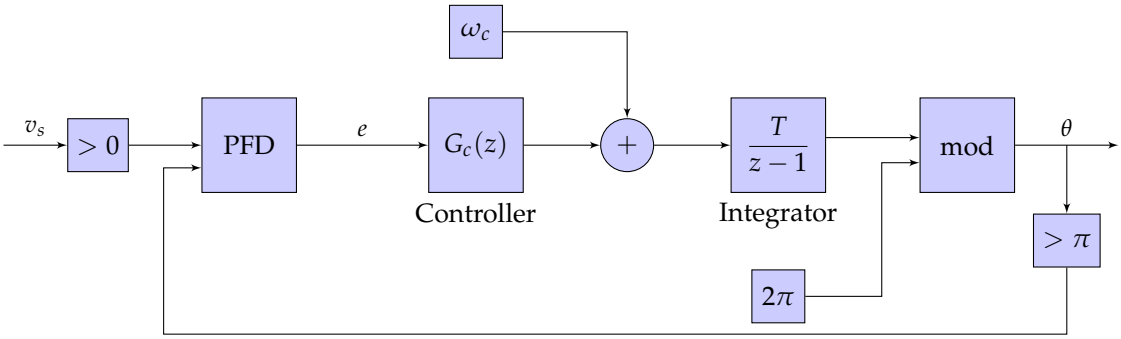
DIGITAL CONTROL OF POWER ELECTRONICS

Single Phase PLL using fixed point Q format



We are going to convert the low pass filter design to a digital controller. Below are the gain, pole location, and transfer function for the controller/ low pass filter/ loop filter.

$$k = 105075 \quad \omega_p = 258.6 \tag{1}$$

$$G_{LF}(s) = \frac{105075}{s + 258.6} \tag{2}$$

Below is the matlab code to develop the digital controllers for a low pass controller

```
%% low pass single phase pll
clear
syms s wp k p

gol = 1/(2*p) * k/(s+wp) * 1/s
gcl = gol/(1+gol)

clear
s=tf('s');
opts = bodeoptions('cstprefs');
opts.FreqUnits = 'Hz';
opts.XLim= {[.1 10000]}

kvco = 1

fbw = 10
zeta = 1
w = 2 * pi * fbw
a =1
b = -(2^2*zeta^2*2*pi*w^2)
c = -(2*pi)^2*w^4

k1 = (-b+sqrt(b^2-4*a*c))/2
k2 = (-b-sqrt(b^2-4*a*c))/2
wf = 2*zeta*sqrt(k1/(2*pi))

GLPF = k1/(s+wf)
%digital controller
Ts = 1/10e3
Z=tf('z',Ts)
```

```
sback = ((Z-1)/(Z*Ts))
gc_dig_backward = k1 / (sback +wf)
gc_dig_zoh = c2d(GLPF,1/10e3,'zoh')
gc_dig_tustin = c2d(GLPF,1/10e3,'tustin')


%% calculate coeff for fixed point Q21 backward euler
Q = 21;
Bcoeff = int32(gc_dig_backward.Numerator{1}*2^Q);
Acoeff = int32(gc_dig_backward.Denominator{1}*2^Q);

fprintf('int32 A1 = %i;\n',Acoeff(1))
fprintf('int32 A0 = %i;\n',Acoeff(2))
fprintf('int32 B1 = %i;\n',Bcoeff(1))
fprintf('int32 B0 = %i;\n',Bcoeff(2))

%% calculate coeff for fixed point Q21 tustin
Q = 21;
Bcoeff = int32(gc_dig_tustin.Numerator{1}*2^Q);
Acoeff = int32(gc_dig_tustin.Denominator{1}*2^Q);

fprintf('int32 A1 = %i;\n',Acoeff(1))
fprintf('int32 A0 = %i;\n',Acoeff(2))
fprintf('int32 B1 = %i;\n',Bcoeff(1))
fprintf('int32 B0 = %i;\n',Bcoeff(2))
```

Below are the coefficients for backwards euler.

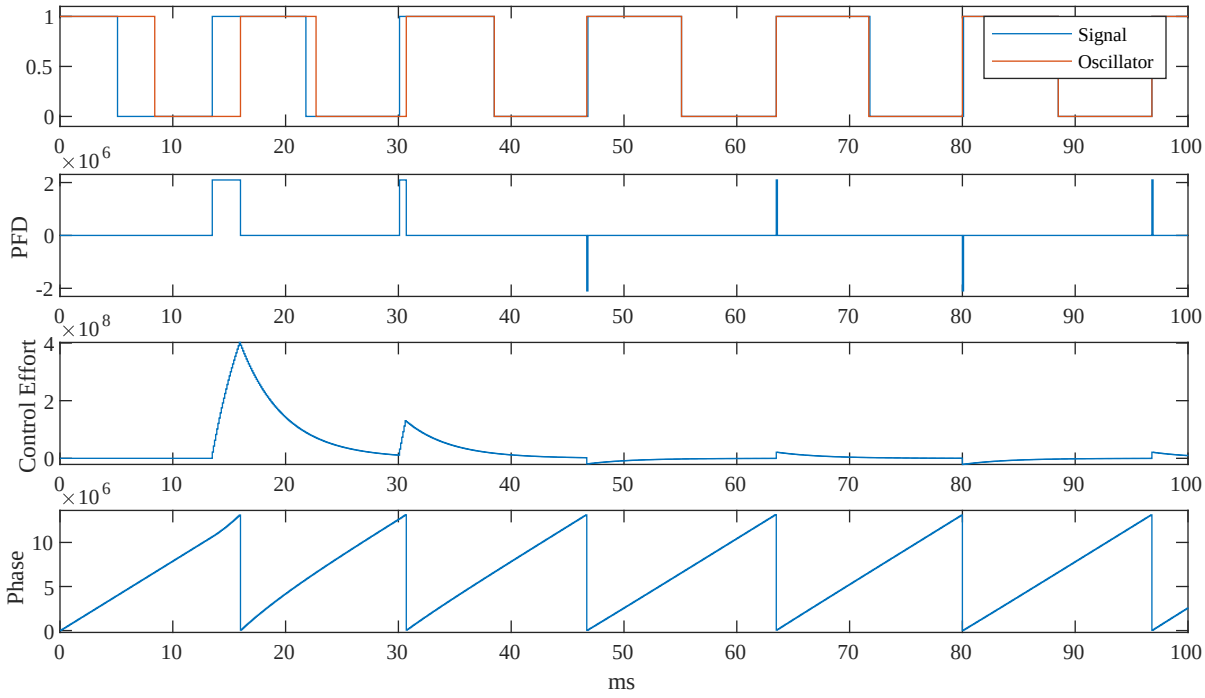
```
int32 A1 = 2151392;
int32 A0 = -2097152;
int32 B1 = 22035983;
int32 B0 = 0;
```

Below are the coefficients for tustin.

```
int32 A1 = 2097152;
int32 A0 = -2043604;
int32 B1 = 10877327;
int32 B0 = 10877327;
```

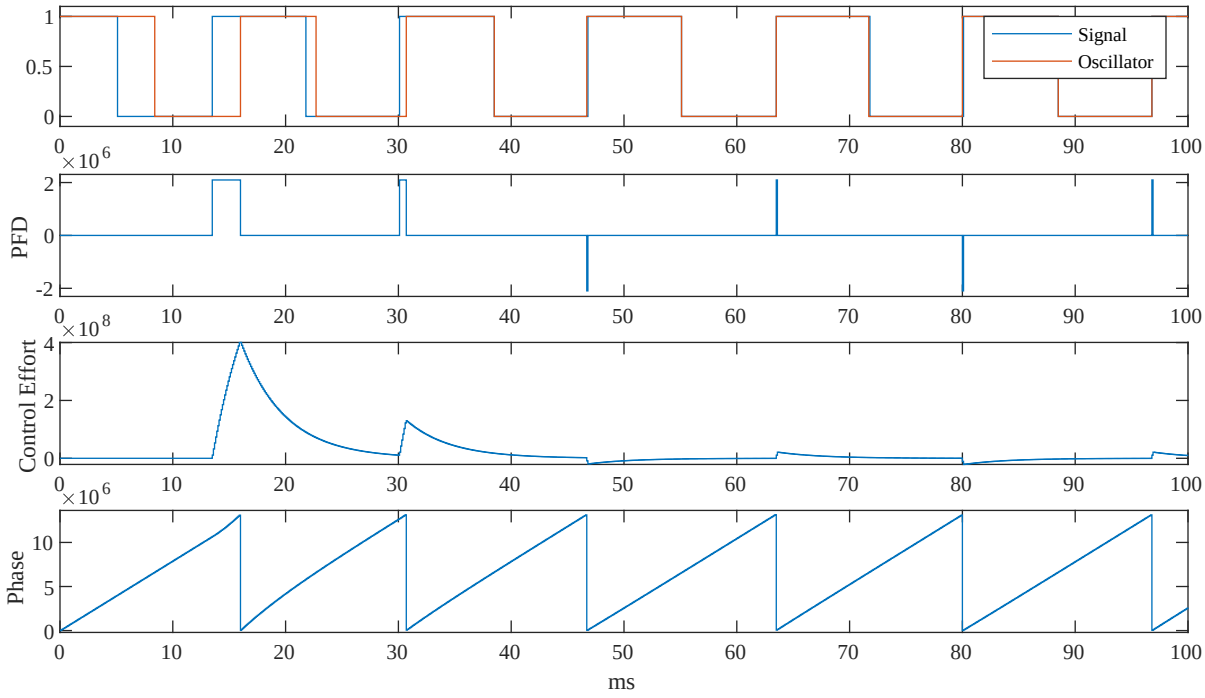
Use backward euler we arrive at a controller with.

$$G_c(z) = \frac{10.51z}{1.026z - 1} \tag{3}$$



The tustin transformation will arrive a the below controller

$$G_c(z) = \frac{5.187z + 5.187}{z - 0.9745} \tag{4}$$



```
%% PI controller
damping = 1

omega_n = 2*pi*4

kp = 4*pi*damping*omega_n
ki = 2*pi*omega_n^2
GLPF = ki/s + kp

%digital controller
Ts = 1/10e3
Z=tf('z',Ts)
sback = ((Z-1)/(Z*Ts))
gc_dig_backward = ki/sback + kp
gc_dig_zoh = c2d(GLPF,1/10e3,'zoh')
gc_dig_tustin = c2d(GLPF,1/10e3,'tustin')

%% calculate coeff for fixed point Q21 backward euler
Q = 21;
Bcoeff = int32(gc_dig_backward.Numerator{1}*2^Q);
Acoeff = int32(gc_dig_backward.Denominator{1}*2^Q);

fprintf('int32 A1 = %i;\n',Acoeff(1))
fprintf('int32 A0 = %i;\n',Acoeff(2))
fprintf('int32 B1 = %i;\n',Bcoeff(1))
fprintf('int32 B0 = %i;\n',Bcoeff(2))

%% calculate coeff for fixed point Q21 tustin
Q = 21;
Bcoeff = int32(gc_dig_tustin.Numerator{1}*2^Q);
Acoeff = int32(gc_dig_tustin.Denominator{1}*2^Q);

fprintf('int32 A1 = %i;\n',Acoeff(1))
fprintf('int32 A0 = %i;\n',Acoeff(2))
fprintf('int32 B1 = %i;\n',Bcoeff(1))
fprintf('int32 B0 = %i;\n',Bcoeff(2))
```

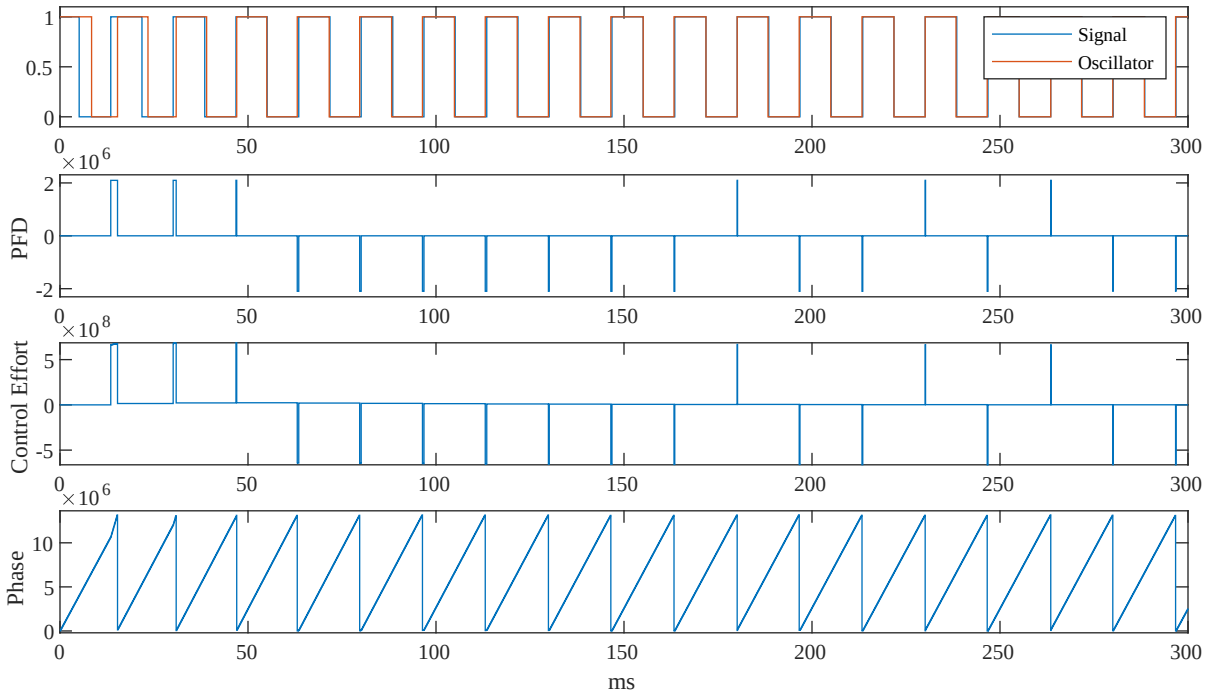
Below are the coefficients for backwards euler.

```
int32 A1 = 2097152;
int32 A0 = -2097152;
int32 B1 = 663170258;
int32 B0 = -662337939;
```

Below are the coefficients for tustin.

```
int32 A1 = 2097152;
int32 A0 = -2097152;
int32 B1 = 662754099;
int32 B0 = -661921780;
```

$$G_c(z) = \frac{316.2z - 315.8}{z - 1} \tag{5}$$



$$G_c(z) = \frac{316z - 315.6}{z - 1} \tag{6}$$