2nd-order Butterworth

```
> H := 1/((s/(2*Pi*fc))^2 + 1.414*s/(2*Pi*fc) + 1);
```

$$H := \frac{1}{\frac{s^2}{4\,\pi^2\,fc^2} + \frac{0.7070000000\,s}{\pi\,fc} + 1}$$

```
> H := subs(fc=0.325/(2*Pi),H);
```

$$H := \frac{1}{9.467455622\,s^2 + 4.350769231\,s + 1}$$

```
> Hz := subs(s=(z-1)/(z+1),H);
```

$$Hz := \frac{1}{\frac{9.467455622\,(z-1)^2}{(z+1)^2} + \frac{4.350769231\,(z-1)}{z+1} + 1}$$

```
> Hz := simplify(Hz);
```

$$Hz := \frac{0.1000000000\,10^{10}\,(z+1.)^2}{0.1481822485\,10^{11}\,z^2 - 0.1693491124\,10^{11}\,z + 0.6116686391\,10^{10}}$$

```
> den := expand(denom(Hz));
```

$$den := 0.1481822485\,10^{11}\,z^2 - 0.1693491124\,10^{11}\,z + 0.6116686391\,10^{10}$$

```
> scale := coeff(den,z,degree(den,z));
```

$$scale := 0.1481822485\,10^{11}$$

```
> den/scale;
```

$$1.000000000\,z^2 - 1.142843452\,z + 0.4127813185$$

```
> num := expand(numer(Hz));
```

$$num := 0.1000000000\,10^{10}\,z^2 + 0.2000000000\,10^{10}\,z + 0.1000000000\,10^{10}$$

```
> num/scale;
```

$$0.06748446660\,z^2 + 0.1349689332\,z + 0.06748446660$$

```
>
```

MATLAB

```
>> [b,a] = butter(2, 2000/10000)
b =
    0.0675    0.1349    0.0675
a =
```

```
    1.0000   -1.1430    0.4128
```