Solution to ECE Test 13 S09

We have studied the following seven digital filter design techniques:

Impulse Invariant (II), Step Invariant (SI), Finite Difference (FD), Direct Substitution (DS), Matched z (MZ), Bilinear (BL) and Windowing an Ideal Impulse Response (WI).

I. Answer the following questions using the two-letter acronyms above.

1. Which of the techniques produce an IIR digital filter ?

   All except WI.

2. Which of the techniques use a transformation from s to z to convert an analog filter to a digital filter without directly using any time-domain functions?

   FD, DS, MZ, BL

3. Which techniques guarantee that an analog lowpass filter will be transformed into a digital filter whose response at $\Omega = \pm\pi$ is zero?

   BL

II.

1. An analog filter has a tranfer function $\mathrm{H}(s) = \dfrac{s^2 - 2}{s^2 + 4s + 3}$. A digital filter is designed by the direct substitution method with a sampling rate $f_s = 5$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   In the s plane the zeros are at $\pm\sqrt{2}$ and the poles are at $-1,-3$.
   In the z plane the zeros are at $e^{\pm\sqrt{2}/5} = 1.3269$ and 0.7536 .
   In the z plane the poles are at $e^{-1/5} = 0.8187$ and $e^{-3/5} = 0.5488$

2. An analog filter has a transfer function $\mathrm{H}(s) = 1/s$. A digital filter is designed by the bilinear method with a sampling rate $f_s = 30$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   $$\mathrm{H}(z) = \left[1/s\right]_{s \to \frac{2}{T_s}\frac{z-1}{z+1}} = \frac{T_s}{2}\frac{z+1}{z-1} = \frac{1}{60}\frac{z+1}{z-1} .$$
   In the z plane the zero is at $z = -1$.
   In the z plane the pole is at $z = 1$.

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   BL

II.

1. An analog filter has a tranfer function $\mathrm{H}(s) = \dfrac{s^2+2}{s^2+6s+5}$. A digital filter is designed by the direct substitution method with a sampling rate $f_s = 5$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   In the s plane the zeros are at $\pm j\sqrt{2}$ and the poles are at $-1,-5$.
   In the z plane the zeros are at $e^{\pm j\sqrt{2}/5} = e^{\pm j0.2828} = 0.9603 \pm j0.2791$.
   In the z plane the poles are at $e^{-1/5} = 0.8187$ and $e^{-5/5} = 0.3678$

2. An analog filter has a transfer function $\mathrm{H}(s) = 1/s$. A digital filter is designed by the bilinear method with a sampling rate $f_s = 30$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   $$\mathrm{H}(z) = \left[1/s\right]_{s \to \frac{2}{T_s}\frac{z-1}{z+1}} = \frac{T_s}{2}\frac{z+1}{z-1} = \frac{1}{60}\frac{z+1}{z-1} .$$
   In the z plane the zero is at $z = -1$.
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   BL

II.

1. An analog filter has a tranfer function $\mathrm{H}(s) = \dfrac{s^2+1}{s^2+8s+7}$. A digital filter is designed by the direct substitution method with a sampling rate $f_s = 5$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   In the s plane the zeros are at $\pm j$ and the poles are at $-1,-7$.
   In the z plane the zeros are at $e^{\pm j/5} = 0.980 \pm j0.199$.
   In the z plane the poles are at $e^{-1/5} = 0.8187$ and $e^{-7/5} = 0.2466$

2. An analog filter has a transfer function $\mathrm{H}(s) = 1/s$. A digital filter is designed by the bilinear method with a sampling rate $f_s = 30$ samples/second . List the numerical locations of all its poles and zeros in the z plane.

   $$\mathrm{H}(z) = \left[1/s\right]_{s \to \frac{2}{T_s}\frac{z-1}{z+1}} = \frac{T_s}{2}\frac{z+1}{z-1} = \frac{1}{60}\frac{z+1}{z-1} \ .$$
   In the z plane the zero is at $z = -1$.
   In the z plane the pole is at $z = 1$.