Sistem Instrumentasi Elektronika - Modul 4

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Perbandingan Semua Filter **85**

Libraries

```
library(ggplot2)    # Plotting
library(patchwork)  # Plotting extension
library(tidyverse)  # Table operations
```

Read Exported Data

```
freq_resp <- read.csv("Exports/HPF_FreqResponse.csv")
time_domain_10Hz <- read_csv("Exports/HPF_10Hz.csv")
time_domain_100Hz <- read_csv("Exports/HPF_100Hz.csv")
time_domain_1000Hz <- read_csv("Exports/HPF_1000Hz.csv")
time_domain_10000Hz <- read_csv("Exports/HPF_10000Hz.csv")
```

Global Variables

```
CUTOFF <- 1000  # cutoff 1000 Hz
MAG_3dB <- -3   # -3dB point
```

4.1 Filter Orde 2

Mengambil data filter orde 2.

```
freq_resp_2 <- freq_resp %>%
  dplyr::select(FREQ, Butterworth2, Bessel2, Chebychev2)
```

4.1.1 Butterworth

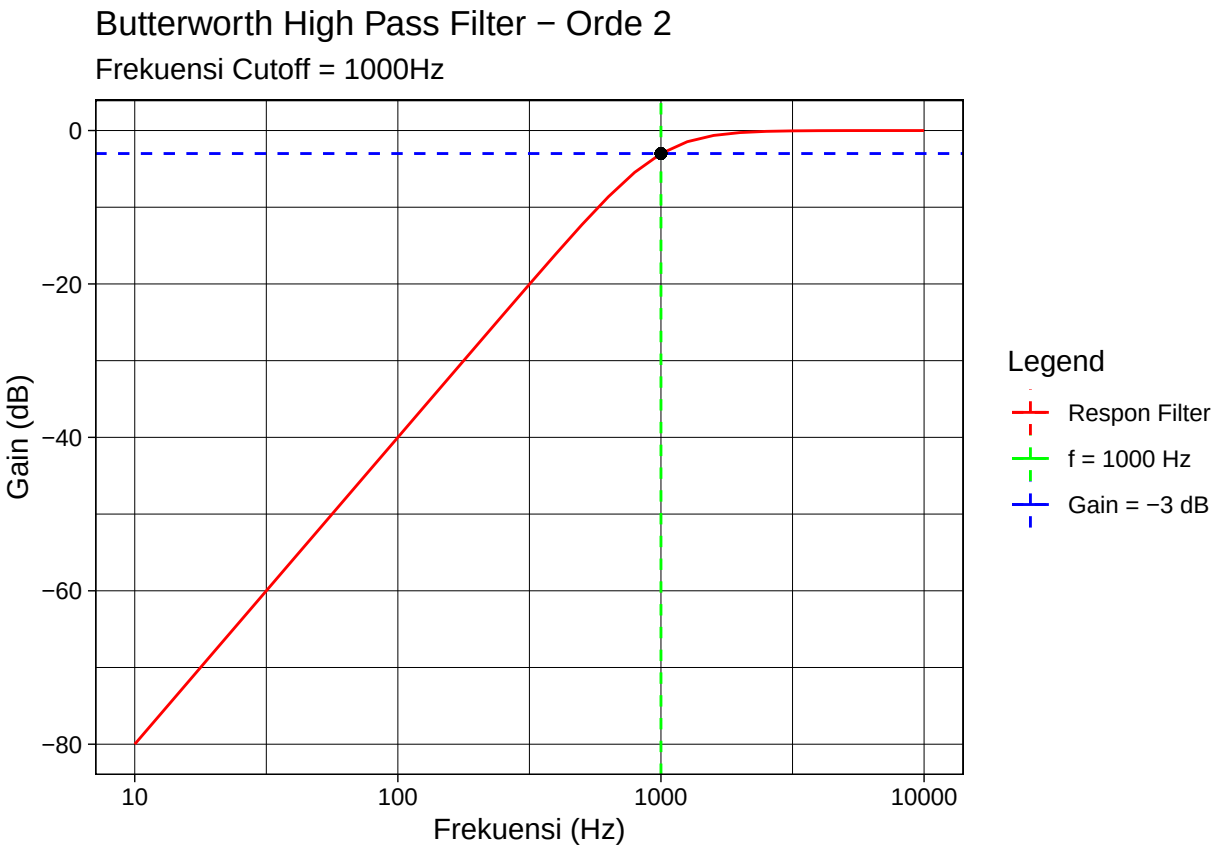
4.1.1 a) Frequency Response

Mengambil data untuk respon frekuensi Butterworth orde 2 saja.

```
butter2_freq <- freq_resp_2 %>%
  dplyr::select(FREQ, Butterworth2)
```

Respon Frekuensi High Pass Filter Butterworth Orde 2

```
ggplot(butter2_freq) +
  geom_line(aes(x = FREQ, y = Butterworth2, color = "butter2")) +
  geom_vline(aes(xintercept = CUTOFF, color = "Cutoff"), linetype = 2) +
  geom_hline(aes(yintercept = MAG_3dB, color = "3dB"), linetype = 2) +
  geom_point(aes(x = CUTOFF, y = MAG_3dB)) +

  # Skala log
  scale_x_log10() +

  # Plot info
  labs(title = "Butterworth High Pass Filter - Orde 2",
       subtitle = "Frekuensi Cutoff = 1000Hz",
       x = "Frekuensi (Hz)",
       y = "Gain (dB)") +
  scale_color_manual(name = "Legend",
                     values = c("butter2" = "red", "Cutoff" = "green",
                                "3dB" = "blue"),
                     labels = c("Respon Filter", "f = 1000 Hz",
                                "Gain = -3 dB")
                     ) +
  theme_linedraw()
```


Butterworth High Pass Filter − Orde 2
Frekuensi Cutoff = 1000Hz
0
−20
−40
−60
−80
Gain (dB)
10
100
1000
10000
Frekuensi (Hz)
Legend
Respon Filter
f = 1000 Hz
Gain = −3 dB

4.1.1 b) Time Domain

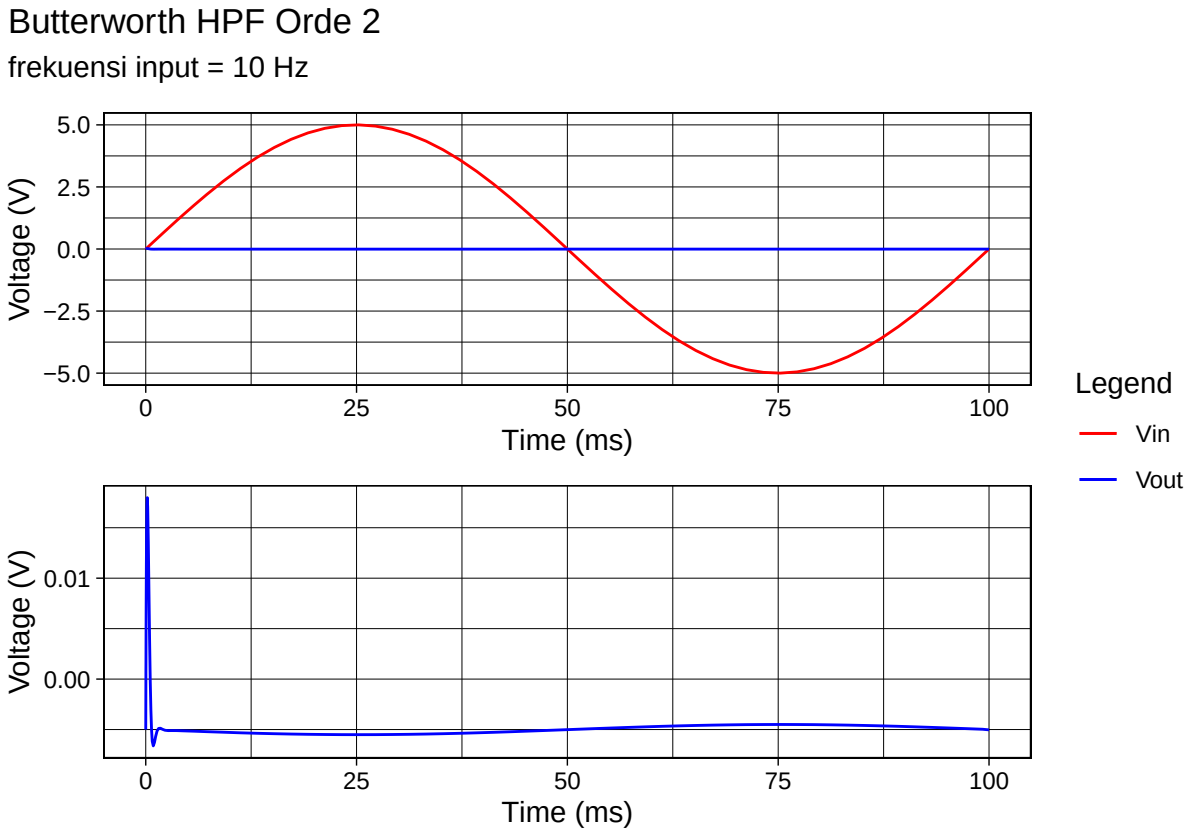
Mengambil data untuk Butterworth orde 2 saja.

```
butter2_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Butterworth2)

butter2_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Butterworth2)

butter2_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Butterworth2)

butter2_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Butterworth2)
```

F = 10 Hz

Plot sinyal V_{input} & V_{out} saat $f = 10Hz$

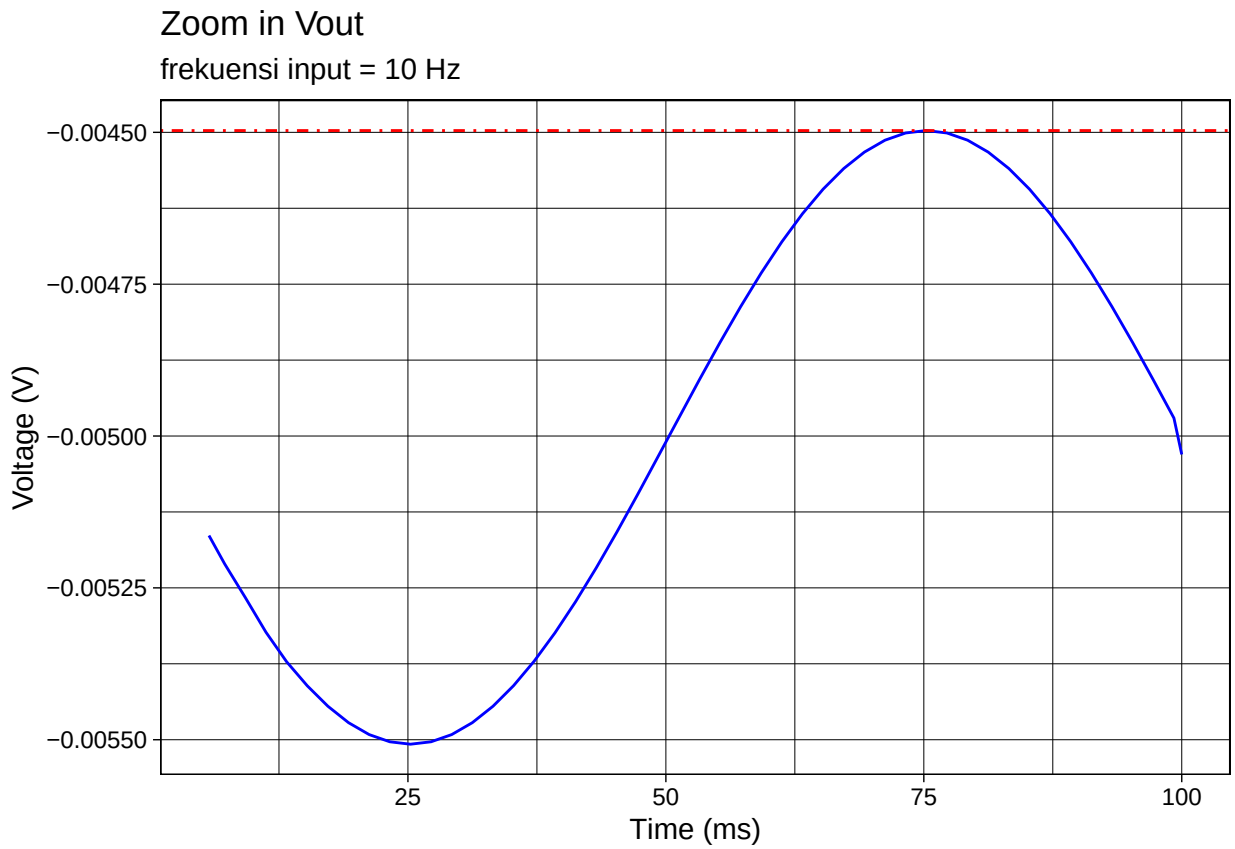
```
# Semua sinyal di stack
plot_all_signal <-
  ggplot(butter2_10Hz) +
    geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2, color = "Vout")) +
    xlab("Time (ms)") +
    ylab("Voltage (V)") +
    scale_color_manual(name = "Legend",
                       values = c("Vin" = "red", "Vout" = "blue"),
                       labels = c("Vin", "Vout"))

# Vout only
plot_vout <-
  ggplot(butter2_10Hz) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2), color = "blue") +
    xlab("Time (ms)") +
    ylab("Voltage (V)")

plot_all_signal / plot_vout +
  plot_annotation(title = "Butterworth HPF Orde 2",
                  subtitle = "frekuensi input = 10 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom ke V_{out} lebih dekat, namun dengan mengambil data untuk syarat t:

$$t > 5ms$$

```r
# filter untuk t > 5ms
zoomin <- butter2_10Hz %>%
  dplyr::filter(TIME * 1000 > 5)

vpeak <- max(zoomin$Butterworth2)

ggplot(zoomin) +
  geom_line(aes(TIME * 1000, Butterworth2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # Plot info
  labs(title = "Zoom in Vout",
       subtitle = "frekuensi input = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, dapat terlihat bahwa V_{PEAK} adalah (dalam volt):

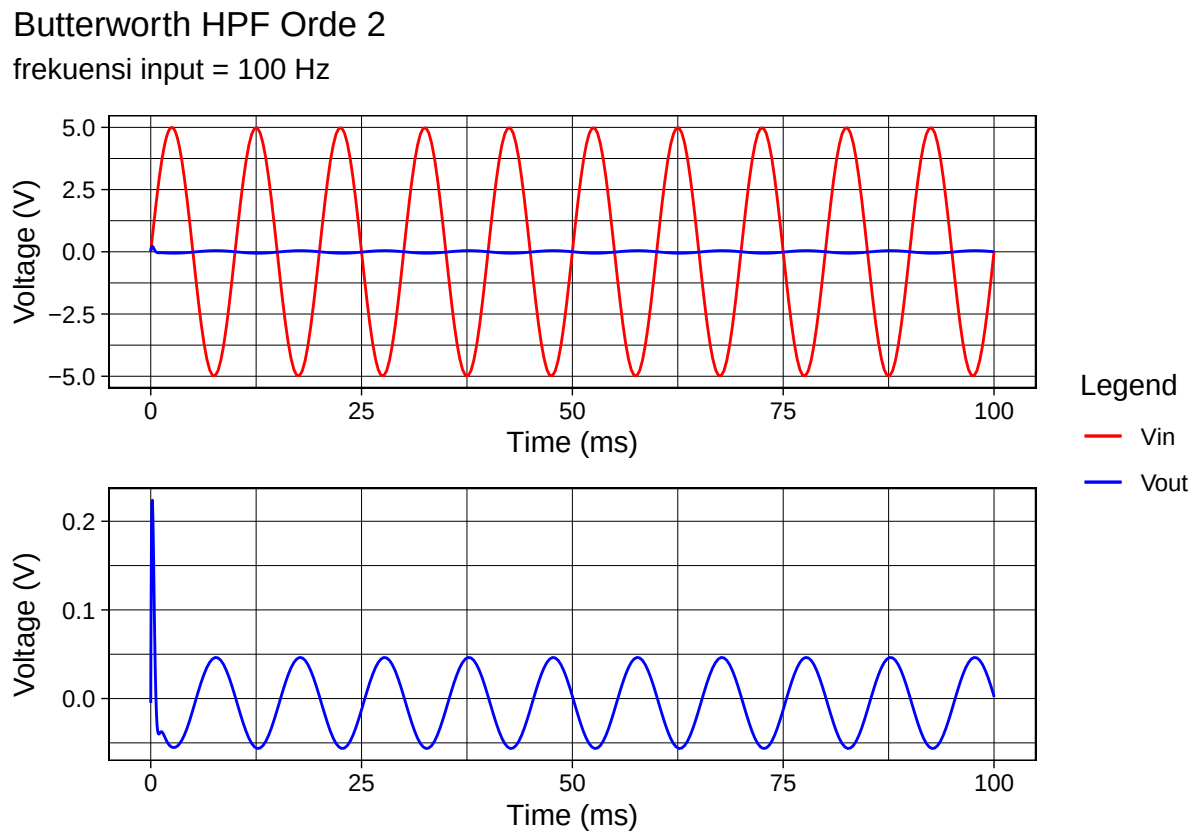
```
vpeak
```

```
## [1] -0.00449706
```

F = 100 Hz

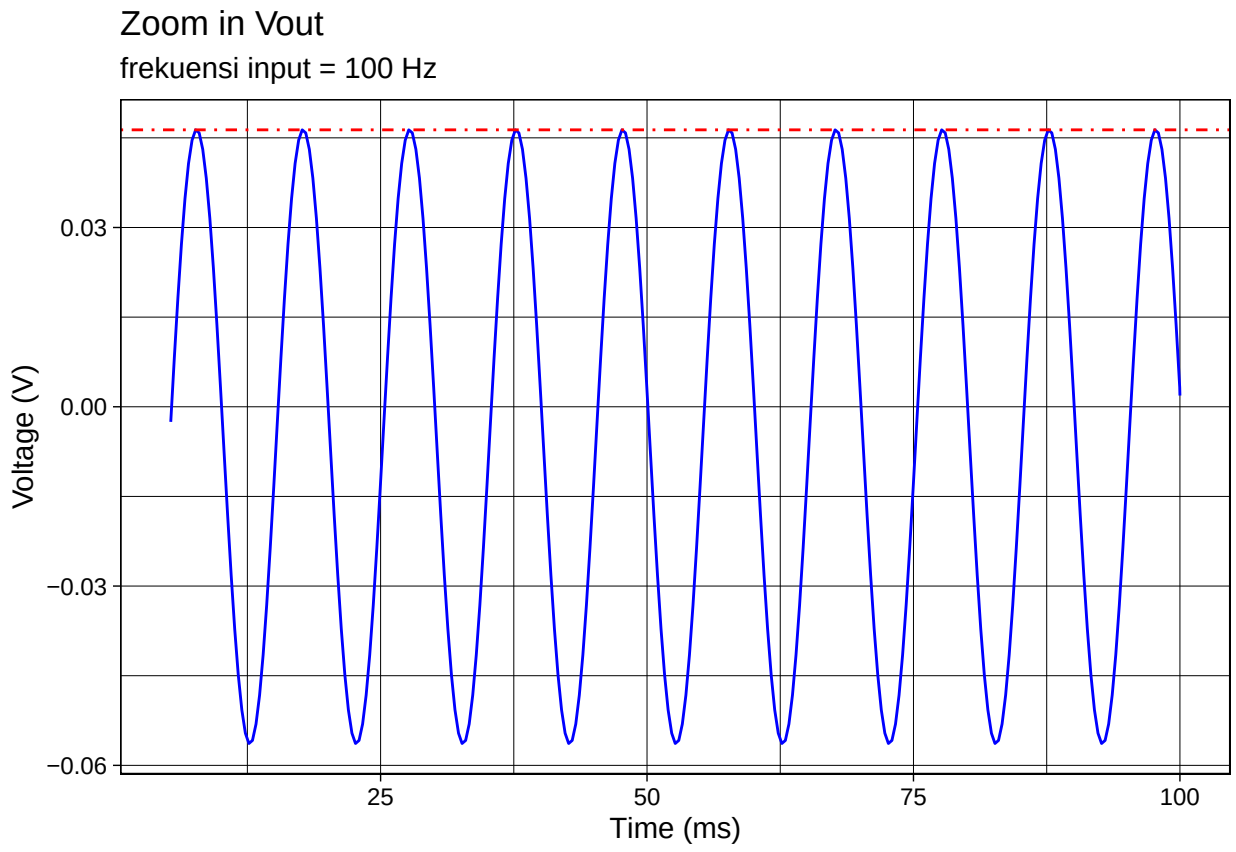
Plot sinyal V_{input} & V_{out} saat $f = 100Hz$

```
# Semua sinyal di stack
plot_all_signal <-
  ggplot(butter2_100Hz) +
    geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2, color = "Vout")) +
    xlab("Time (ms)") +
    ylab("Voltage (V)") +
    scale_color_manual(name = "Legend",
                       values = c("Vin" = "red", "Vout" = "blue"),
                       labels = c("Vin", "Vout"))

# Vout only
plot_vout <-
  ggplot(butter2_100Hz) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2), color = "blue") +
    xlab("Time (ms)") +
    ylab("Voltage (V)")

plot_all_signal / plot_vout +
  plot_annotation(title = "Butterworth HPF Orde 2",
                  subtitle = "frekuensi input = 100 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom ke V_{out} lebih dekat, namun dengan mengambil data untuk $t > 5ms$, agar zoom tidak terpengaruh oleh overshoot yang besar di awal.

```
# filter untuk t > 5ms
zoomin <- butter2_100Hz %>%
  dplyr::filter(TIME * 1000 > 5)

vpeak <- max(zoomin$Butterworth2)

ggplot(zoomin) +
  geom_line(aes(TIME * 1000, Butterworth2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # Plot info
  labs(title = "Zoom in Vout",
       subtitle = "frekuensi input = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, dapat terlihat bahwa V_{PEAK} adalah (dalam volt):

```
vpeak
```

```
## [1] 0.0463392
```

F = 1000 Hz

Subset data untuk $0ms < t < 25ms$

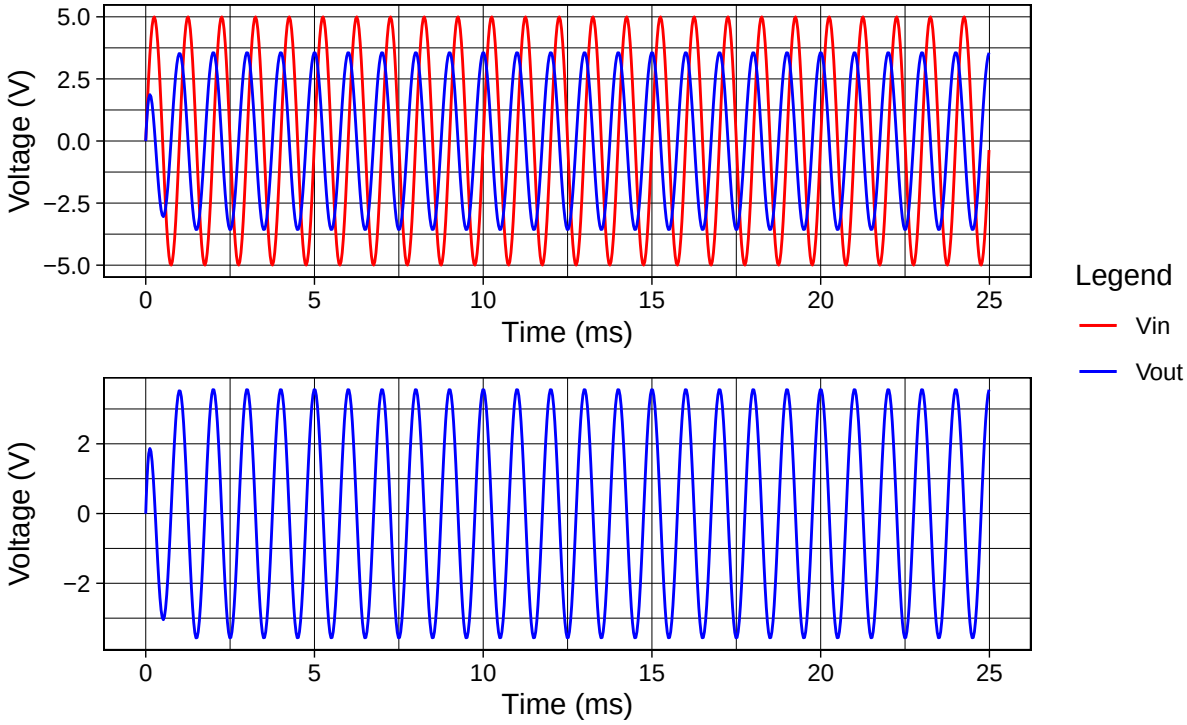
```
butter2_1000Hz <- butter2_1000Hz %>%
  dplyr::filter(TIME * 1000 < 25)
```

Plot sinyal V_{input} & V_{out} saat $f = 1000Hz$

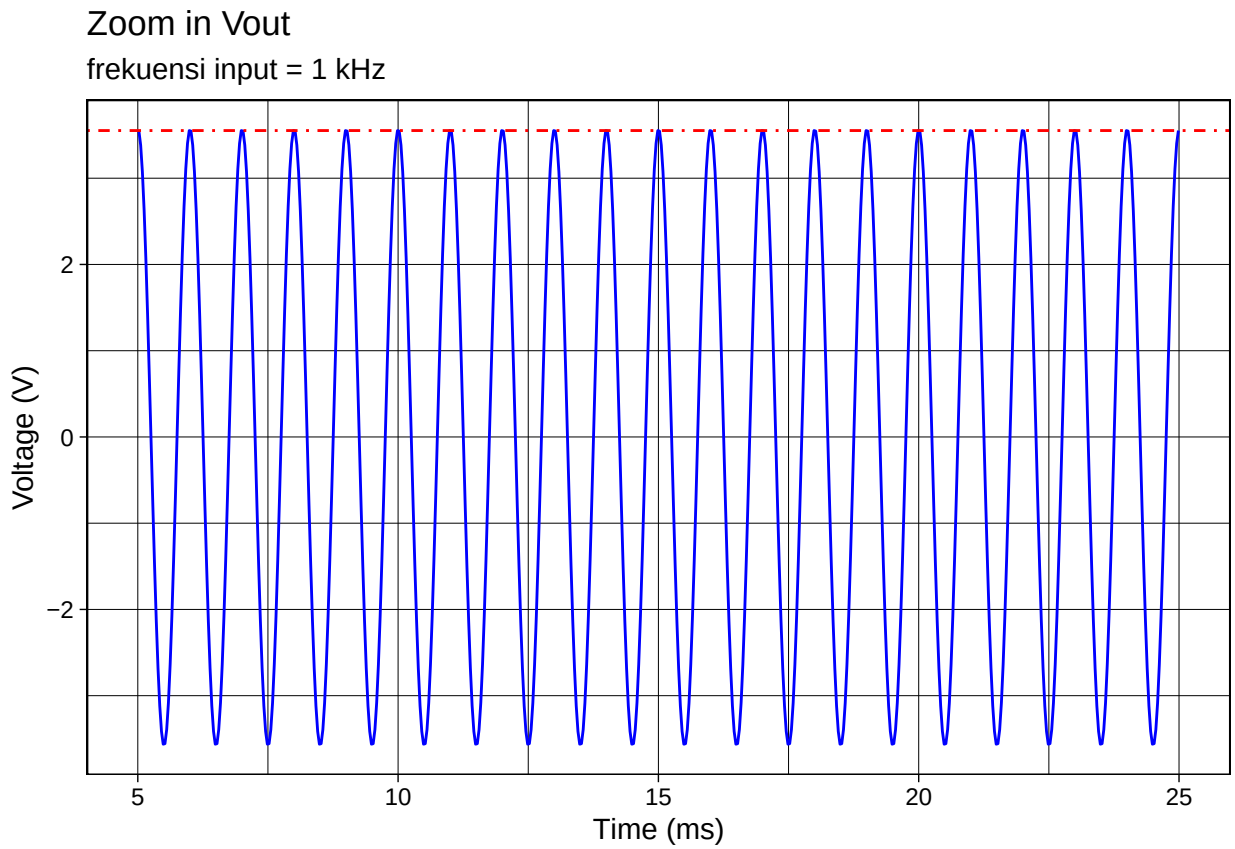
```
# Semua sinyal di stack
plot_all_signal <-
  ggplot(butter2_1000Hz) +
    geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2, color = "Vout")) +
    xlab("Time (ms)") +
    ylab("Voltage (V)") +
    scale_color_manual(name = "Legend",
                       values = c("Vin" = "red", "Vout" = "blue"),
                       labels = c("Vin", "Vout"))

# Vout only
plot_vout <-
  ggplot(butter2_1000Hz) +
    geom_line(aes(x = TIME * 1000, y = Butterworth2), color = "blue") +
    xlab("Time (ms)") +
    ylab("Voltage (V)")

plot_all_signal / plot_vout +
  plot_annotation(title = "Butterworth HPF Orde 2",
                  subtitle = "frekuensi input = 1 kHz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```

Butterworth HPF Orde 2

frekuensi input = 1 kHz




```r
# filter untuk t > 5ms
zoomin <- butter2_1000Hz %>%
  dplyr::filter(TIME * 1000 > 5)

vpeak <- max(zoomin$Butterworth2)

ggplot(zoomin) +
  geom_line(aes(TIME * 1000, Butterworth2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # Plot info
  labs(title = "Zoom in Vout",
       subtitle = "frekuensi input = 1 kHz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, dapat terlihat bahwa V_{PEAK} adalah (dalam volt):

```
vpeak
```

```
## [1] 3.55269
```

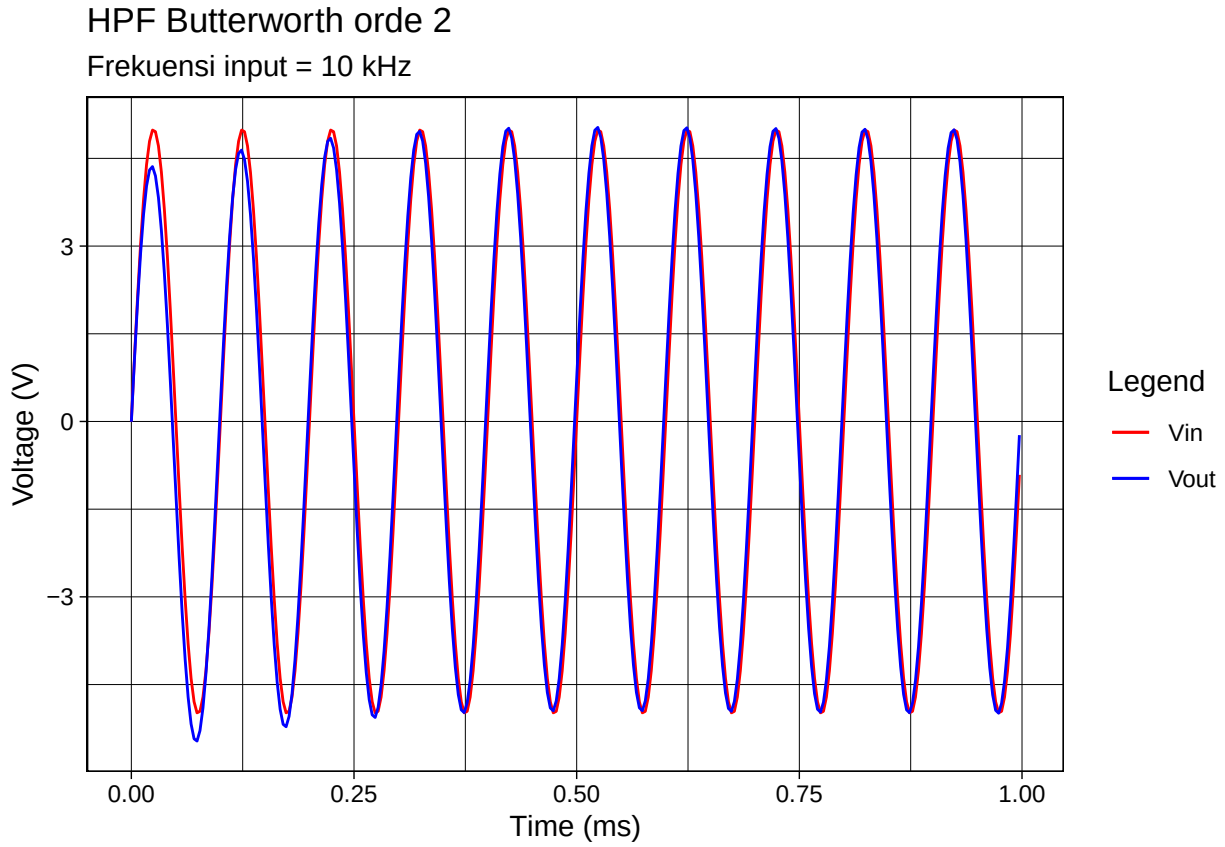
F = 10000 Hz

Subset data untuk $0ms < t < 1ms$

```
butter2_10000Hz <- butter2_10000Hz %>%
  dplyr::filter(TIME * 1000 < 1)
```

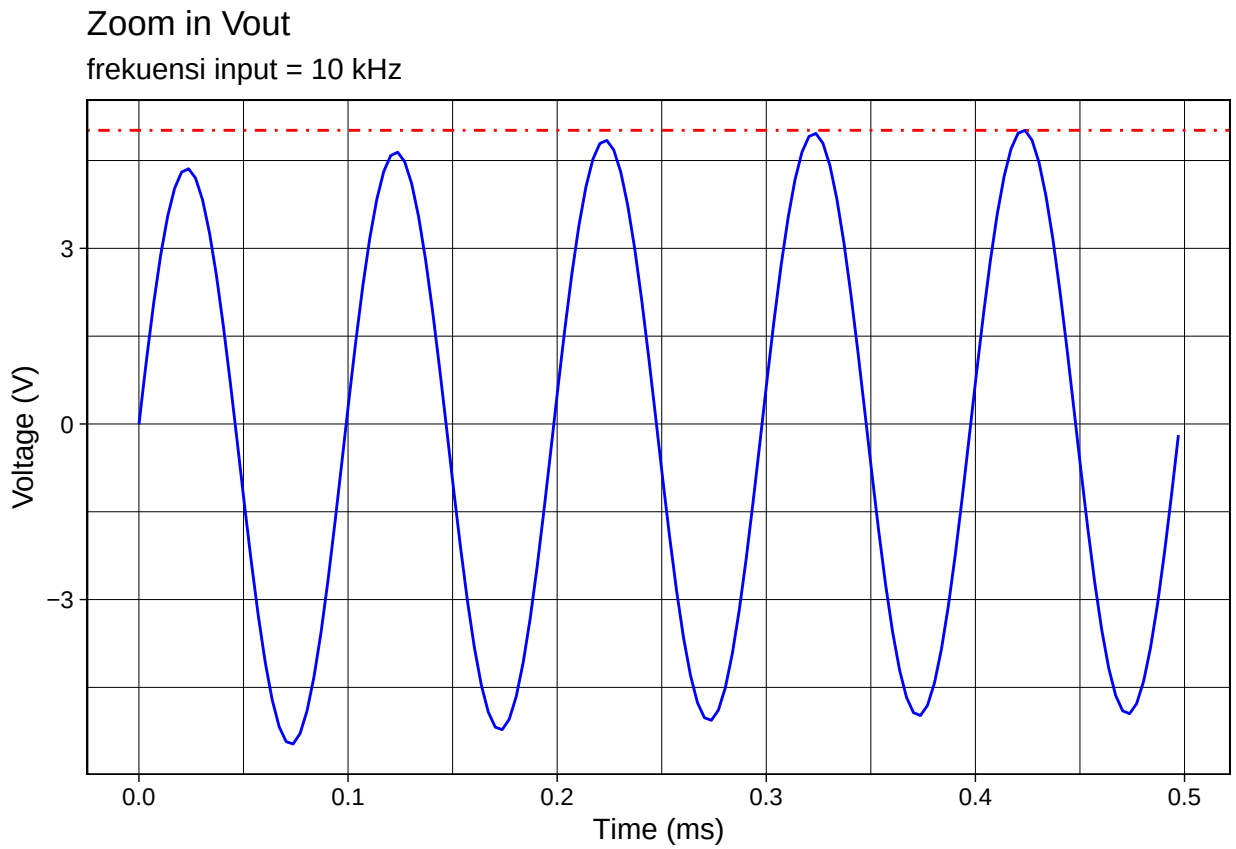
Plot sinyal V_{input} & V_{out} saat $f = 10000Hz$

```
# Semua sinyal di stack
ggplot(butter2_10000Hz) +
  geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
  geom_line(aes(x = TIME * 1000, y = Butterworth2, color = "Vout")) +
  labs(title = "HPF Butterworth orde 2",
       subtitle = "Frekuensi input = 10 kHz",
       y = "Voltage (V)",
       x = "Time (ms)") +
  scale_color_manual(name = "Legend",
                     values = c("Vin" = "red", "Vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  theme_linedraw()
```




```
# ambil data untuk t < 0.5 ms
zoomin <- butter2_10000Hz %>%
  dplyr::filter(TIME * 1000 < 0.50)

vpeak <- max(zoomin$Butterworth2)
```

```
ggplot(zoomin) +
  geom_line(aes(TIME * 1000, Butterworth2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # Plot info
  labs(title = "Zoom in Vout",
       subtitle = "frekuensi input = 10 kHz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, dapat terlihat bahwa V_{PEAK} adalah (dalam volt):

```
vpeak
```

```
## [1] 5.01627
```

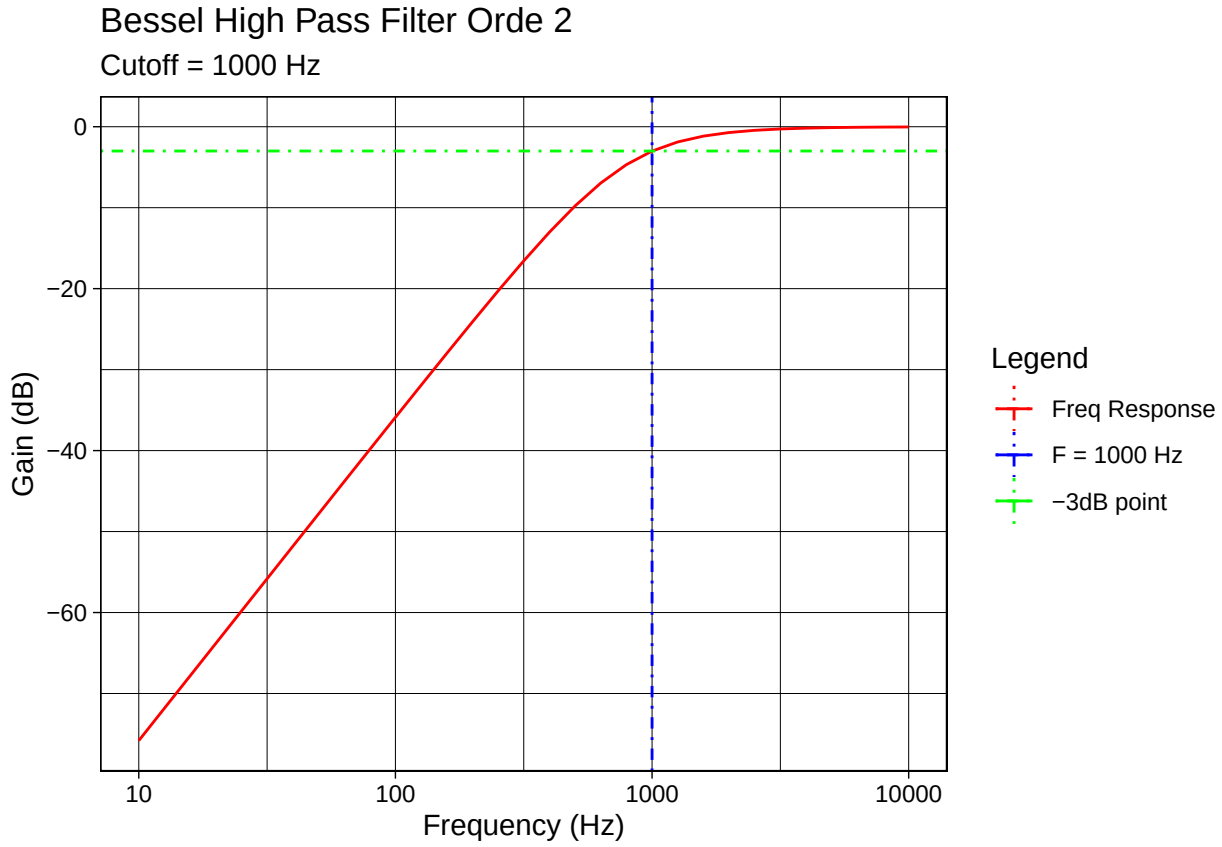
4.1.2 Bessel

Mengambil data untuk respon frekuensi filter tipe Bessel orde 2 saja.

```
bessel2_freq <- freq_resp_2 %>%
  dplyr::select(FREQ, Bessel2)
```

4.1.2 a) Frequency Response

```
ggplot(bessel2_freq) +
  geom_line(aes(x = FREQ, y = Bessel2, color = "resp")) +
  geom_vline(aes(xintercept = CUTOFF, color = "cutoff"), linetype = 4) +
  geom_hline(aes(yintercept = MAG_3dB, color = "3dB"), linetype = 4) +

  # Plot info
  labs(title = "Bessel High Pass Filter Orde 2",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)") +
  scale_x_log10() +
  scale_color_manual(name = "Legend",
                     values = c("resp" = "red", "cutoff" = "blue", "3dB" = "green"),
                     labels = c("Freq Response", "F = 1000 Hz", "-3dB point")) +
  theme_linedraw()
```



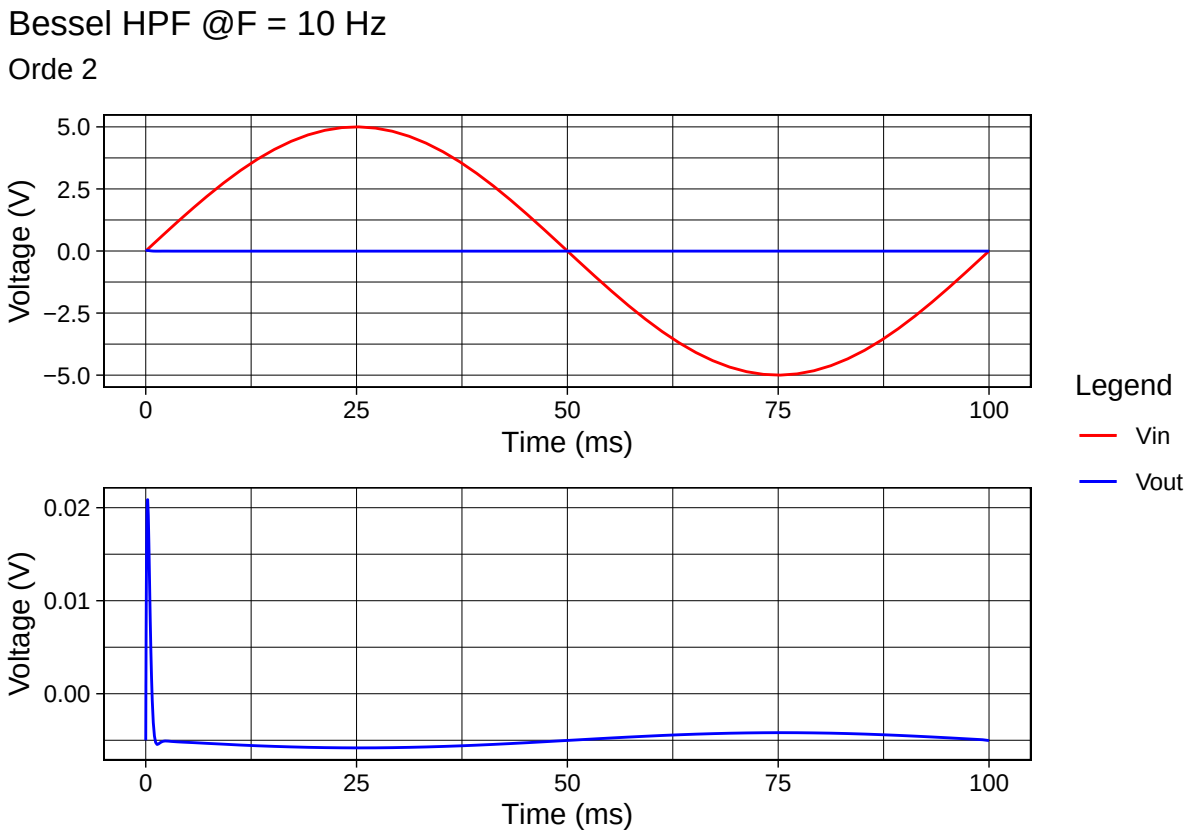
4.1.2 b) Time Domain

Subset data untuk Bessel filter saja.

```
bessel2_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Bessel2)
```

F = 10 Hz

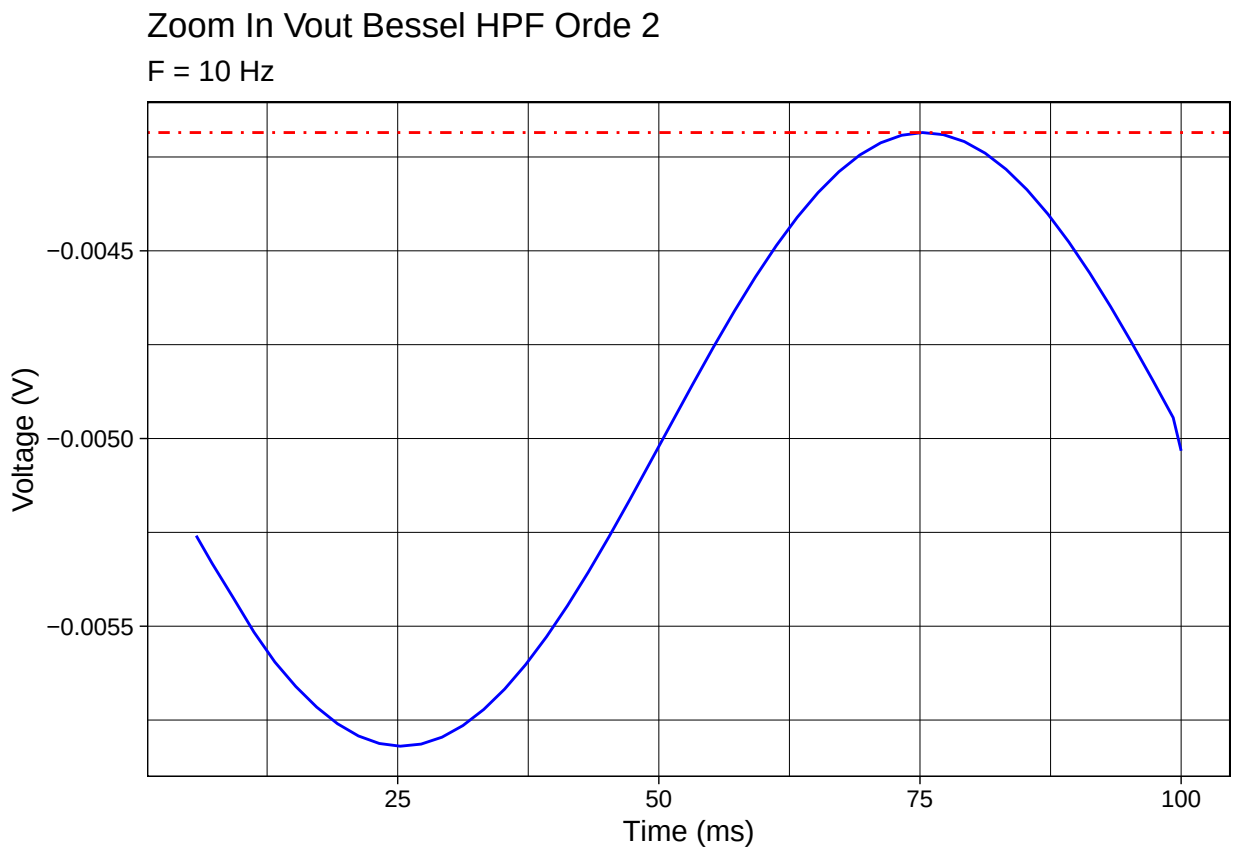
```
# Plot Vin & Vout di stack
p1 <-
ggplot(bessel2_10Hz) +
  geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
  geom_line(aes(x = TIME * 1000, y = Bessel2, color = "Vout")) +
  scale_color_manual(name = "Legend",
                     values = c("Vin" = "red", "Vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(bessel2_10Hz) +
  geom_line(aes(x = TIME * 1000, y = Bessel2), color = "blue")


p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Bessel HPF @F = 10 Hz",
                  subtitle = "Orde 2") &
  xlab("Time (ms)") &
  ylab("Voltage (V)") &
  theme_linedraw()
```



Untuk mendapatkan peak, maka sebaiknya di subset dahulu untuk $t > 5ms$ (perkiraan)

```
bessel2_10Hz <- bessel2_10Hz %>%
  dplyr::filter( TIME * 1000 > 5)

vpeak <- max(bessel2_10Hz$Bessel2)
```

```
ggplot(bessel2_10Hz) +
  geom_line(aes(TIME * 1000, Bessel2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot informations
  labs(title = "Zoom In Vout Bessel HPF Orde 2",
       subtitle = "F = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  scale_color_manual() +
  theme_linedraw()
```



Dari grafik tersebut, kurang lebih nilai V_{peak} output adalah:

```
vpeak
```

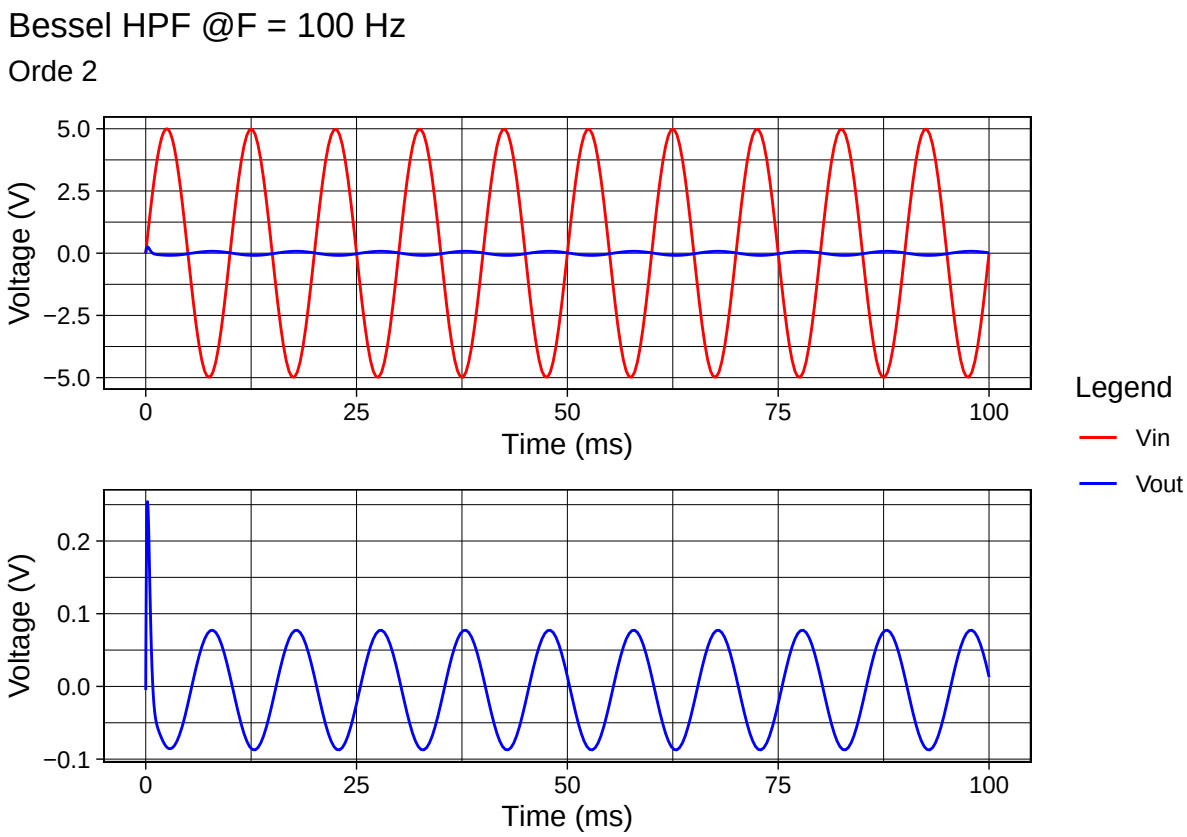
```
## [1] -0.00418491
```

F = 100 Hz

Subset data untuk Bessel filter saja.

```
bessel2_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Bessel2)
```

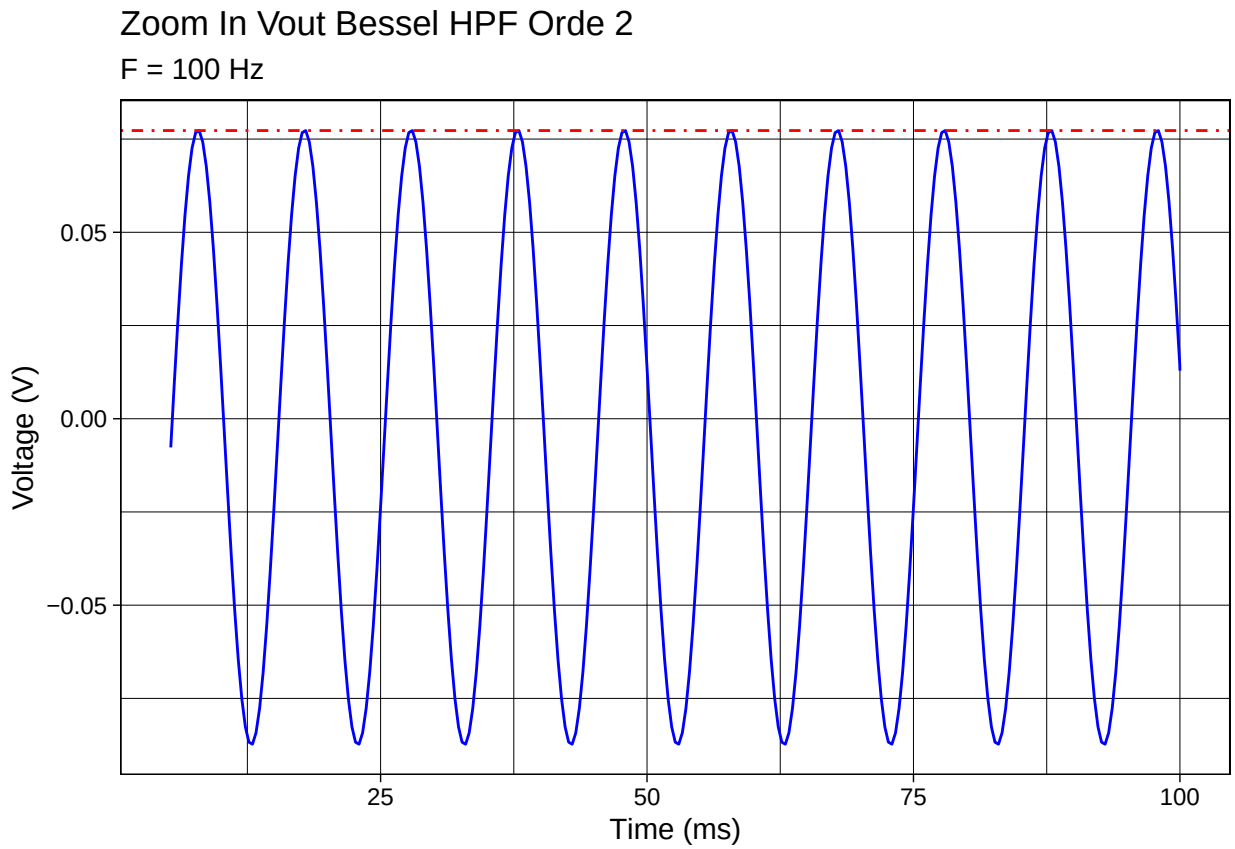
```
# Plot Vin & Vout di stack
p1 <-
ggplot(bessel2_100Hz) +
  geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
  geom_line(aes(x = TIME * 1000, y = Bessel2, color = "Vout")) +
  scale_color_manual(name = "Legend",
                     values = c("Vin" = "red", "Vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(bessel2_100Hz) +
  geom_line(aes(x = TIME * 1000, y = Bessel2), color = "blue")


p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Bessel HPF @F = 100 Hz",
                  subtitle = "Orde 2") &
  xlab("Time (ms)") &
  ylab("Voltage (V)") &
  theme_linedraw()
```



Untuk mendapatkan peak, maka sebaiknya di subset dahulu untuk $t > 5ms$ (perkiraan)

```
bessel2_100Hz <- bessel2_100Hz %>%
  dplyr::filter( TIME * 1000 > 5)

vpeak <- max(bessel2_100Hz$Bessel2)
```

```
ggplot(bessel2_100Hz) +
  geom_line(aes(TIME * 1000, Bessel2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot information
  labs(title = "Zoom In Vout Bessel HPF Orde 2",
       subtitle = "F = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, kurang lebih nilai V_{peak} output adalah:

```
vpeak
```

```
## [1] 0.0772873
```

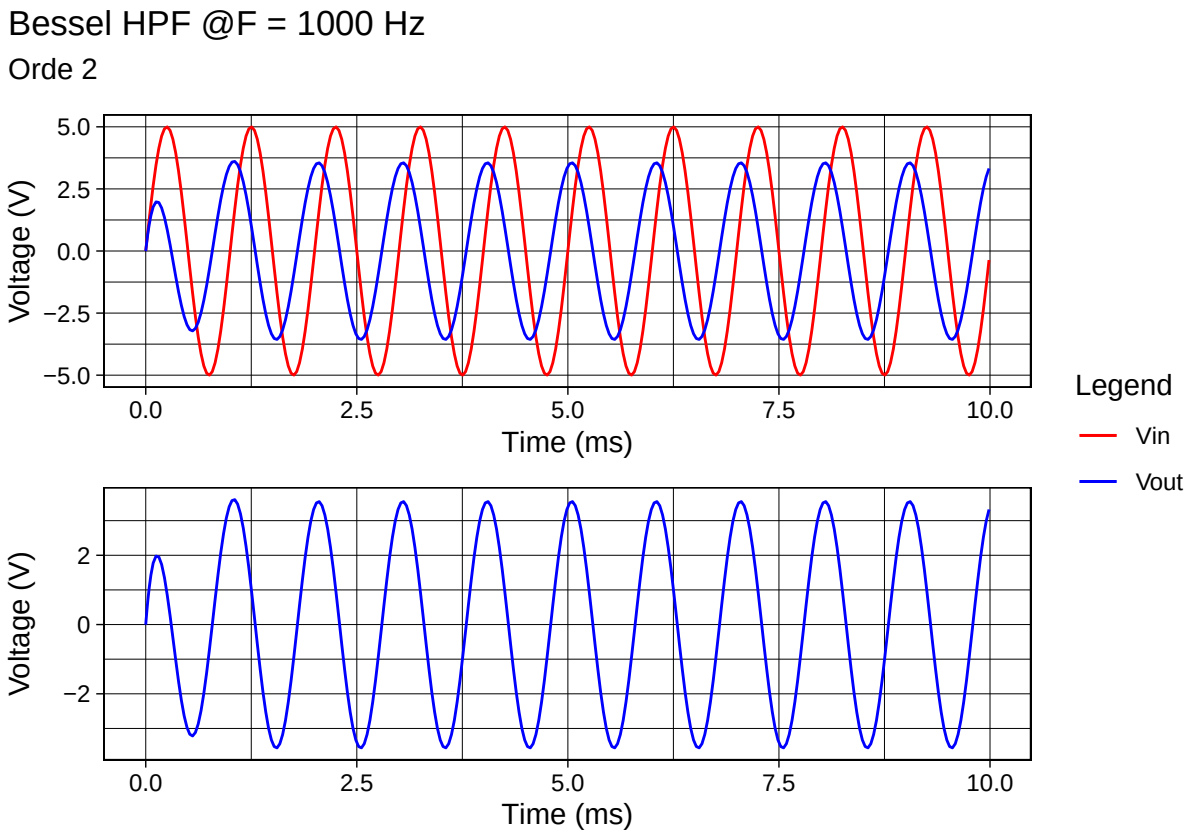
F = 1000 Hz

Subset data untuk Bessel filter saja, lalu mengambil data untuk rentang t:

$$0 \leq t \leq 10ms$$

```
bessel2_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Bessel2) %>%
  dplyr::filter(TIME * 1000 <= 10)
```

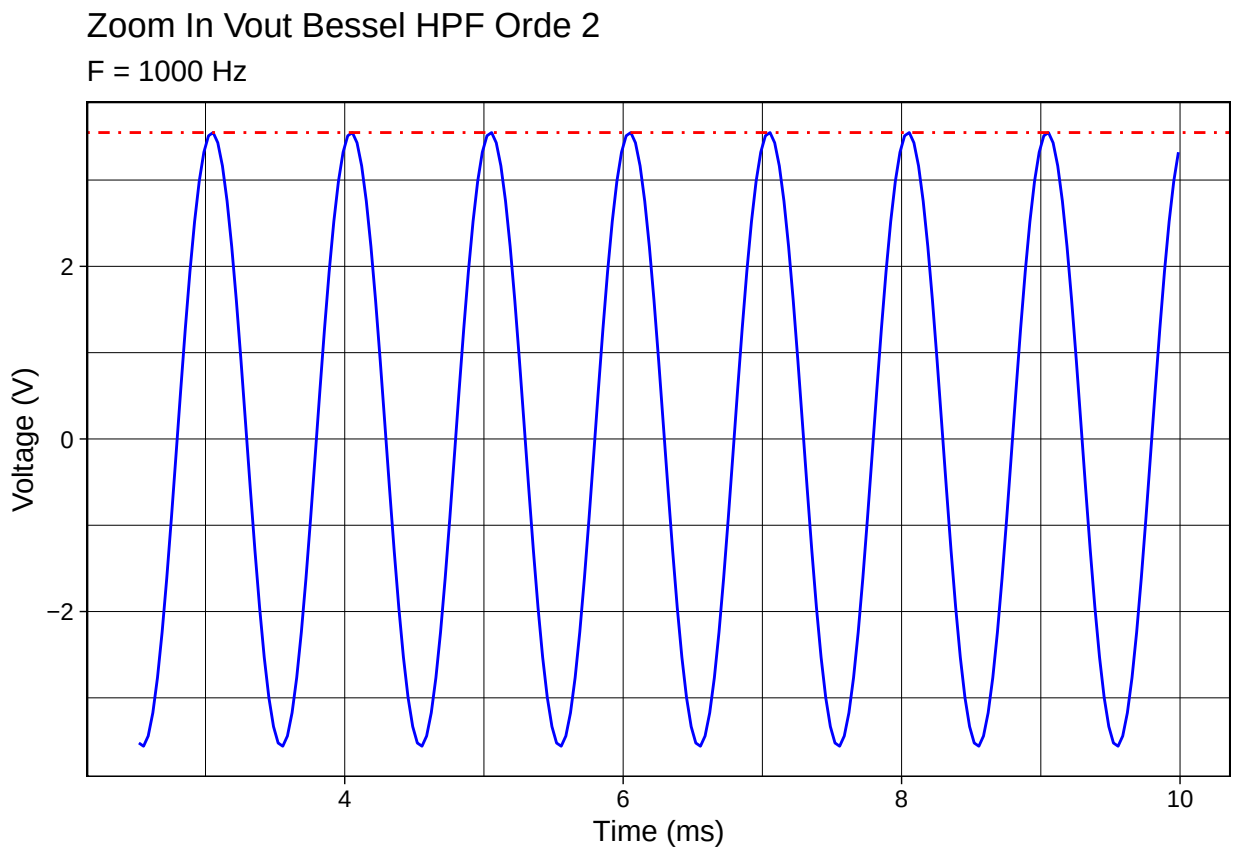
```
# Plot Vin & Vout di stack
p1 <-
ggplot(bessel2_1000Hz) +
  geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
  geom_line(aes(x = TIME * 1000, y = Bessel2, color = "Vout")) +
  scale_color_manual(name = "Legend",
                     values = c("Vin" = "red", "Vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(bessel2_1000Hz) +
  geom_line(aes(x = TIME * 1000, y = Bessel2), color = "blue")


p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Bessel HPF @F = 1000 Hz",
                  subtitle = "Orde 2") &
  xlab("Time (ms)") &
  ylab("Voltage (V)") &
  theme_linedraw()
```



Untuk mendapatkan peak, maka sebaiknya di subset dahulu untuk $t > 2.5ms$ (perkiraan)

```
bessel2_1000Hz <- bessel2_1000Hz %>%
  dplyr::filter( TIME * 1000 > 2.5)

vpeak <- max(bessel2_1000Hz$Bessel2)
```

```
ggplot(bessel2_1000Hz) +
  geom_line(aes(TIME * 1000, Bessel2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot informations
  labs(title = "Zoom In Vout Bessel HPF Orde 2",
       subtitle = "F = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, kurang lebih nilai V_{peak} output adalah:

```
vpeak
```

```
## [1] 3.55056
```

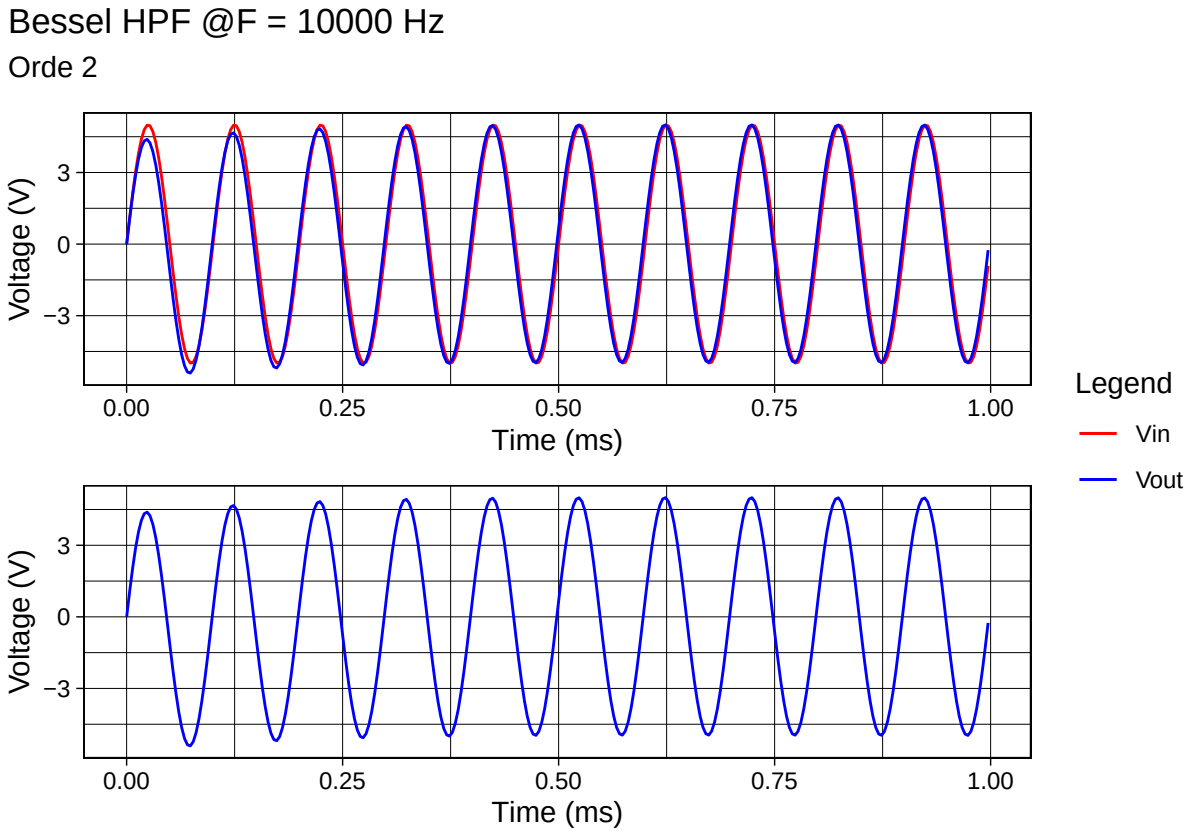
F = 10000 Hz

Subset data untuk Bessel filter saja, lalu mengambil data untuk rentang t:

$$0 \leq t \leq 1ms$$

```
bessel2_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Bessel2) %>%
  dplyr::filter(TIME * 1000 <= 1)
```

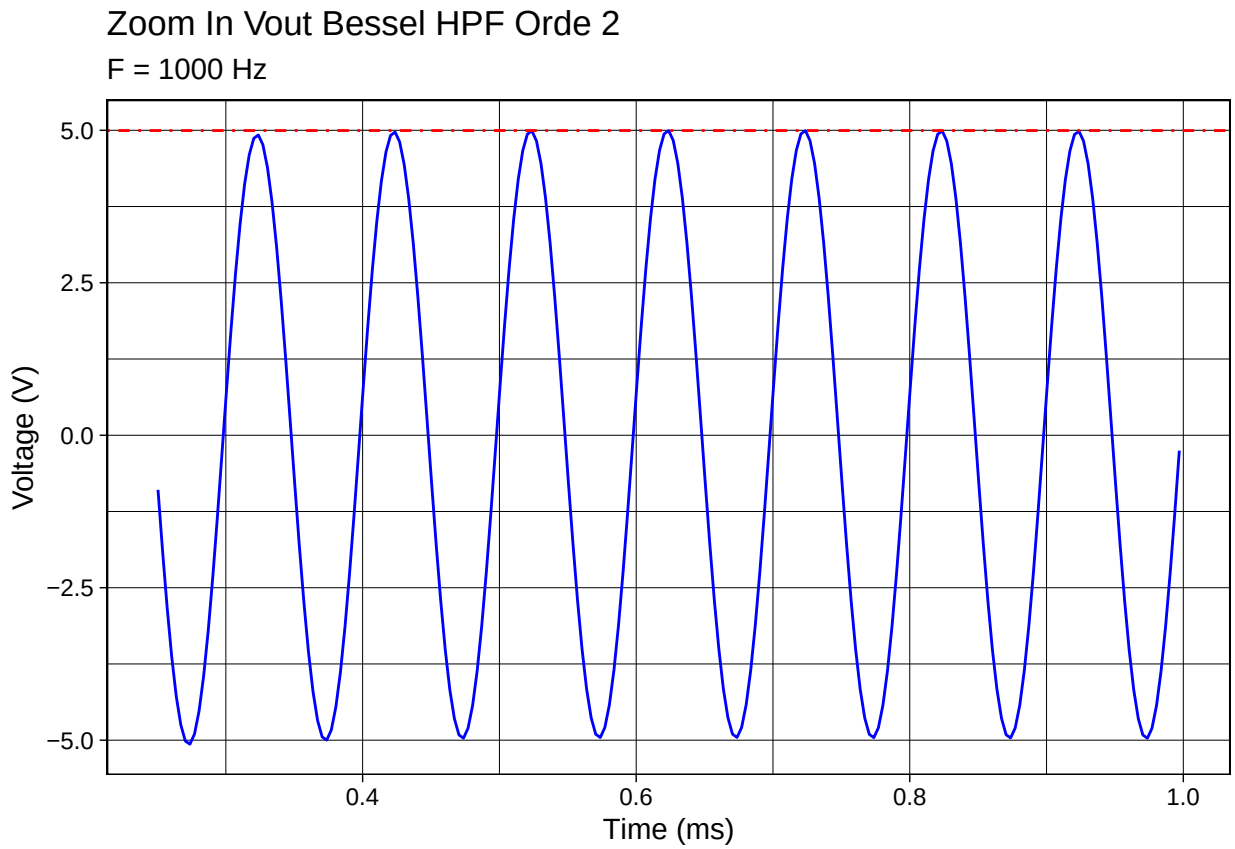
```
# Plot Vin & Vout di stack
p1 <-
ggplot(bessel2_10000Hz) +
  geom_line(aes(x = TIME * 1000, y = Vin, color = "Vin")) +
  geom_line(aes(x = TIME * 1000, y = Bessel2, color = "Vout")) +
  scale_color_manual(name = "Legend",
                     values = c("Vin" = "red", "Vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(bessel2_10000Hz) +
  geom_line(aes(x = TIME * 1000, y = Bessel2), color = "blue")


p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Bessel HPF @F = 10000 Hz",
                  subtitle = "Orde 2") &
  xlab("Time (ms)") &
  ylab("Voltage (V)") &
  theme_linedraw()
```



Untuk mendapatkan peak, maka sebaiknya di subset dahulu untuk $t > 0.25ms$ (perkiraan)

```
bessel2_10000Hz <- bessel2_10000Hz %>%
  dplyr::filter( TIME * 1000 > 0.25)

vpeak <- max(bessel2_10000Hz$Bessel2)
```

```
ggplot(bessel2_10000Hz) +
  geom_line(aes(TIME * 1000, Bessel2), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot informations
  labs(title = "Zoom In Vout Bessel HPF Orde 2",
       subtitle = "F = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



Dari grafik tersebut, kurang lebih nilai V_{peak} output adalah:

```
vpeak
```

```
## [1] 4.99587
```

4.1.3 Chebychev

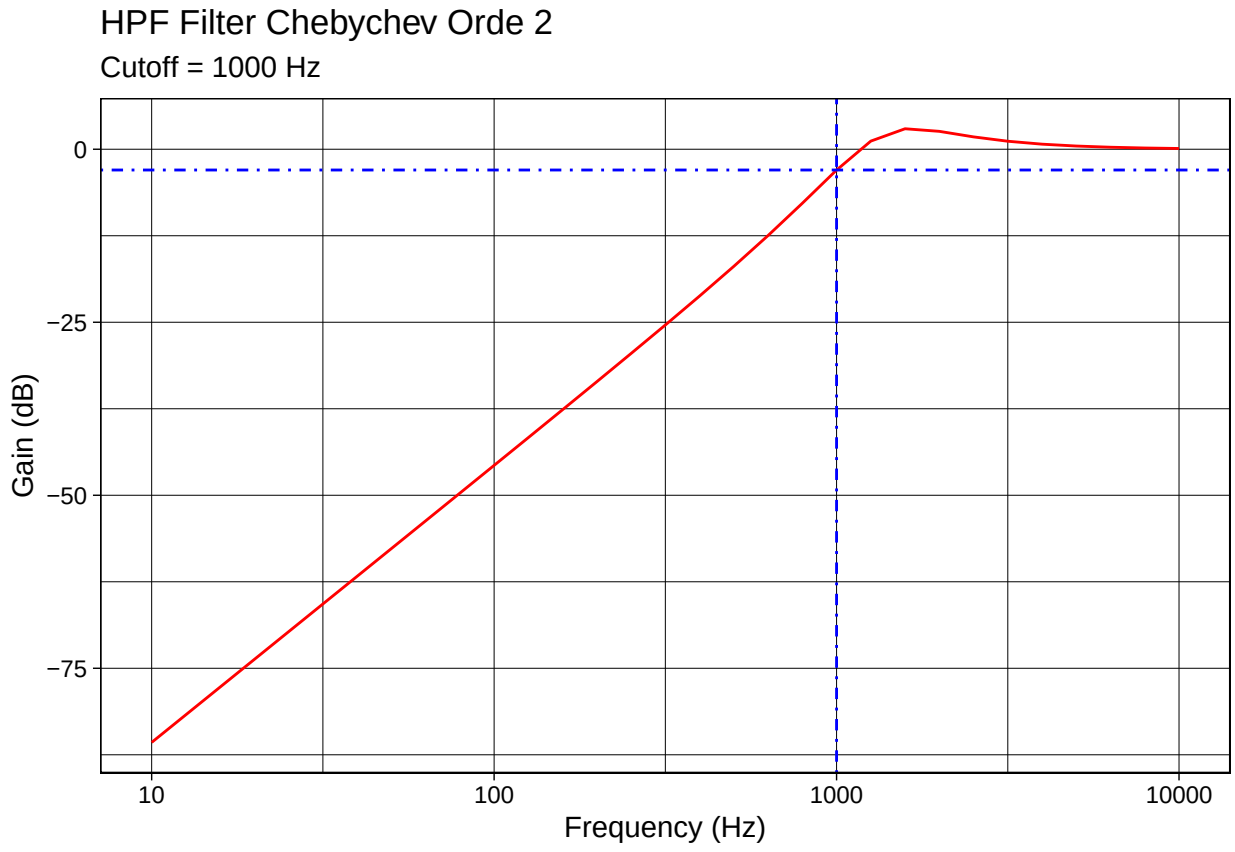
4.1.3 a) Frequency Response

Mengambil data untuk Chebychev saja.

```
cheby2_freq <- freq_resp %>%
  dplyr::select(FREQ, Chebychev2)
```

Plot respon frekuensi, juga disertakan garis bantu untuk cutoff frequency.

```
cheby2_freq_plot <-
ggplot(cheby2_freq) +
  geom_line(aes(FREQ, Chebychev2), color = "red") +
  geom_vline(xintercept = CUTOFF, color = "blue", linetype = 4) +
  geom_hline(yintercept = MAG_3dB, color = "blue", linetype = 4) +

  # Plot plot parameters
  labs(title = "HPF Filter Chebychev Orde 2",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)") +
  scale_x_log10() +
  theme_linedraw()

cheby2_freq_plot
```



Max Ripple

Ripple maksimum pada Chebychev didapatkan melalui fungsi `.max()` dari kolom `Chebychev2`. Dan frekuensi saat ripple didapat dengan melakukan `filter()` data, dengan syarat $G_{dB} = ripple$, lalu mengambil kolom `FREQ` saja.

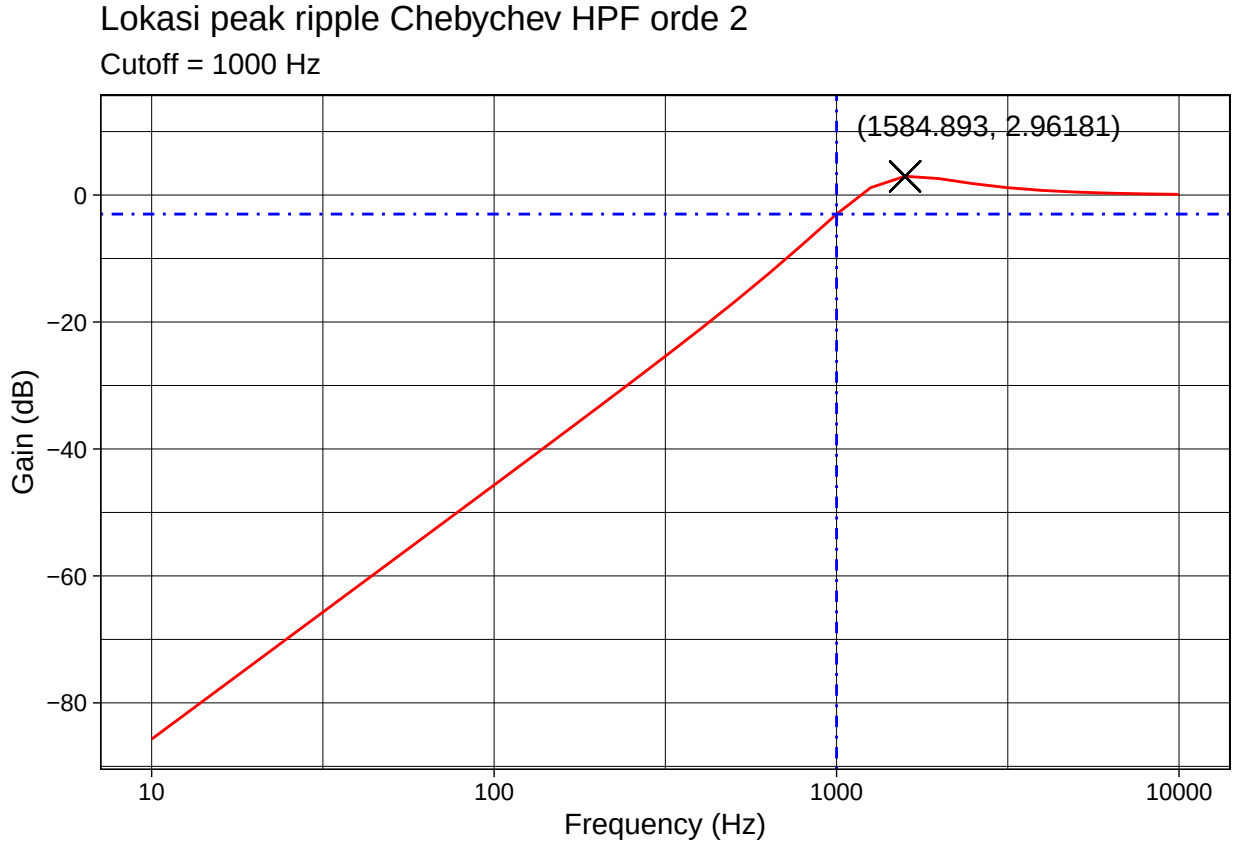
```
ripple <- max(cheby2_freq$Chebychev2)
freq_at_ripple <- cheby2_freq %>%
  dplyr::filter(Chebychev2 == ripple) %>%
  dplyr::select(FREQ) %>%
  as.numeric()

ripple
```

```
## [1] 2.96181
```

```
freq_at_ripple
```

```
## [1] 1584.893
```

```
cheby2_freq_plot +
  geom_point(aes(x = freq_at_ripple, y = ripple), color = "black",
             shape = 4, size = 5) +
  annotate("text", x = freq_at_ripple + 1200, y = ripple + 8,
           label = "(1584.893, 2.96181)") +
  labs(title = "Lokasi peak ripple Chebychev HPF orde 2")
```



4.1.3 b) Time Domain

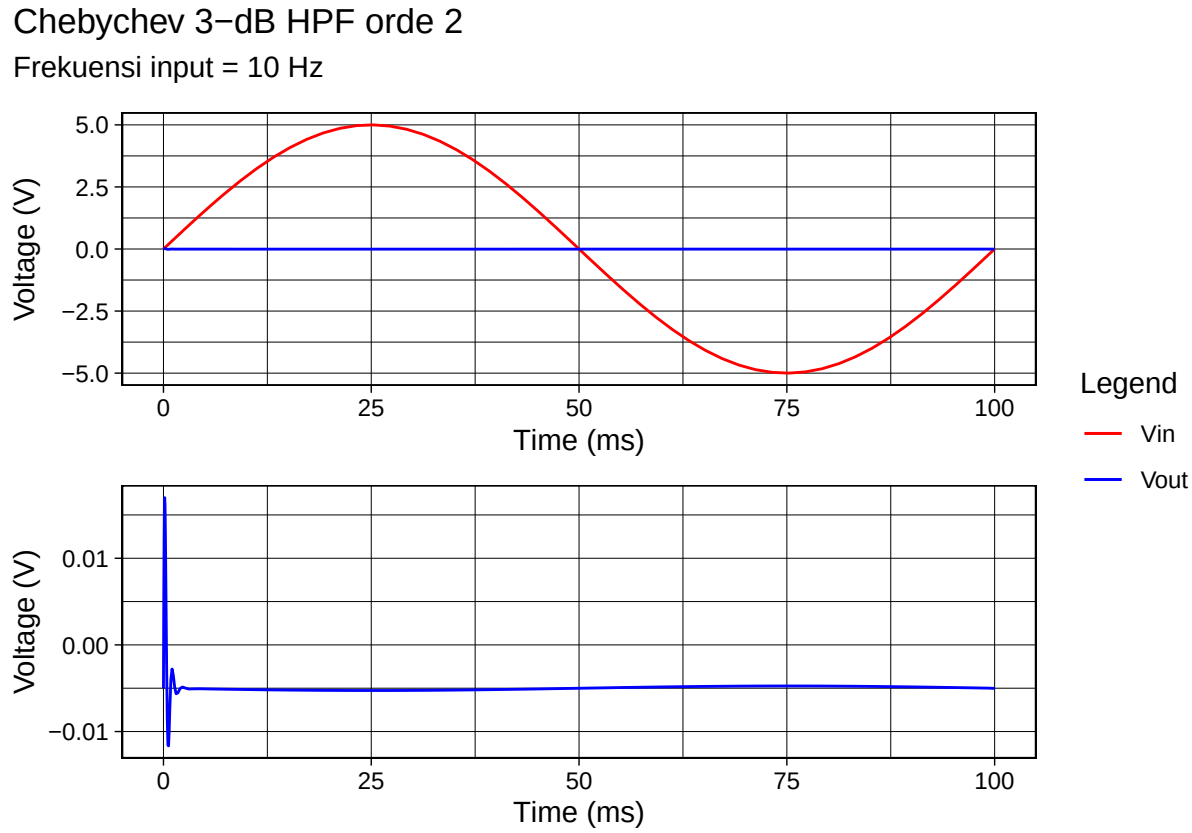
F = 10 Hz

Subset data untuk time domain saja:

```
cheby2_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Chebychev2)
```

Plot perbandingan input dan output.

```
p1 <-
ggplot(cheby2_10Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev2, color = "vout")) +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  theme_linedraw()


p2 <-
ggplot(cheby2_10Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev 3-dB HPF orde 2",
                  subtitle = "Frekuensi input = 10 Hz")
```



Zoom in ke Vout saja, dengan melakukan subset data untuk syarat t:

$$t > 5ms$$

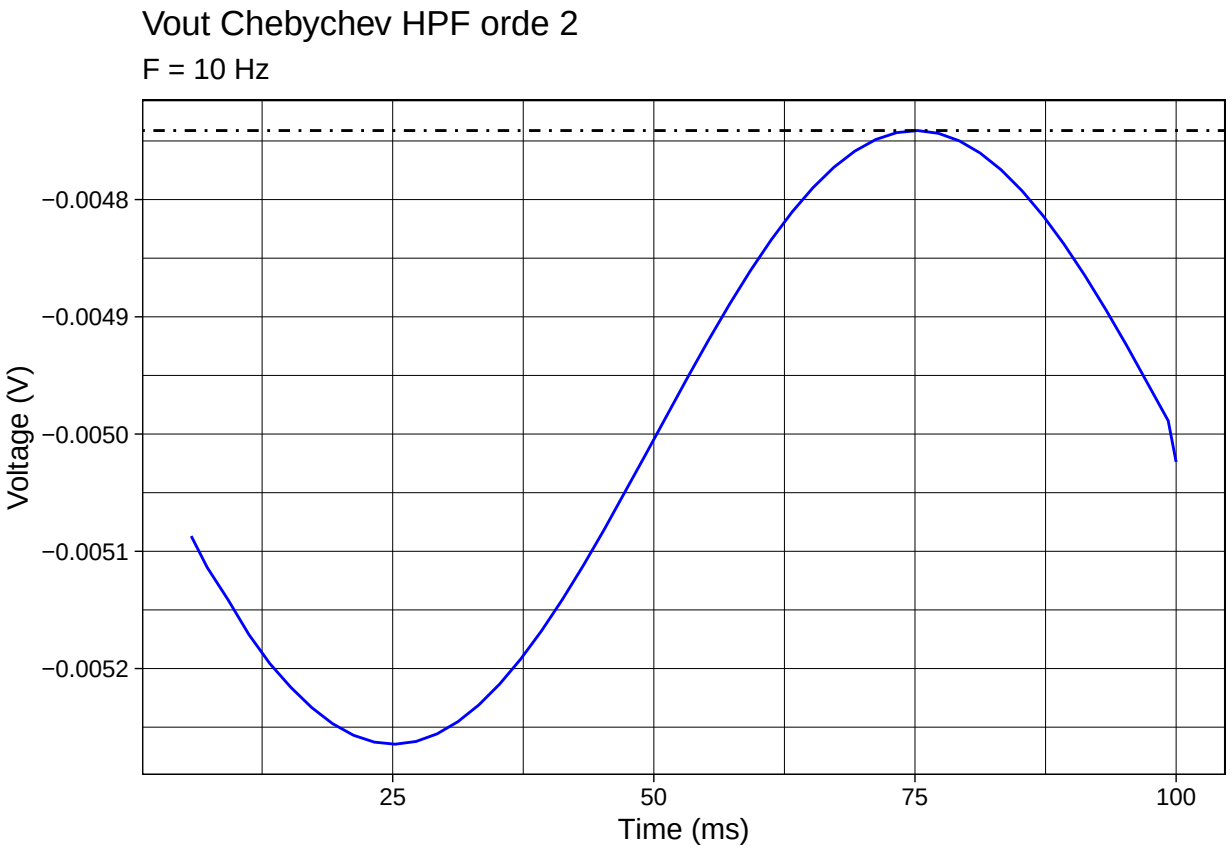
```
cheby2_10Hz %>%
  dplyr::filter(TIME * 1000 > 5) -> cheby2_10Hz
```

Untuk mendapatkan V_{peak} maka menggunakan `max()`

```
vpeak <- max(cheby2_10Hz$Chebychev2)
vpeak
```

```
## [1] -0.00474113
```

```
ggplot(cheby2_10Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +
  geom_hline(aes(yintercept = vpeak), color = "black", linetype = 4) +

  # plot information
  labs(title = "Vout Chebychev HPF orde 2",
       subtitle = "F = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Vout Chebychev HPF orde 2
F = 10 Hz
−0.0048
−0.0049
−0.0050
−0.0051
−0.0052
Voltage (V)
25
50
75
100
Time (ms)

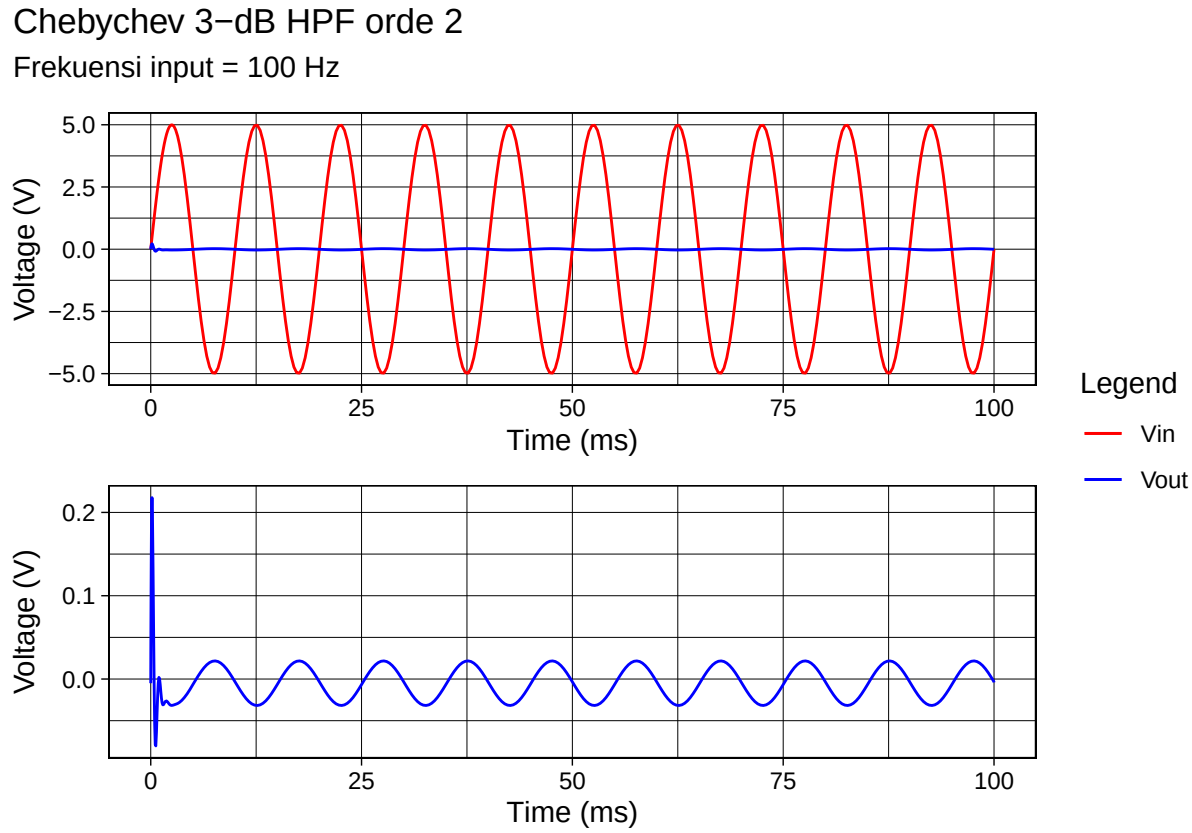
F = 100 Hz

Subset data untuk time domain saja:

```
cheby2_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Chebychev2)
```

Plot perbandingan input dan output.

```
p1 <-
ggplot(cheby2_100Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev2, color = "vout")) +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  theme_linedraw()


p2 <-
ggplot(cheby2_100Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev 3-dB HPF orde 2",
                  subtitle = "Frekuensi input = 100 Hz")
```



Zoom in ke Vout saja, dengan melakukan subset data untuk syarat t:

$$t > 5ms$$

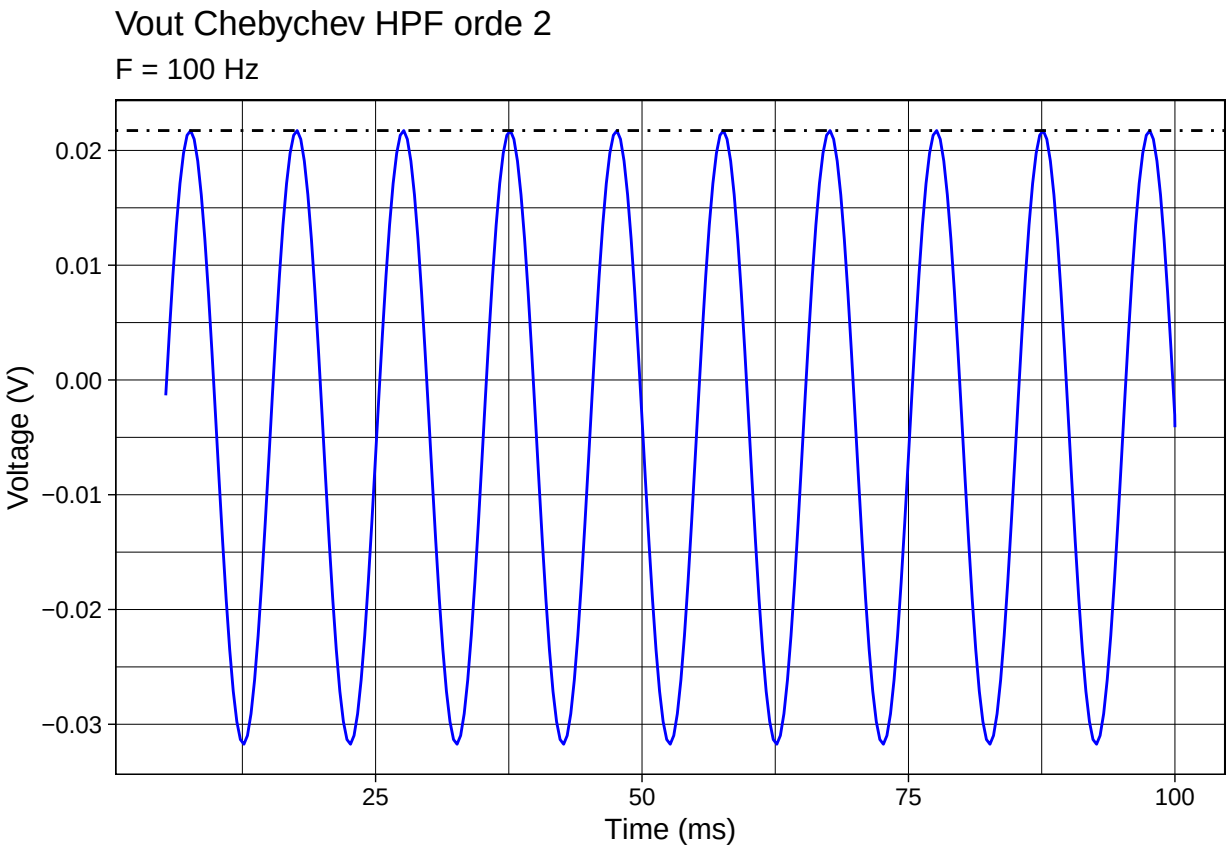
```
cheby2_100Hz %>%
  dplyr::filter(TIME * 1000 > 5) -> cheby2_100Hz
```

Untuk mendapatkan V_{peak} maka menggunakan `max()`

```
vpeak <- max(cheby2_100Hz$Chebychev2)
vpeak
```

```
## [1] 0.0217318
```

```
ggplot(cheby2_100Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +
  geom_hline(aes(yintercept = vpeak), color = "black", linetype = 4) +

  # plot information
  labs(title = "Vout Chebychev HPF orde 2",
       subtitle = "F = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Vout Chebychev HPF orde 2
F = 100 Hz
0.02
0.01
0.00
−0.01
−0.02
−0.03
Voltage (V)
25
50
75
100
Time (ms)

F = 1000 Hz

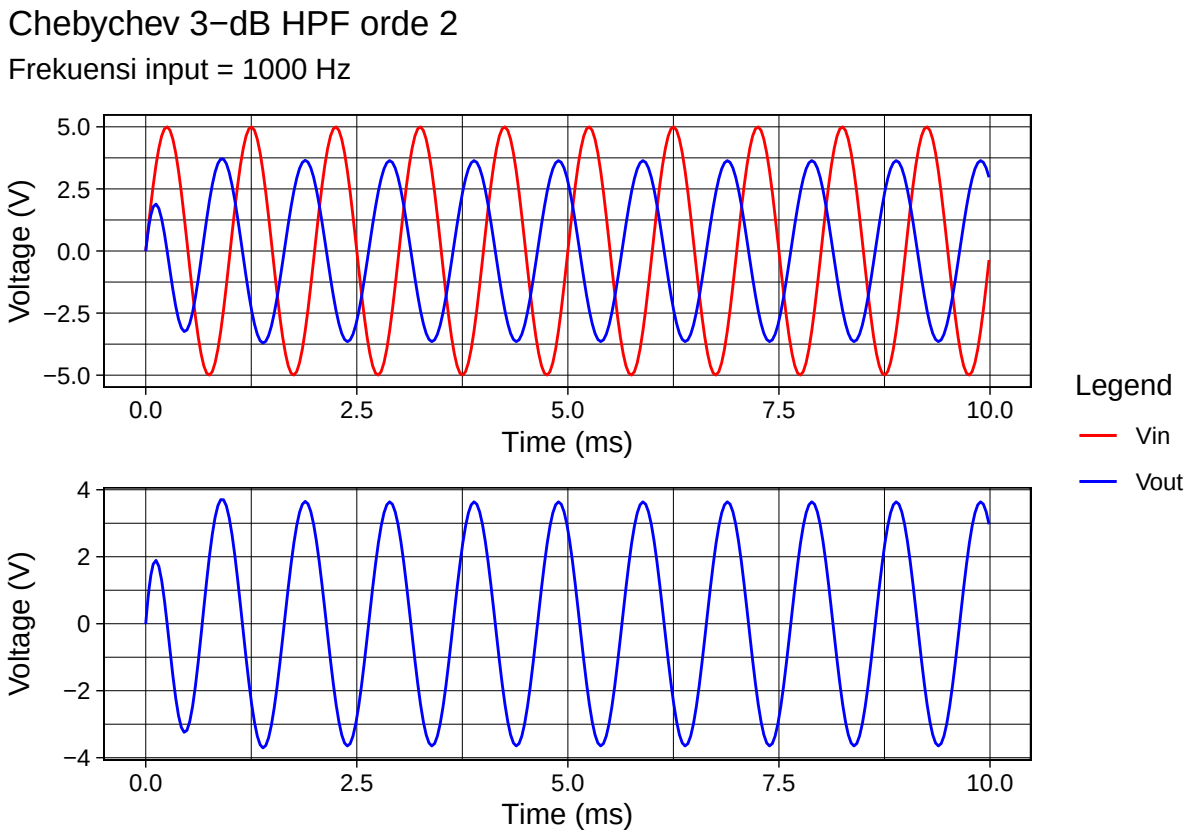
Subset data untuk time domain saja, dengan syarat t:

$$t < 10ms$$

```
cheby2_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Chebychev2) %>%
  dplyr::filter(TIME * 1000 < 10)
```

Plot perbandingan input dan output.

```
p1 <-
ggplot(cheby2_1000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev2, color = "vout")) +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  theme_linedraw()


p2 <-
ggplot(cheby2_1000Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev 3-dB HPF orde 2",
                  subtitle = "Frekuensi input = 1000 Hz")
```



Zoom in ke Vout saja, dengan melakukan subset data untuk syarat t:

$$t > 1ms$$

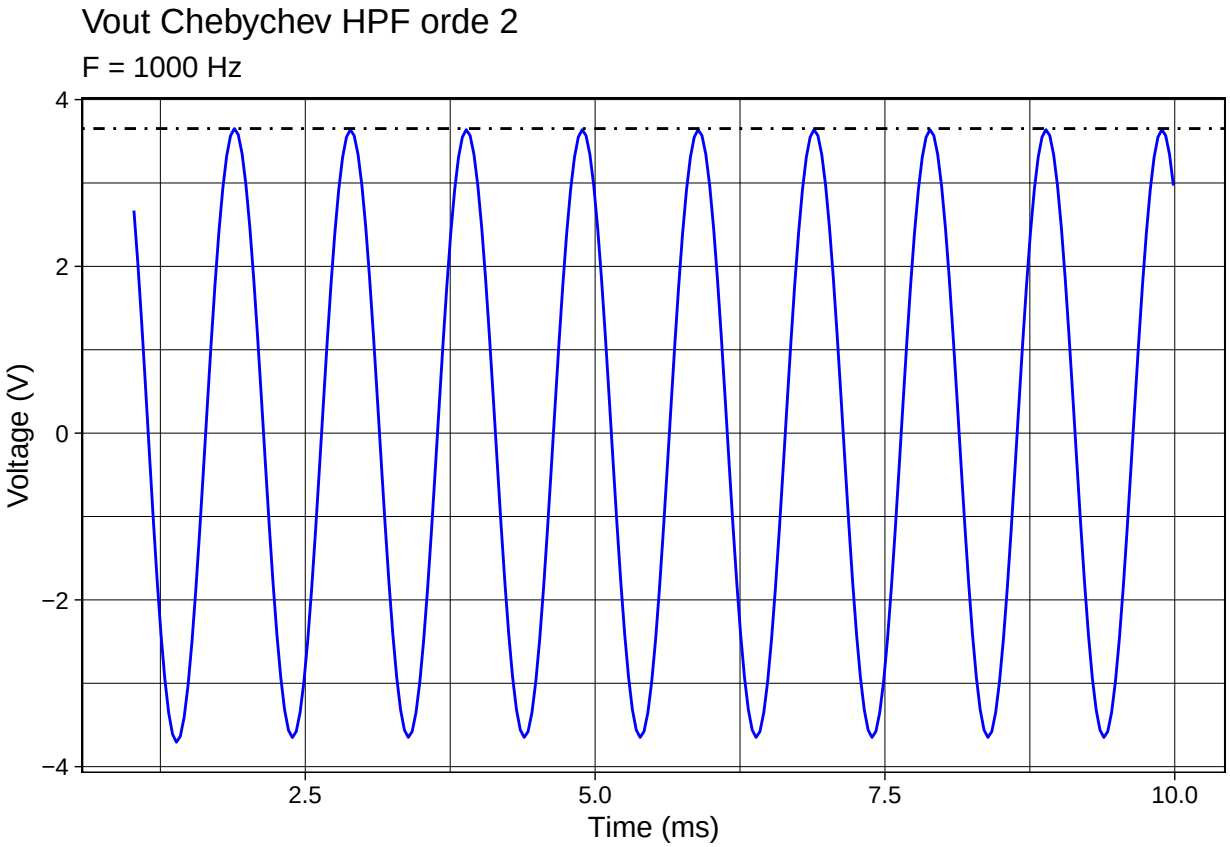
```
cheby2_1000Hz %>%
  dplyr::filter(TIME * 1000 > 1) -> cheby2_1000Hz
```

Untuk mendapatkan V_{peak} maka menggunakan `max()`

```
vpeak <- max(cheby2_1000Hz$Chebychev2)
vpeak
```

```
## [1] 3.65289
```

```
ggplot(cheby2_1000Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +
  geom_hline(aes(yintercept = vpeak), color = "black", linetype = 4) +

  # plot information
  labs(title = "Vout Chebychev HPF orde 2",
       subtitle = "F = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Vout Chebychev HPF orde 2
F = 1000 Hz
Voltage (V)
Time (ms)
4
2
0
−2
−4
2.5
5.0
7.5
10.0

F = 10000 Hz

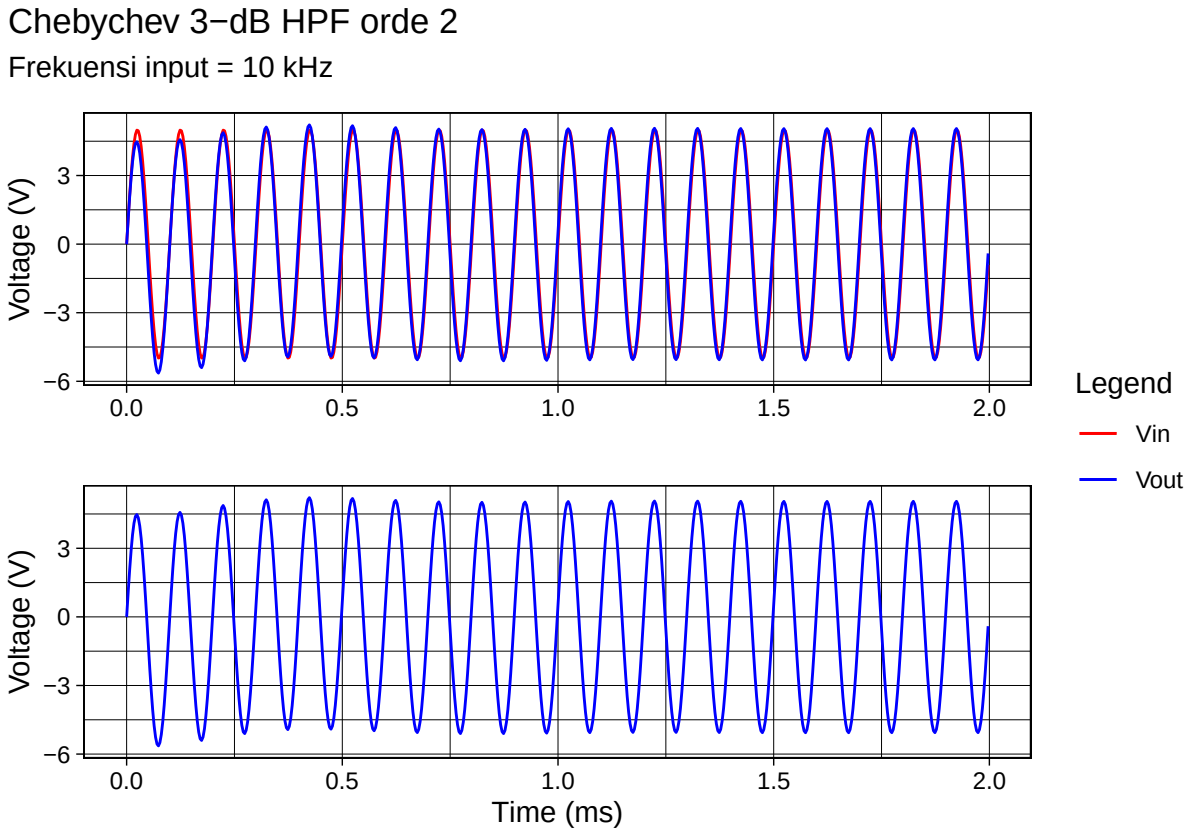
Subset data untuk time domain saja, dengan syarat t:

$$t < 2ms$$

```
cheby2_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Chebychev2) %>%
  dplyr::filter(TIME * 1000 < 2)
```

Plot perbandingan input dan output.

```
p1 <-
ggplot(cheby2_10000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev2, color = "vout")) +

  # plot information
  labs(x = "",
       y = "Voltage (V)") +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  theme_linedraw()


p2 <-
ggplot(cheby2_10000Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +

  # plot information
  labs(x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev 3-dB HPF orde 2",
                  subtitle = "Frekuensi input = 10 kHz")
```



Zoom in ke Vout saja, dengan melakukan subset data untuk syarat t:

$$t > 1ms$$

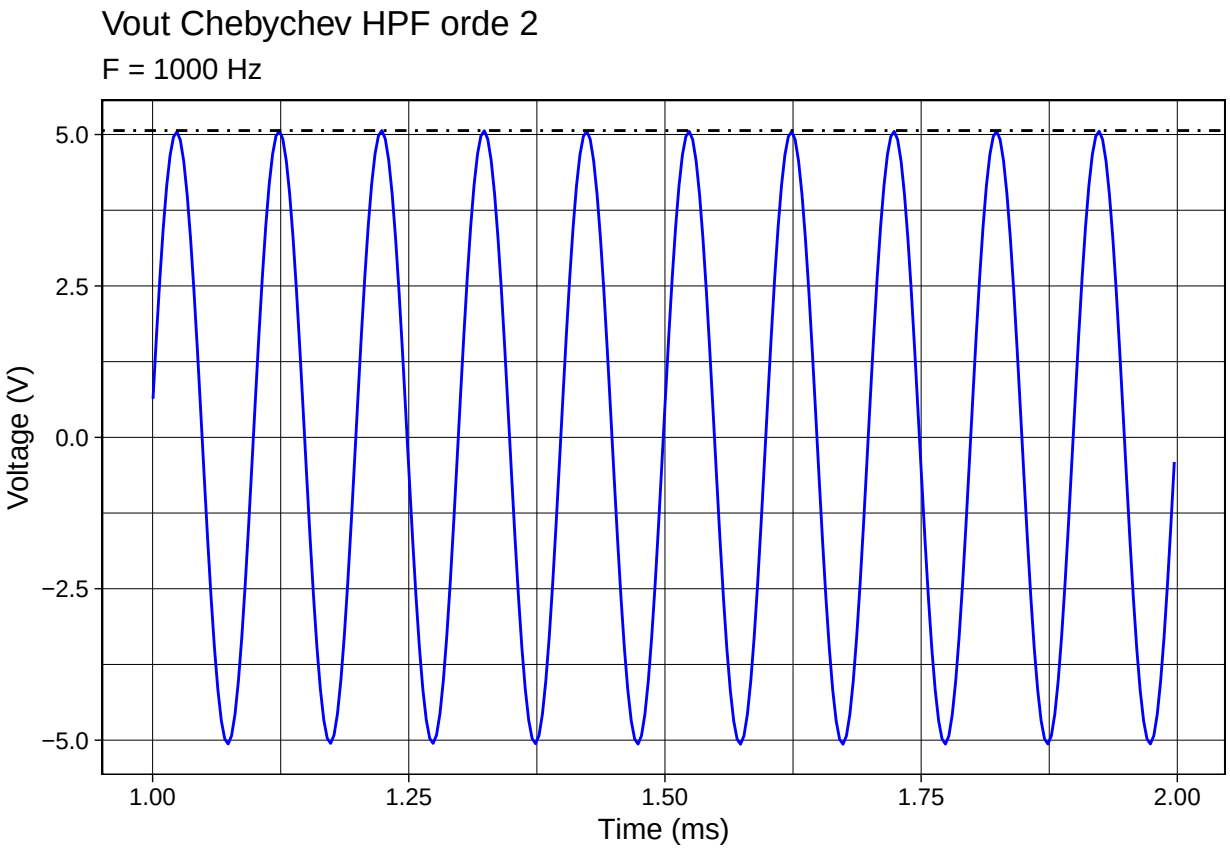
```
cheby2_10000Hz %>%
  dplyr::filter(TIME * 1000 > 1) -> cheby2_10000Hz
```

Untuk mendapatkan V_{peak} maka menggunakan `max()`

```
vpeak <- max(cheby2_10000Hz$Chebychev2)
vpeak
```

```
## [1] 5.06595
```

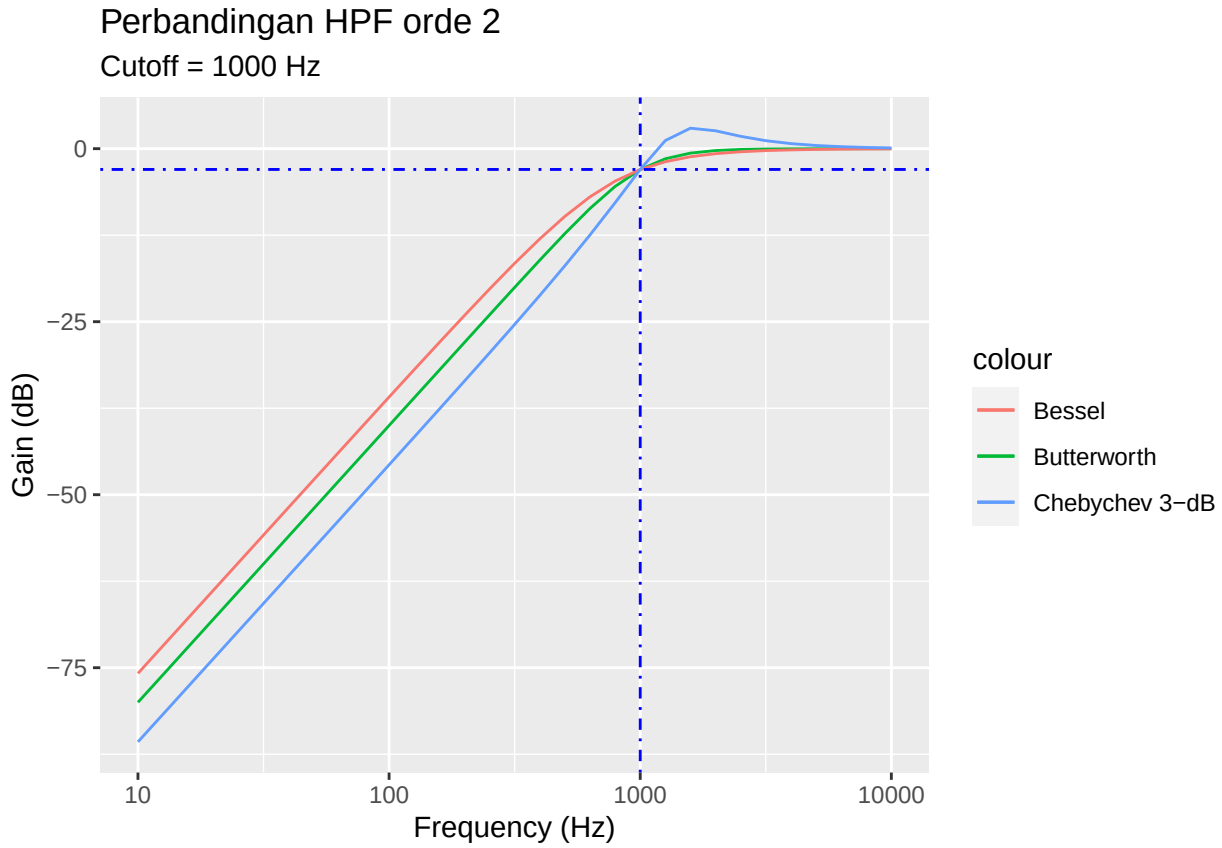
```
ggplot(cheby2_10000Hz) +
  geom_line(aes(TIME * 1000, Chebychev2), color = "blue") +
  geom_hline(aes(yintercept = vpeak), color = "black", linetype = 4) +

  # plot information
  labs(title = "Vout Chebychev HPF orde 2",
       subtitle = "F = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Vout Chebychev HPF orde 2
F = 1000 Hz
5.0
2.5
0.0
−2.5
−5.0
Voltage (V)
1.00
1.25
1.50
1.75
2.00
Time (ms)

4.1.4 Perbandingan Respon Frekuensi

Plot frequency response ketiga filter orde 2, sumbu-x logaritmis, juga disertakan garis bantu untuk frekuensi cutoff & lokasi gain 3 dB.

```
ggplot(freq_resp_2) +
  scale_x_log10() +
  geom_line(aes(FREQ, Butterworth2, color = "Butterworth")) +
  geom_line(aes(FREQ, Bessel2, color = "Bessel")) +
  geom_line(aes(FREQ, Chebychev2, color = "Chebychev 3-dB")) +

  # Garis bantu
  geom_hline(yintercept = -3, color = "blue", linetype = 4) +
  geom_vline(xintercept = 1000, color = "blue", linetype = 4) +

  # plot information
  labs(title = "Perbandingan HPF orde 2",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)")
```



4.2 Filter Orde 3

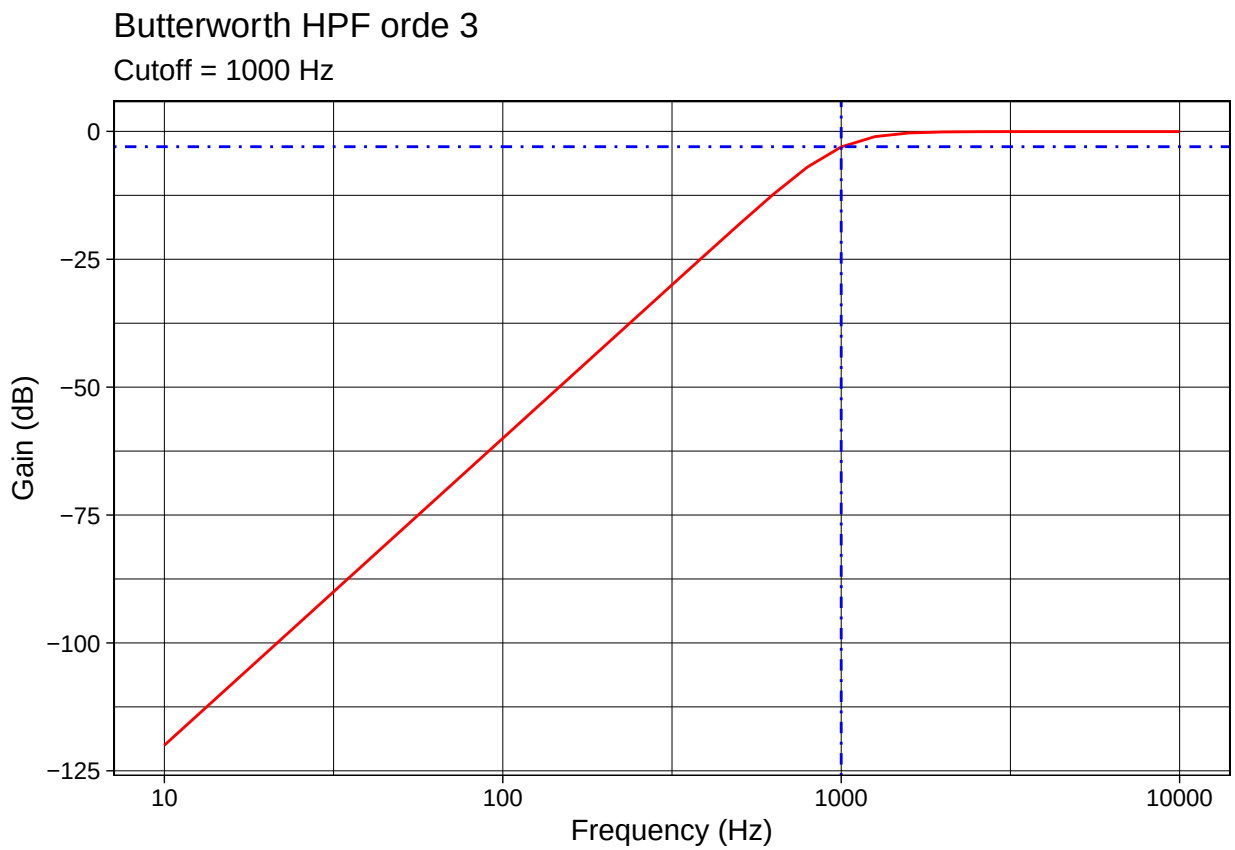
Mengambil data filter orde 3.

```
freq_resp_3 <- freq_resp %>%
  dplyr::select(FREQ, Butterworth3, Bessel3, Chebychev3)
```

4.2.1 Butterworth

4.2.1 a) Frequency Response

```
freq_resp_3 %>%

ggplot() +
  scale_x_log10() +
  geom_line(aes(FREQ, Butterworth3), color = "red") +
  geom_hline(yintercept = -3, color = "blue", linetype = 4) +
  geom_vline(xintercept = 1000, color = "blue", linetype = 4) +

  # plot information
  labs(title = "Butterworth HPF orde 3",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)") +
  theme_linedraw()
```



4.2.1 b) Time Domain

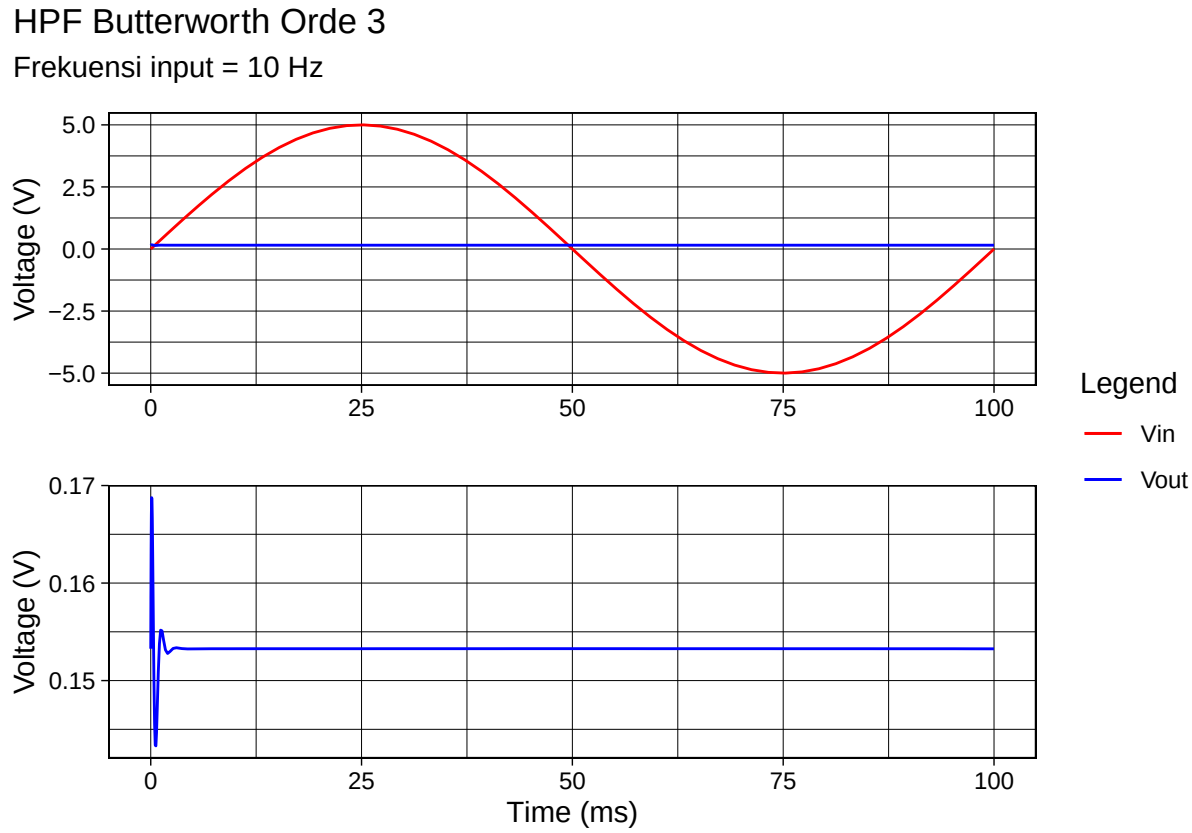
F = 10 Hz

Mengambil data untuk 10 Hz.

```
butter3_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Butterworth3)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(butter3_10Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Butterworth3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(butter3_10Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Butterworth Orde 3",
                  subtitle = "Frekuensi input = 10 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

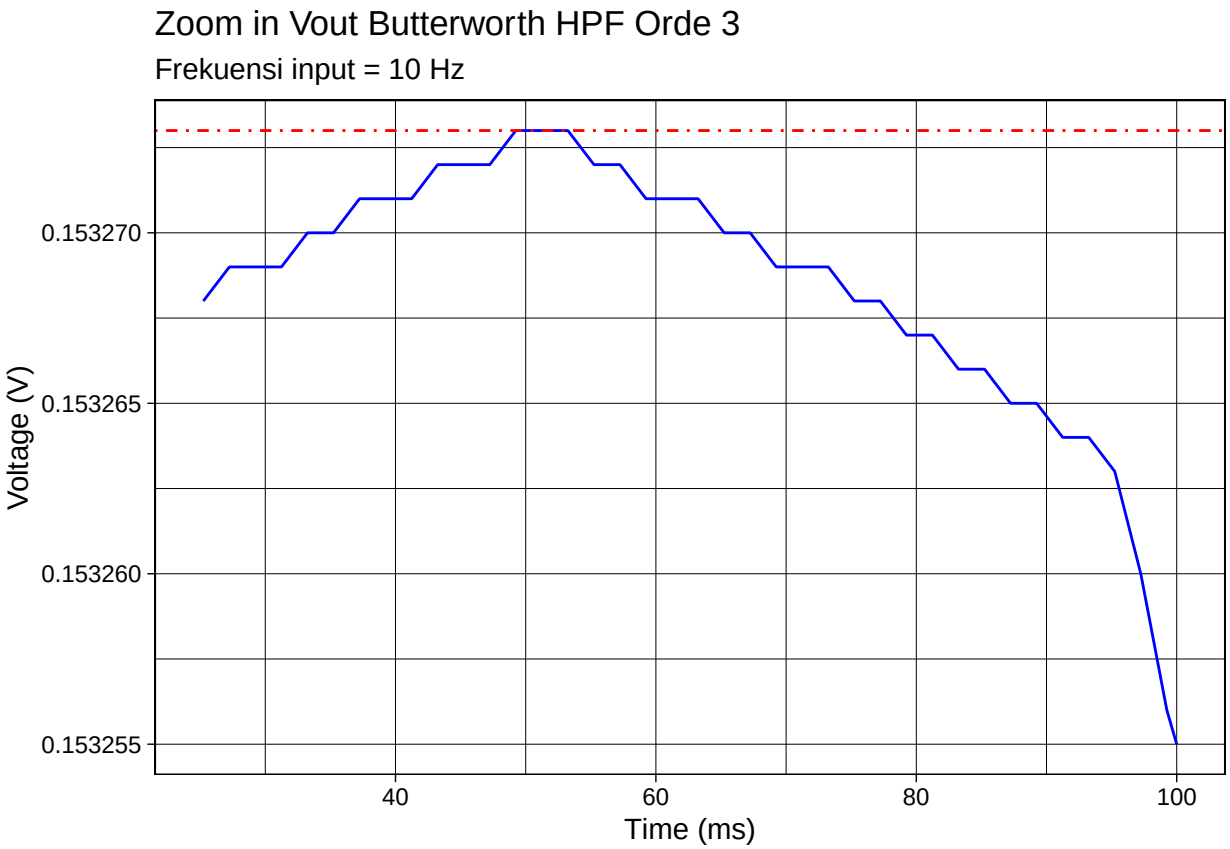
$$t > 25ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
butter3_10Hz <- butter3_10Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(butter3_10Hz$Butterworth3)
vpeak
```

```
## [1] 0.153273
```

```
ggplot(butter3_10Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Butterworth HPF Orde 3",
       subtitle = "Frekuensi input = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Butterworth HPF Orde 3
Frekuensi input = 10 Hz
Voltage (V)
0.153270
0.153265
0.153260
0.153255
40
60
80
100
Time (ms)

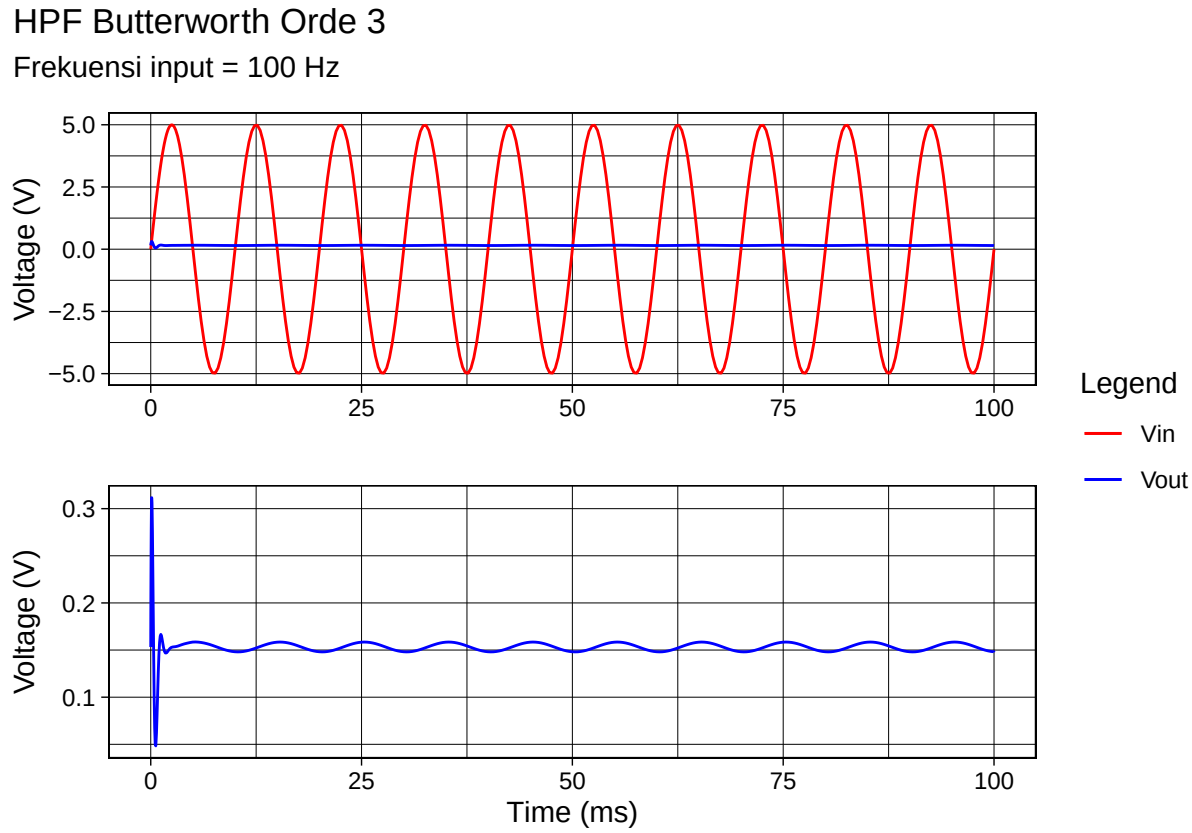
F = 100 Hz

Mengambil data untuk 100 Hz.

```
butter3_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Butterworth3)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(butter3_100Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Butterworth3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(butter3_100Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Butterworth Orde 3",
                  subtitle = "Frekuensi input = 100 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

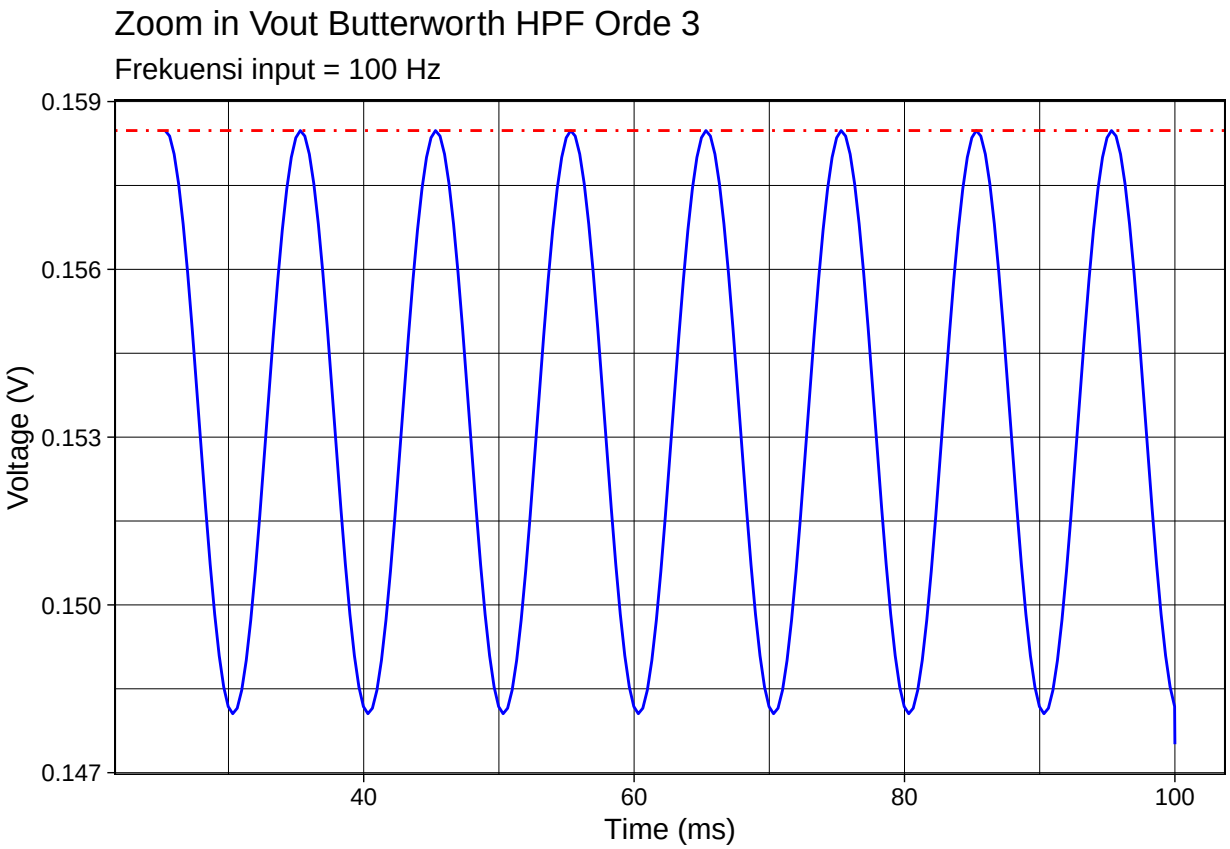
$$t > 25ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
butter3_100Hz <- butter3_100Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(butter3_100Hz$Butterworth3)
vpeak
```

```
## [1] 0.158482
```

```
ggplot(butter3_100Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Butterworth HPF Orde 3",
       subtitle = "Frekuensi input = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Butterworth HPF Orde 3
Frekuensi input = 100 Hz
0.159
0.156
0.153
0.150
0.147
Voltage (V)
40
60
80
100
Time (ms)

F = 1000 Hz

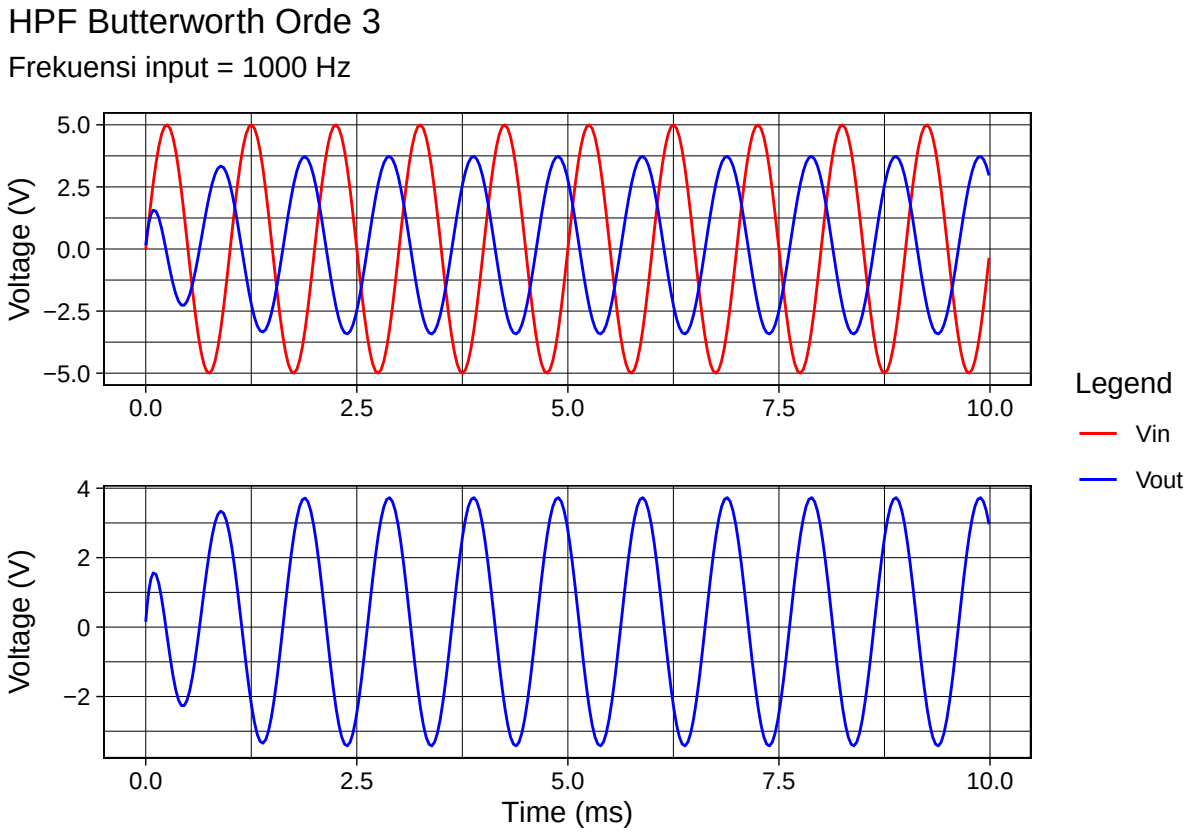
Mengambil data untuk 100 Hz, dengan waktu t:

$$t < 10ms$$

```
butter3_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Butterworth3) %>%
  dplyr::filter(TIME * 1000 < 10)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(butter3_1000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Butterworth3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(butter3_1000Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Butterworth Orde 3",
                  subtitle = "Frekuensi input = 1000 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

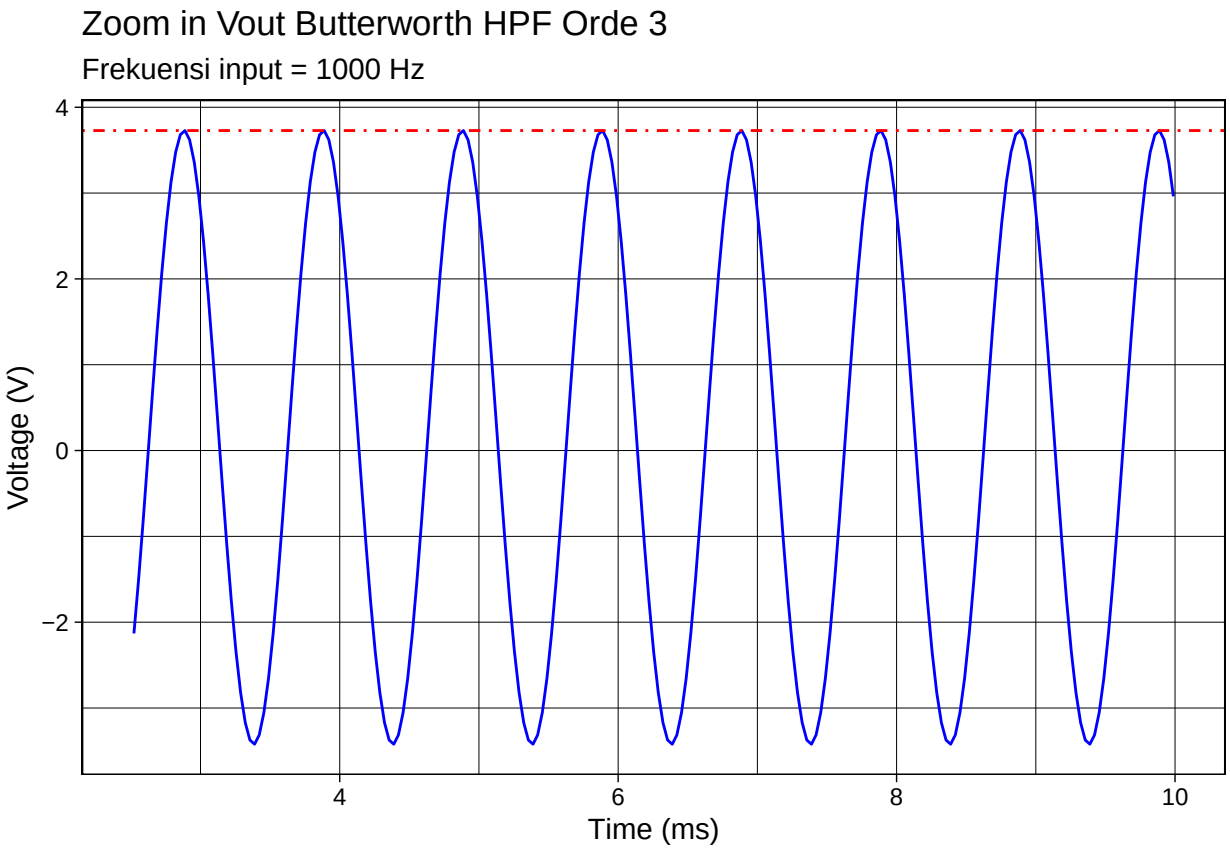
$$t > 2.5ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
butter3_1000Hz <- butter3_1000Hz %>%
  dplyr::filter(TIME * 1000 > 2.5)

vpeak <- max(butter3_1000Hz$Butterworth3)
vpeak
```

```
## [1] 3.72844
```

```
ggplot(butter3_1000Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Butterworth HPF Orde 3",
       subtitle = "Frekuensi input = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Butterworth HPF Orde 3
Frekuensi input = 1000 Hz
Voltage (V)
Time (ms)
4
2
0
−2
4
6
8
10

F = 10000 Hz

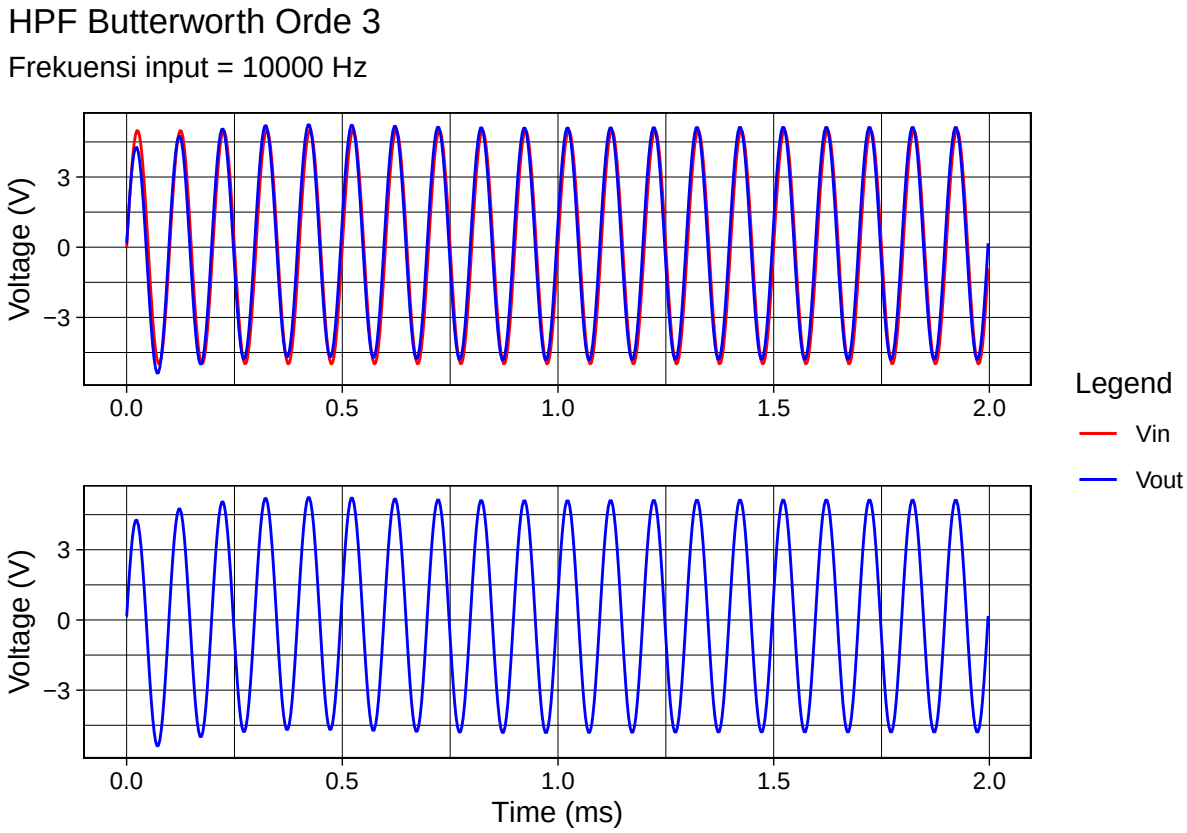
Mengambil data untuk 100 Hz, dengan waktu t:

$$t < 2ms$$

```
butter3_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Butterworth3) %>%
  dplyr::filter(TIME * 1000 < 2)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(butter3_10000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Butterworth3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(butter3_10000Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Butterworth Orde 3",
                  subtitle = "Frekuensi input = 10000 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

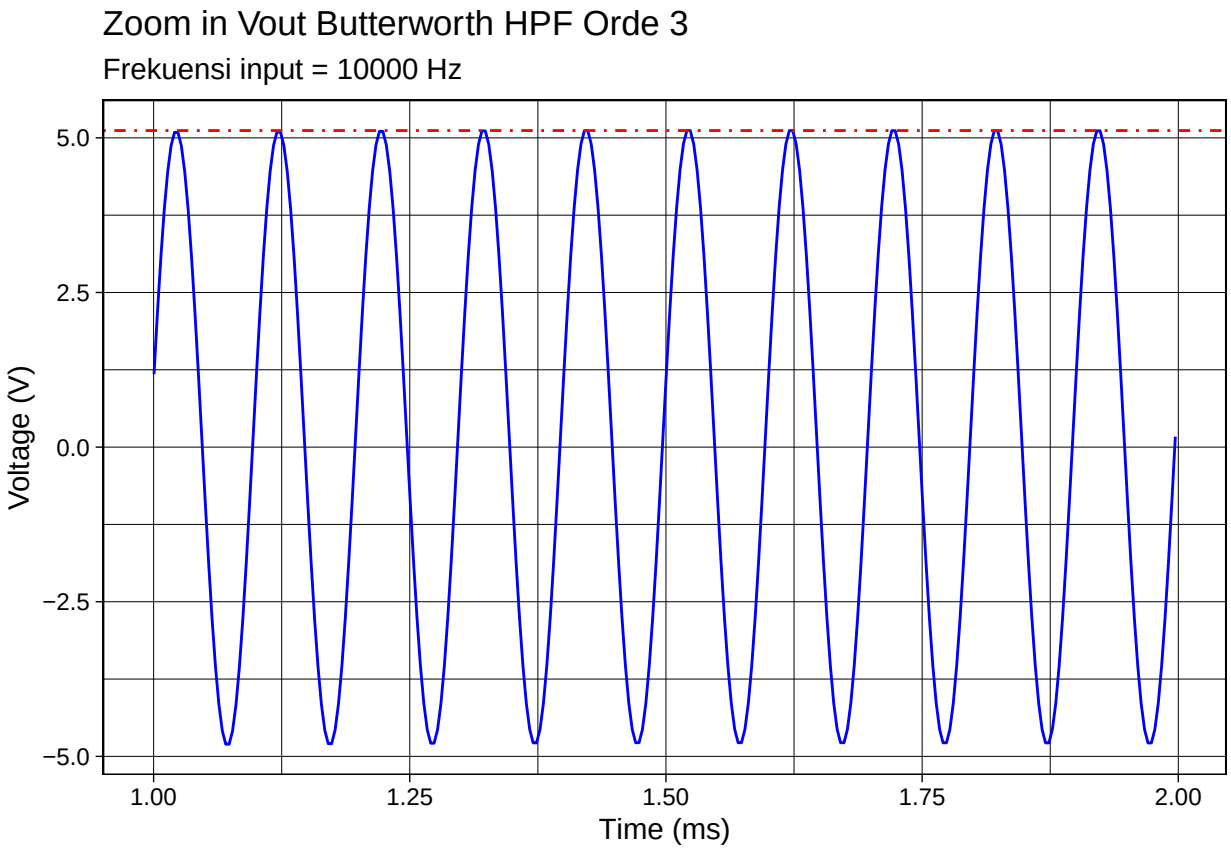
$$t > 1ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
butter3_10000Hz <- butter3_10000Hz %>%
  dplyr::filter(TIME * 1000 > 1)

vpeak <- max(butter3_10000Hz$Butterworth3)
vpeak
```

```
## [1] 5.11806
```

```
ggplot(butter3_10000Hz) +
  geom_line(aes(TIME * 1000, Butterworth3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Butterworth HPF Orde 3",
       subtitle = "Frekuensi input = 10000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Butterworth HPF Orde 3
Frekuensi input = 10000 Hz
5.0
2.5
0.0
−2.5
−5.0
Voltage (V)
1.00
1.25
1.50
1.75
2.00
Time (ms)

4.2.2 Bessel

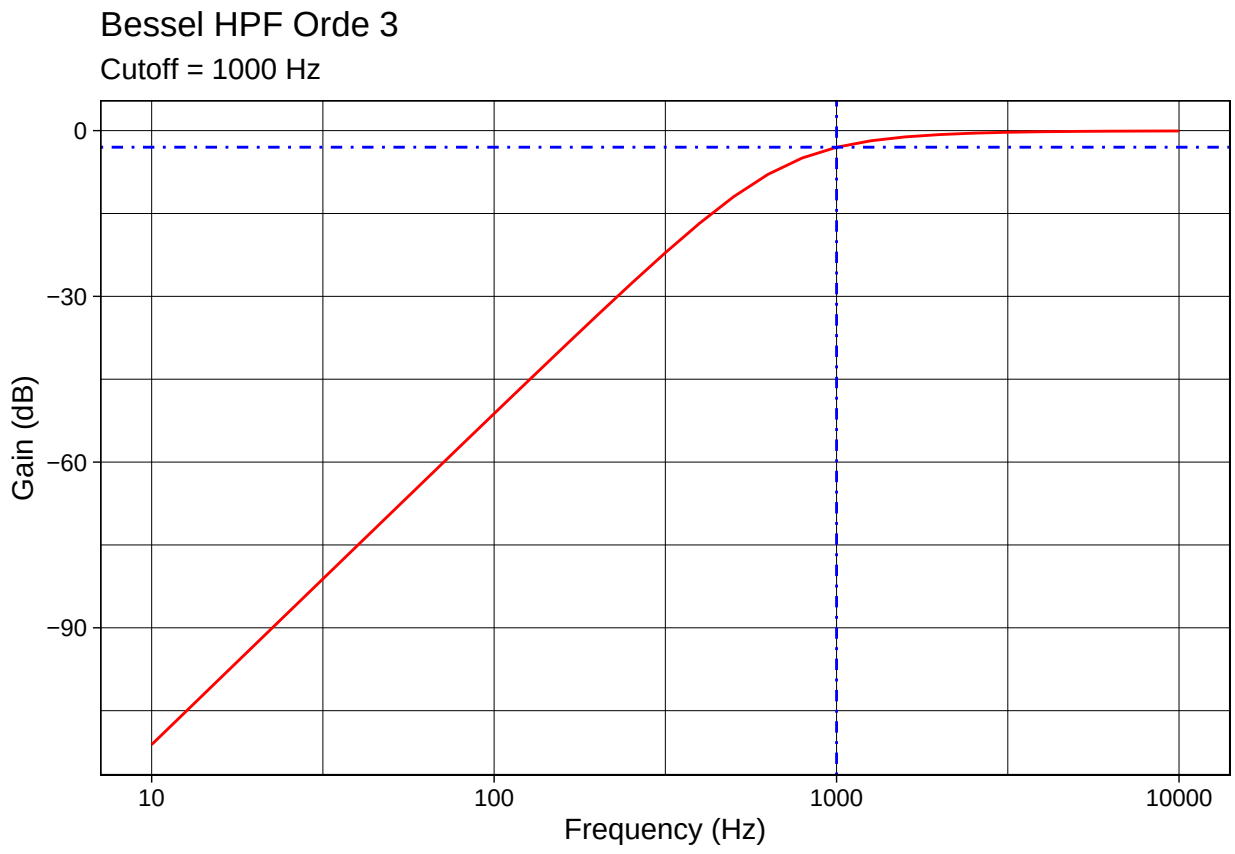
4.2.2 a) Frequency Response

Mengambil data frequency response dari filter Bessel.

```
bessel3_freq <- freq_resp %>%
  dplyr::select(FREQ, Bessel3)
```

Plot respon frekuensi.

```
ggplot(bessel3_freq) +
  scale_x_log10() +
  geom_line(aes(FREQ, Bessel3), color = "red") +
  geom_hline(yintercept = -3, color = "blue", linetype = 4) +
  geom_vline(xintercept = 1000, color = "blue", linetype = 4) +

  # plot information
  labs(title = "Bessel HPF Orde 3",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)") +
  theme_linedraw()
```



4.2.2 b) Time Domain

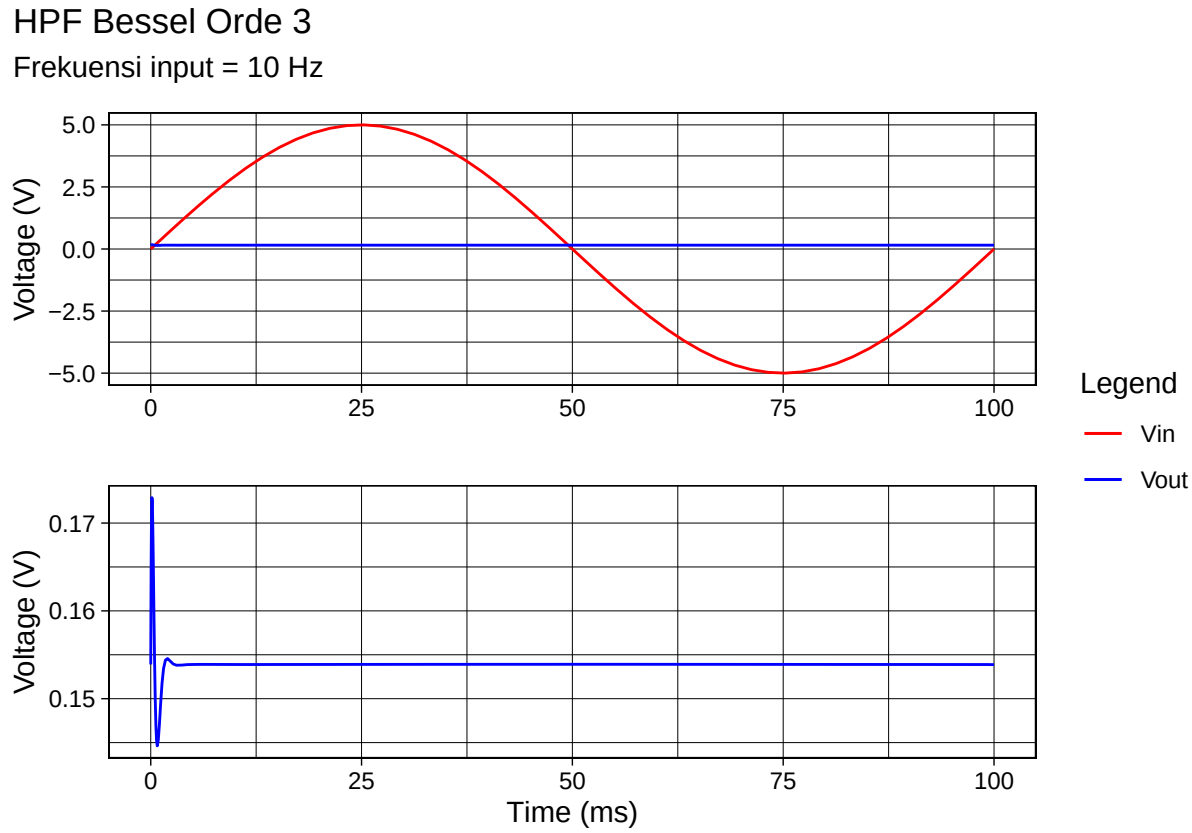
F = 10 Hz

Mengambil data untuk 10 Hz.

```
bessel3_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Bessel3)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(bessel3_10Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Bessel3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(bessel3_10Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Bessel Orde 3",
                  subtitle = "Frekuensi input = 10 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

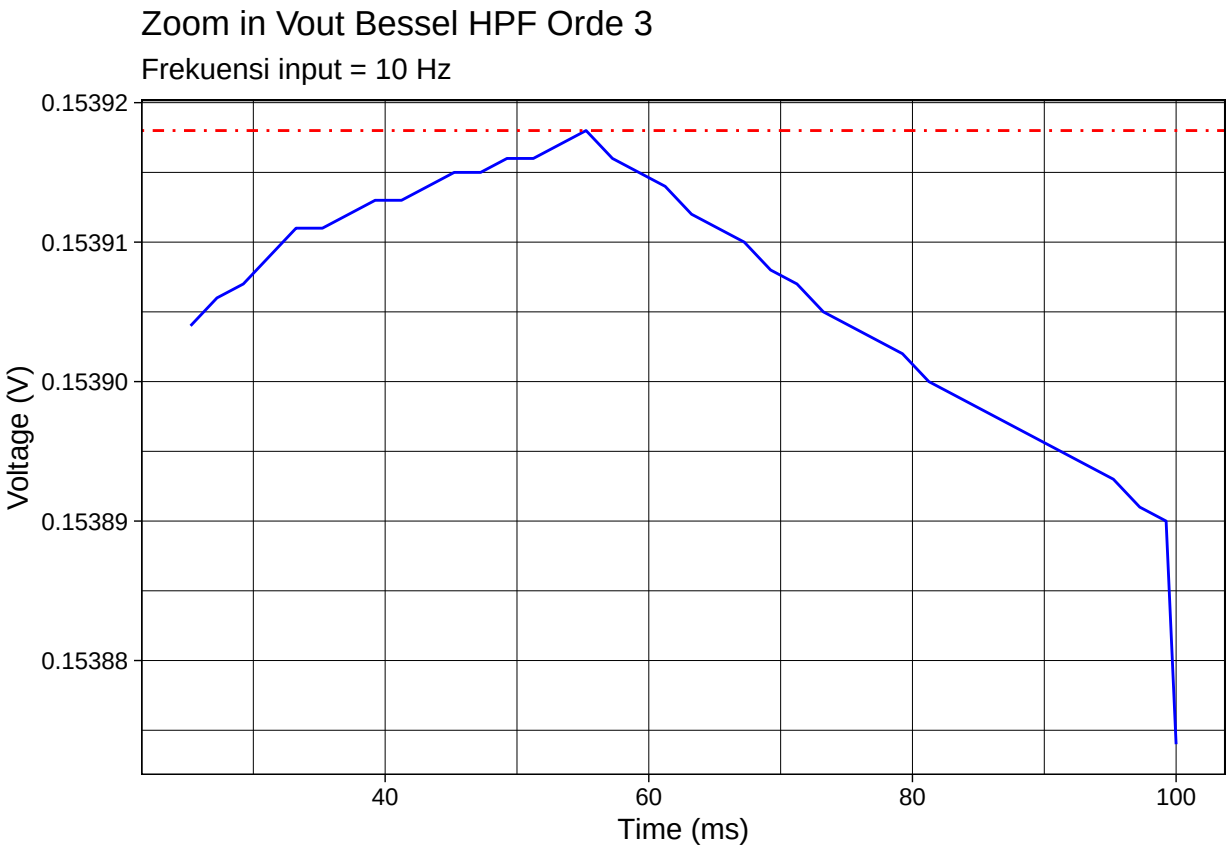
$$t > 25ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
bessel3_10Hz <- bessel3_10Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(bessel3_10Hz$Bessel3)
vpeak
```

```
## [1] 0.153918
```

```
ggplot(bessel3_10Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Bessel HPF Orde 3",
       subtitle = "Frekuensi input = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Bessel HPF Orde 3
Frekuensi input = 10 Hz
0.15392
0.15391
0.15390
0.15389
0.15388
Voltage (V)
40
60
80
100
Time (ms)

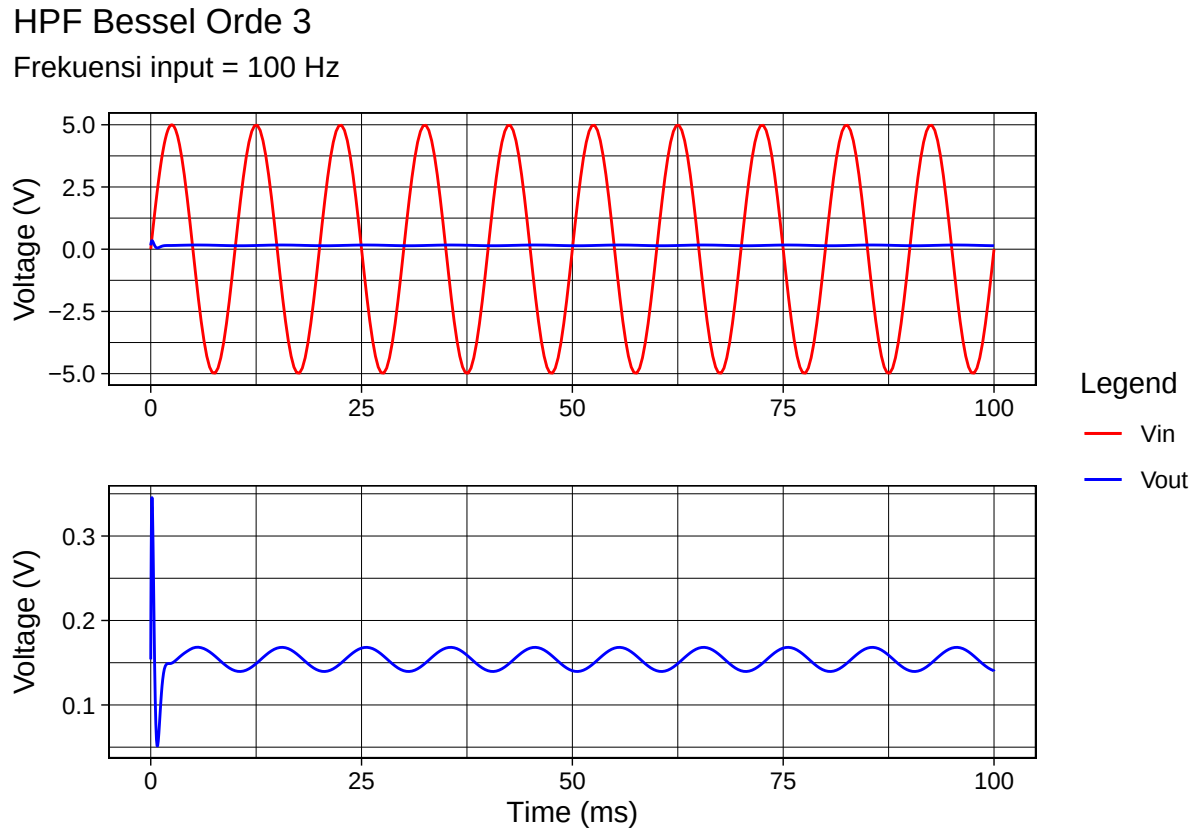
F = 100 Hz

Mengambil data untuk 100 Hz.

```
bessel3_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Bessel3)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(bessel3_100Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Bessel3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(bessel3_100Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Bessel Orde 3",
                  subtitle = "Frekuensi input = 100 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

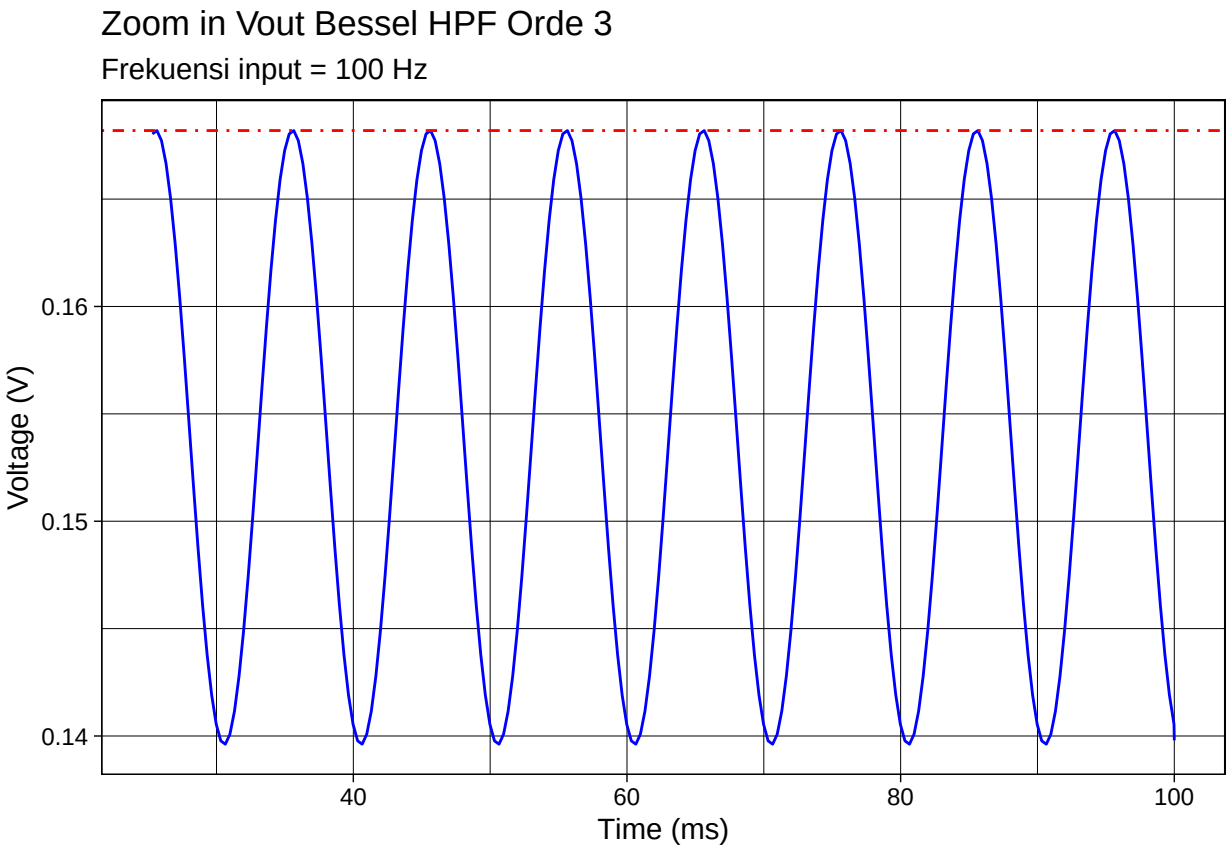
$$t > 25ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
bessel3_100Hz <- bessel3_100Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(bessel3_100Hz$Bessel3)
vpeak
```

```
## [1] 0.168192
```

```
ggplot(bessel3_100Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Bessel HPF Orde 3",
       subtitle = "Frekuensi input = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Bessel HPF Orde 3
Frekuensi input = 100 Hz
Voltage (V)
0.16
0.15
0.14
40
60
80
100
Time (ms)

F = 1000 Hz

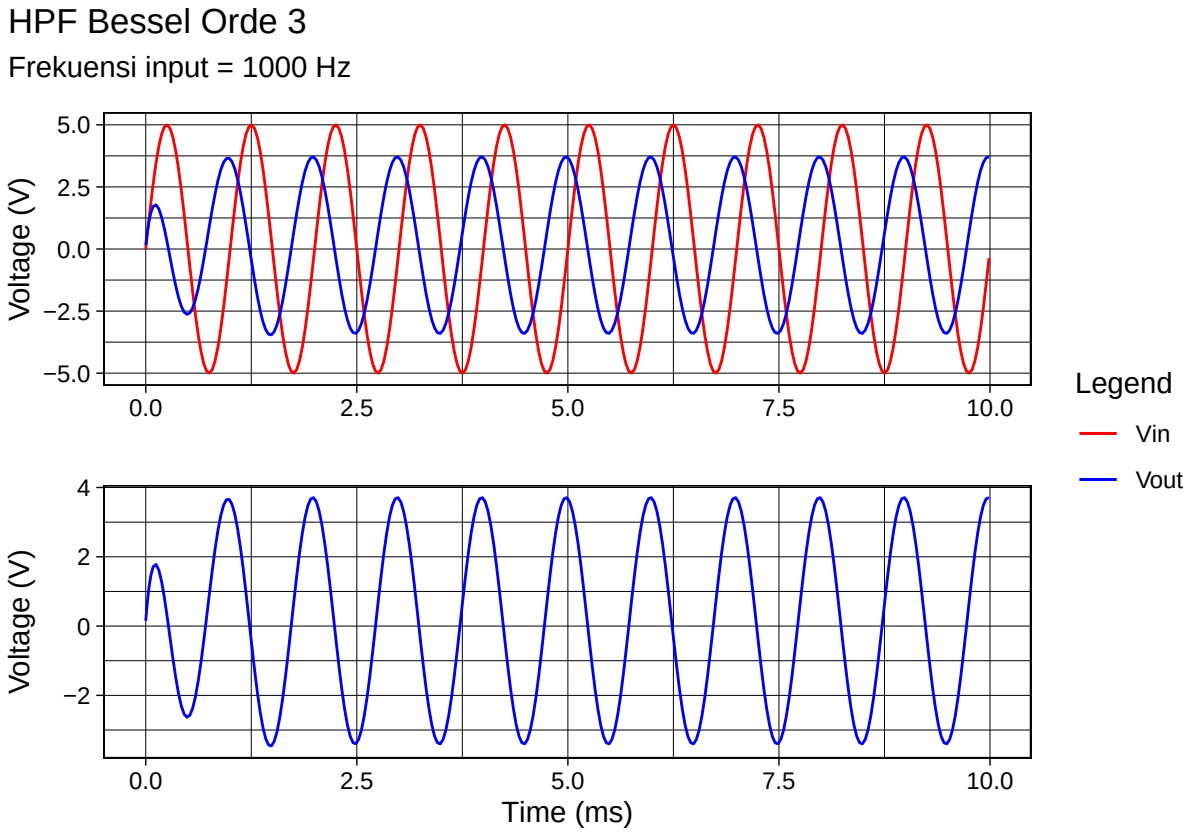
Mengambil data untuk 1000 Hz, dan hanya mengambil untuk t:

$$t < 10ms$$

```
bessel3_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Bessel3) %>%
  dplyr::filter(TIME * 1000 < 10)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(bessel3_1000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Bessel3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(bessel3_1000Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Bessel Orde 3",
                  subtitle = "Frekuensi input = 1000 Hz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

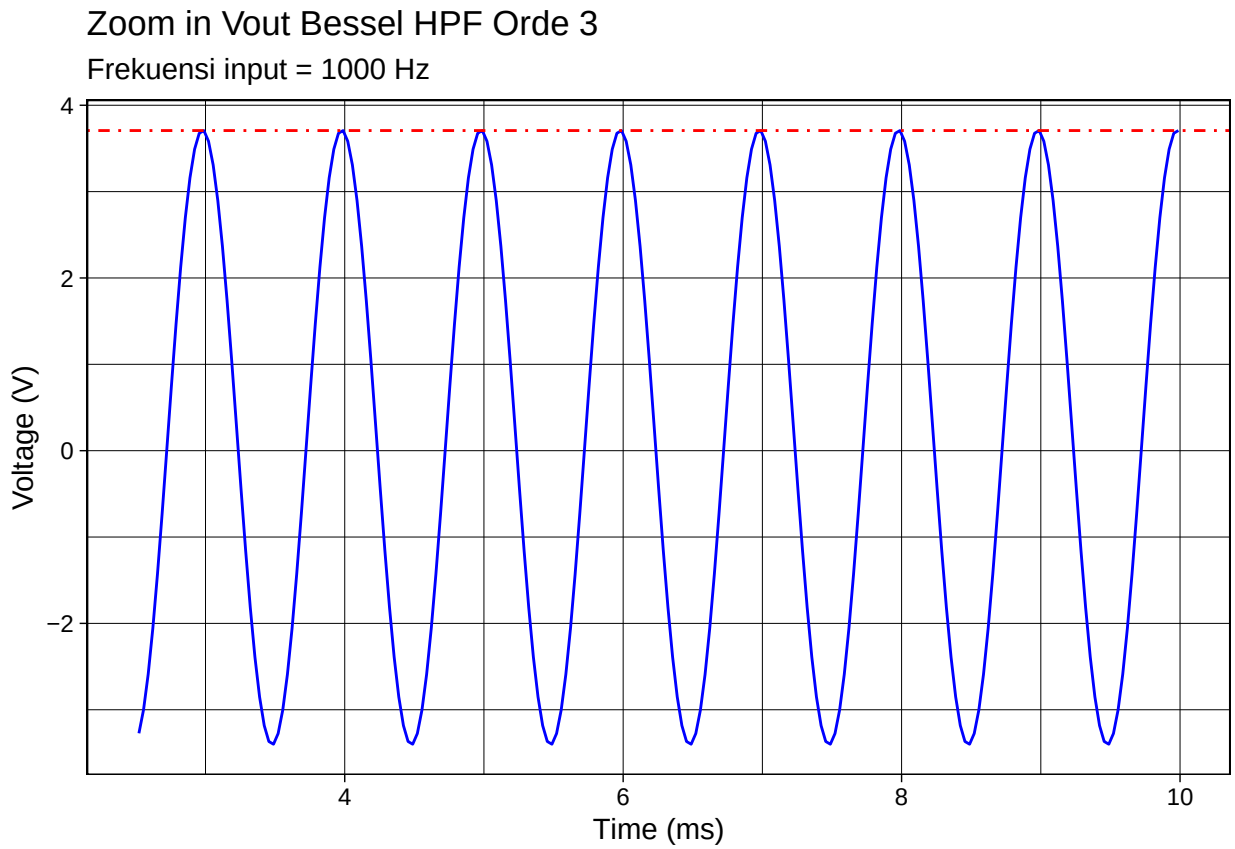
$$t > 2.5ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
bessel3_1000Hz <- bessel3_1000Hz %>%
  dplyr::filter(TIME * 1000 > 2.5)

vpeak <- max(bessel3_1000Hz$Bessel3)
vpeak
```

```
## [1] 3.70712
```

```
ggplot(bessel3_1000Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Bessel HPF Orde 3",
       subtitle = "Frekuensi input = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Bessel HPF Orde 3
Frekuensi input = 1000 Hz
Voltage (V)
4
2
0
−2
4
6
8
10
Time (ms)

F = 10000 Hz

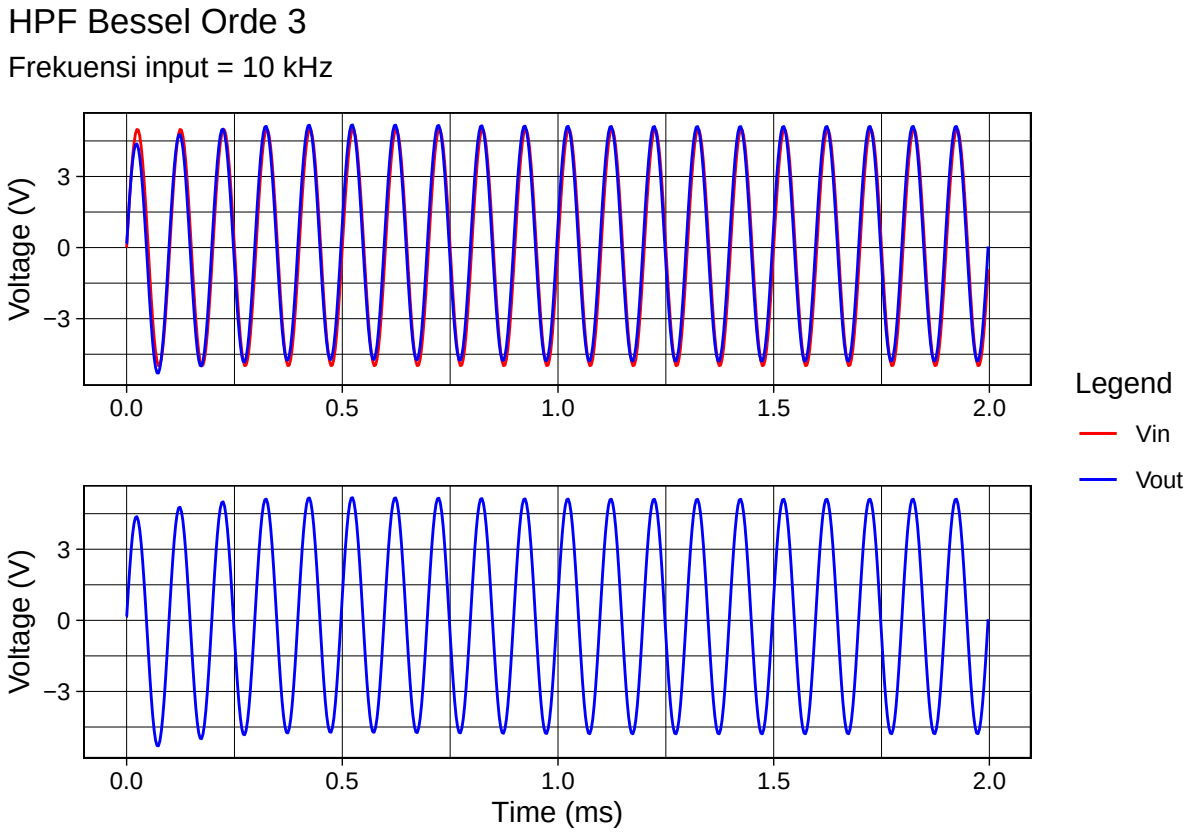
Mengambil data untuk 10000 Hz, dan hanya mengambil untuk t:

$$t < 2ms$$

```
bessel3_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Bessel3) %>%
  dplyr::filter(TIME * 1000 < 2)
```

Plot data time domain untuk 10 Hz

```
# output & input di stack
p1 <- ggplot(bessel3_10000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Bessel3, color = "vout")) +
  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout")) +
  xlab("") +
  ylab("Voltage (V)")

p2 <- ggplot(bessel3_10000Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_annotation(title = "HPF Bessel Orde 3",
                  subtitle = "Frekuensi input = 10 kHz") +
  plot_layout(guides = "collect") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan melakukan subset data untuk syarat t:

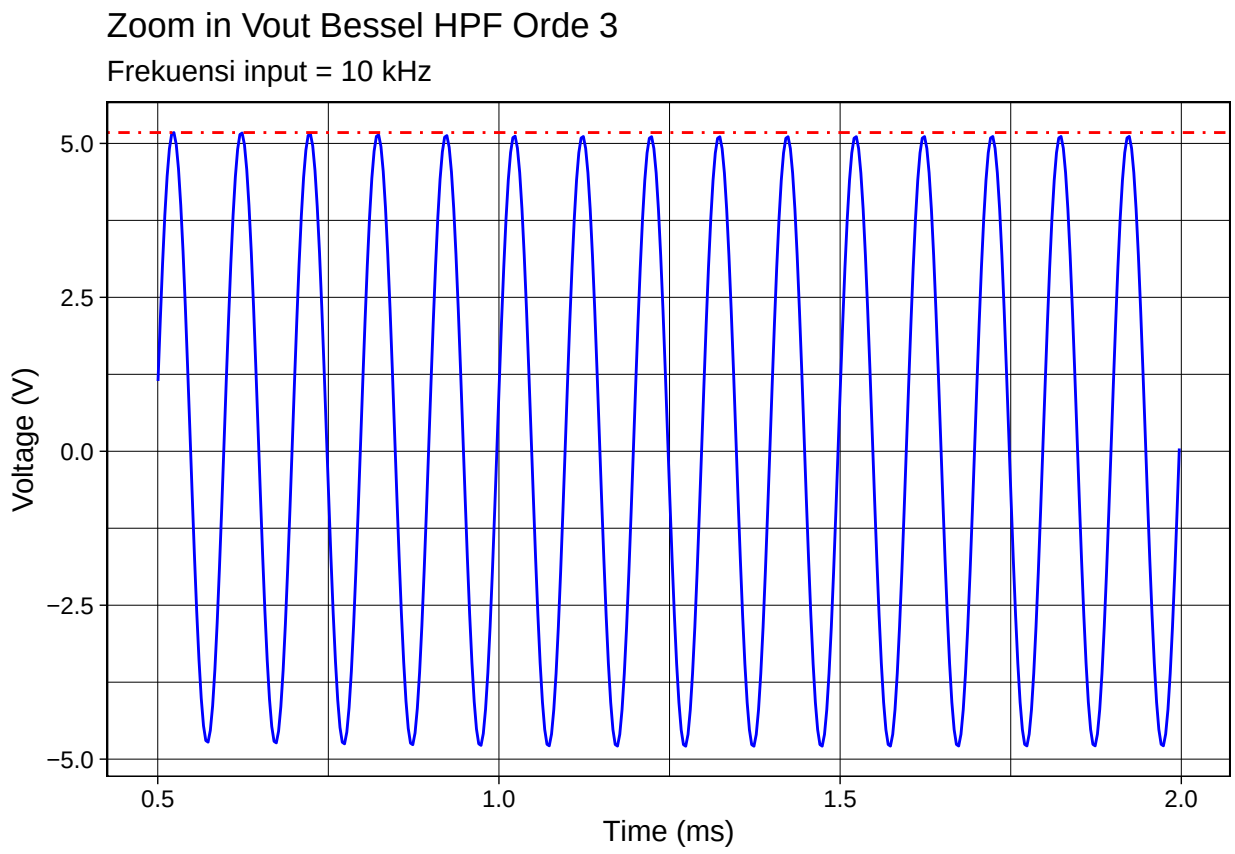
$$t > 0.5ms$$

Dan sekaligus mendapatkan nilai V_{peak}:

```
bessel3_10000Hz <- bessel3_10000Hz %>%
  dplyr::filter(TIME * 1000 > 0.5)

vpeak <- max(bessel3_10000Hz$Bessel3)
vpeak
```

```
## [1] 5.17626
```

```
ggplot(bessel3_10000Hz) +
  geom_line(aes(TIME * 1000, Bessel3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  labs(title = "Zoom in Vout Bessel HPF Orde 3",
       subtitle = "Frekuensi input = 10 kHz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Bessel HPF Orde 3
Frekuensi input = 10 kHz
5.0
2.5
0.0
−2.5
−5.0
Voltage (V)
0.5
1.0
1.5
2.0
Time (ms)

4.2.3 Chebychev

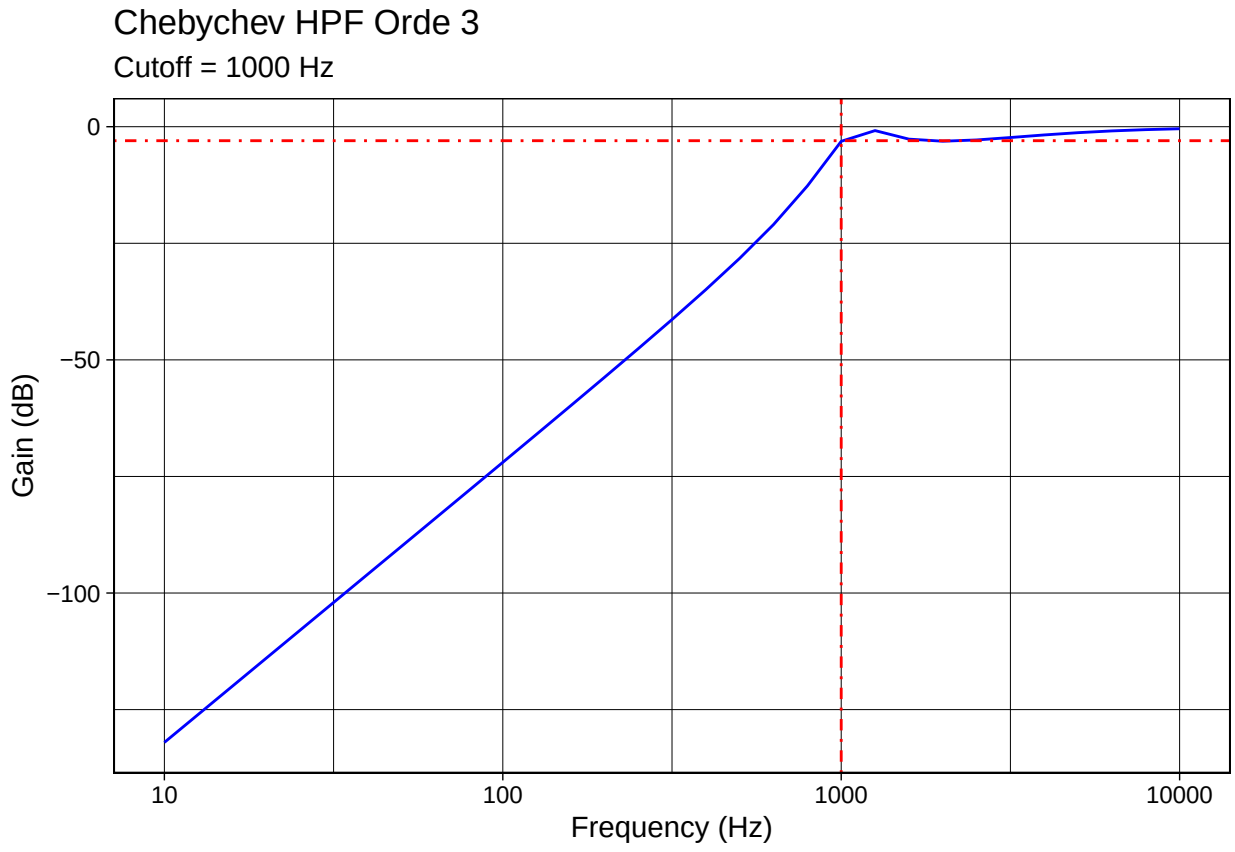
4.2.2 a) Frequency Response

Mengambil data respon frekuensi untuk filter Chebychev.

```
cheby3_freq <- freq_resp %>%
  dplyr::select(FREQ, Chebychev3)
```

Plot untuk respon frekuensi.

```
cheby3_plot <-
ggplot(cheby3_freq) +
  scale_x_log10() +
  geom_line(aes(FREQ, Chebychev3), color = "blue") +
  geom_hline(yintercept = -3, color = "red", linetype = 4) +
  geom_vline(xintercept = 1000, color = "red", linetype = 4) +

  # plot information
  labs(title = "Chebychev HPF Orde 3",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)") +
  theme_linedraw()

cheby3_plot
```



Max Ripple

Karena max ripple sepertinya bersifat menuju Gain (dB) -3dB , maka fungsi yang digunakan adalah `min()`, dan diaplikasikan untuk mencari magnitude dengan lokasi frekuensi:

$$f > 1100Hz$$

Menggunakan 1100 Hz agar daerah dekat cutoff (-3 dB) tidak ikut di *scan* oleh fungsi `min()`.

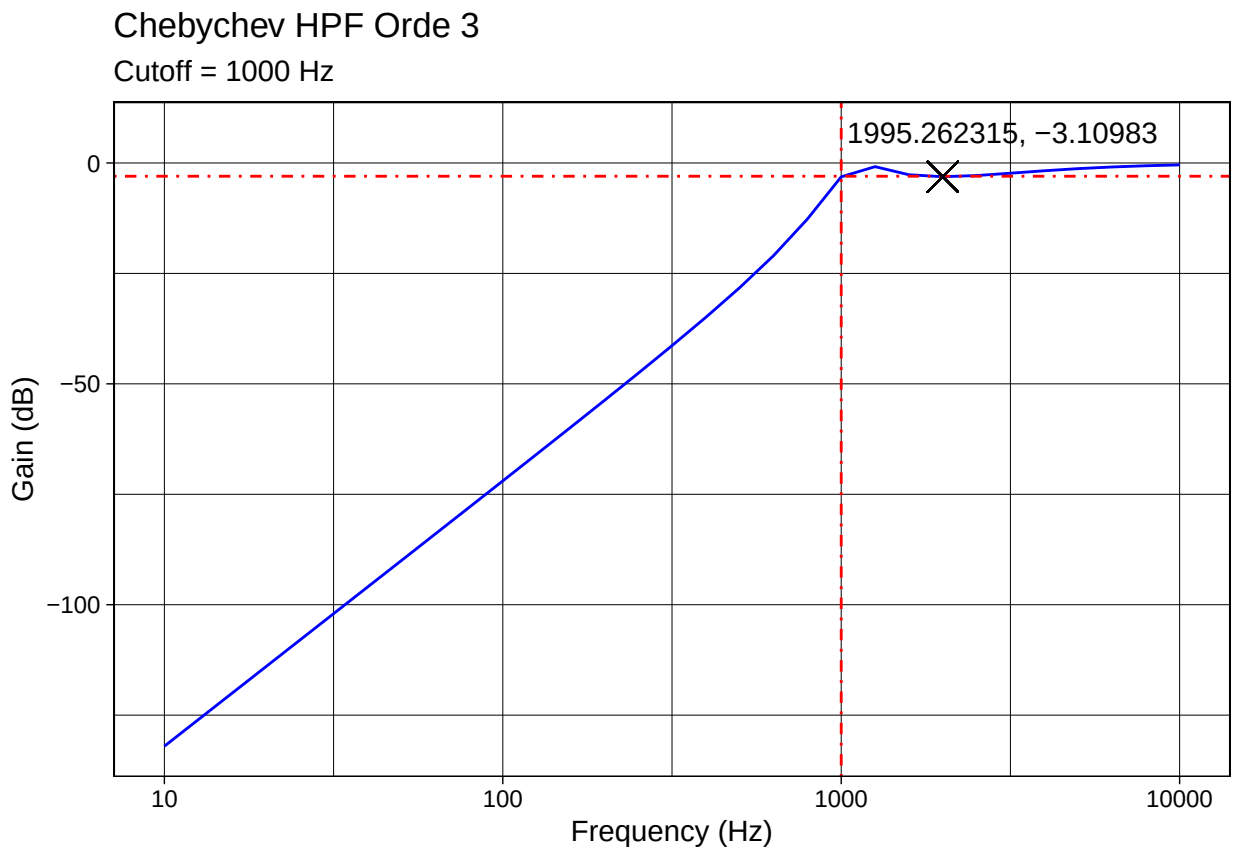
```
ripple <- cheby3_freq %>%
  dplyr::filter(FREQ > 1100) %>%
  min()

freq_at_ripple <- cheby3_freq %>%
  dplyr::filter(Chebychev3 == ripple) %>%
  dplyr::select(FREQ) %>%
  as.numeric()

ripple
```

```
## [1] -3.10983
```

```
freq_at_ripple
```

```
## [1] 1995.262
```

```
# plot ulang dengan lokasi ripple
cheby3_plot +
  geom_point(aes(freq_at_ripple, ripple),
             shape = 4, size = 5, color = "black") +

  annotate("text", x = freq_at_ripple + 1000, y = ripple + 10,
           label = paste(freq_at_ripple, ripple, sep = ", "))
```


Chebychev HPF Orde 3
Cutoff = 1000 Hz
1995.262315, −3.10983
0
−50
−100
Gain (dB)
10
100
1000
10000
Frequency (Hz)

4.2.2 b) Time Domain

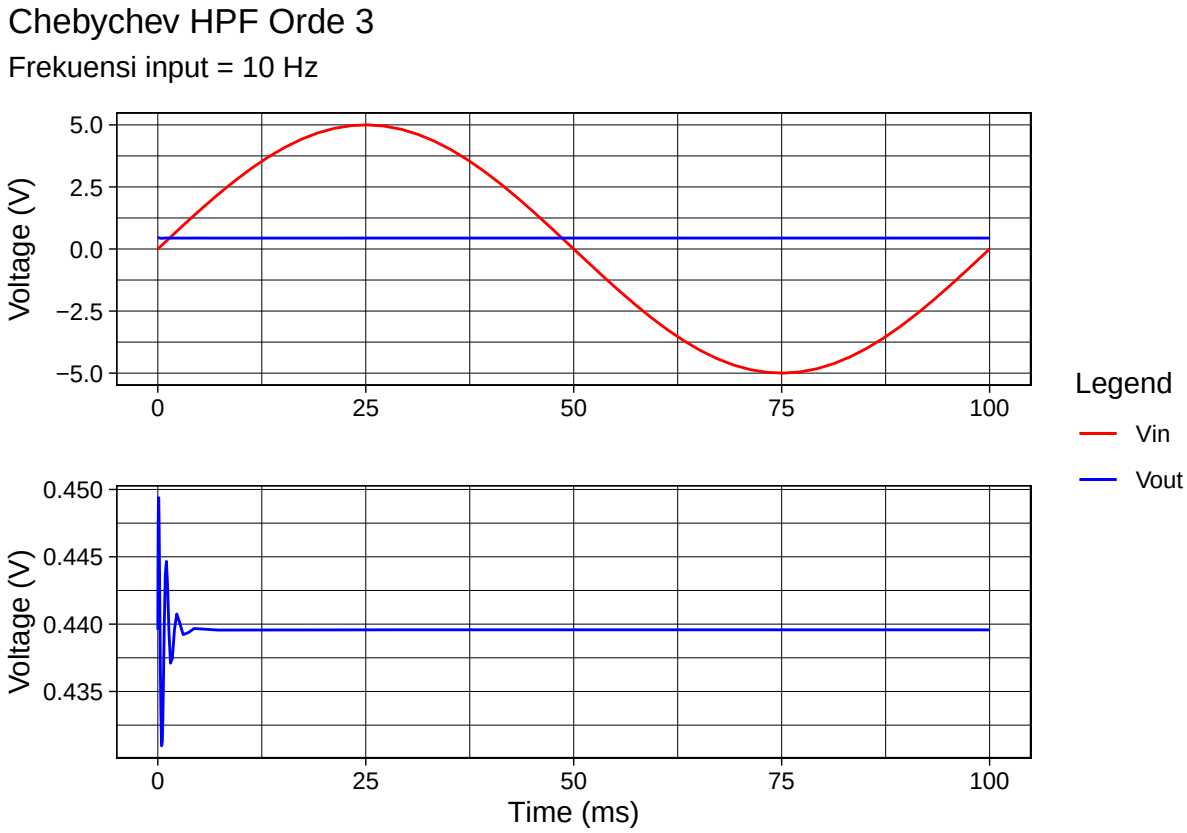
F = 10 Hz

Mengambil data untuk filter Chebychev orde 3

```
cheby3_10Hz <- time_domain_10Hz %>%
  dplyr::select(TIME, Vin, Chebychev3)
```

Plot time domain.

```
# Plot Vout & Vin di stack
p1 <-
ggplot(cheby3_10Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev3, color = "vout")) +
  xlab("") +
  ylab("Voltage (V)") +

  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(cheby3_10Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev HPF Orde 3",
                  subtitle = "Frekuensi input = 10 Hz") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan cara melakukan subset data untuk t:

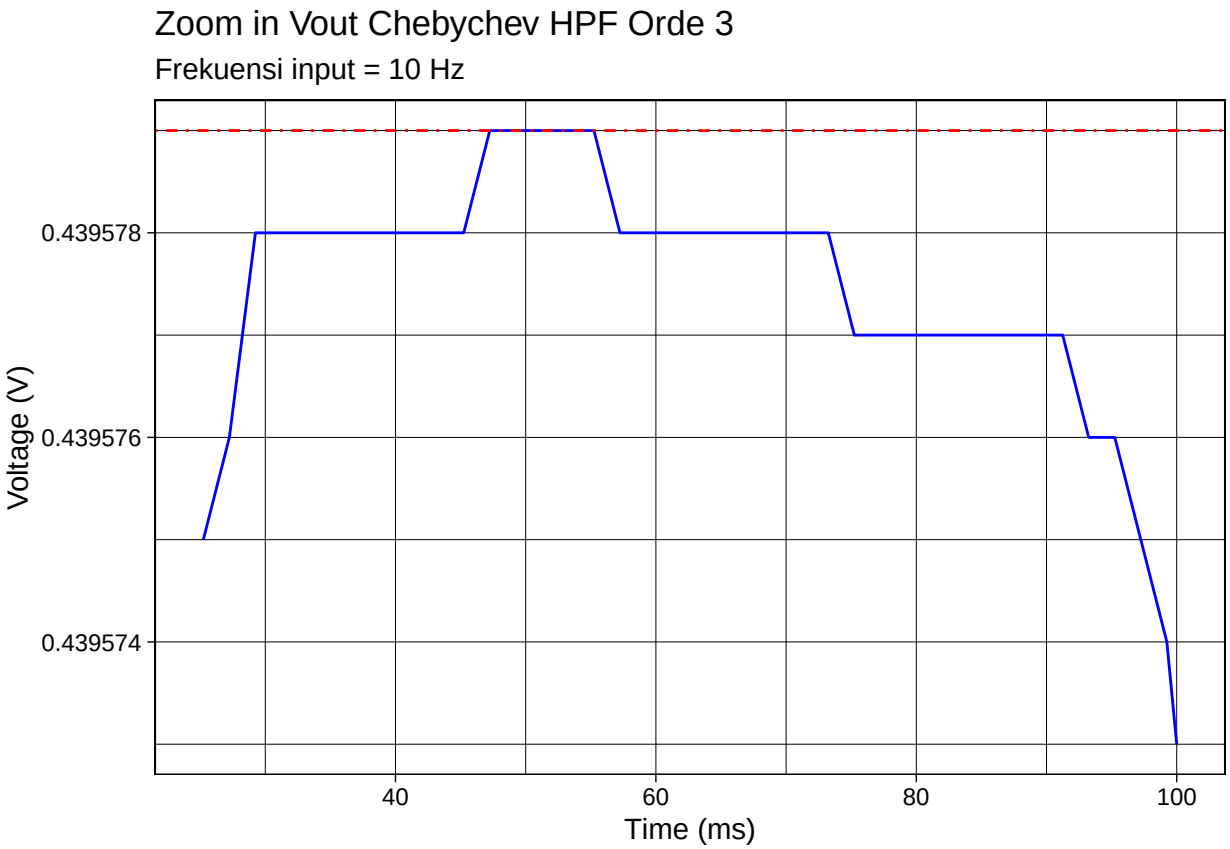
$$t > 25ms$$

Sekaligus mendapatkan V_{peak}:

```
cheby3_10Hz <- cheby3_10Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(cheby3_10Hz$Chebychev3)
vpeak
```

```
## [1] 0.439579
```

```
ggplot(cheby3_10Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot information
  labs(title = "Zoom in Vout Chebychev HPF Orde 3",
       subtitle = "Frekuensi input = 10 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Chebychev HPF Orde 3
Frekuensi input = 10 Hz
0.439578
0.439576
0.439574
Voltage (V)
40
60
80
100
Time (ms)

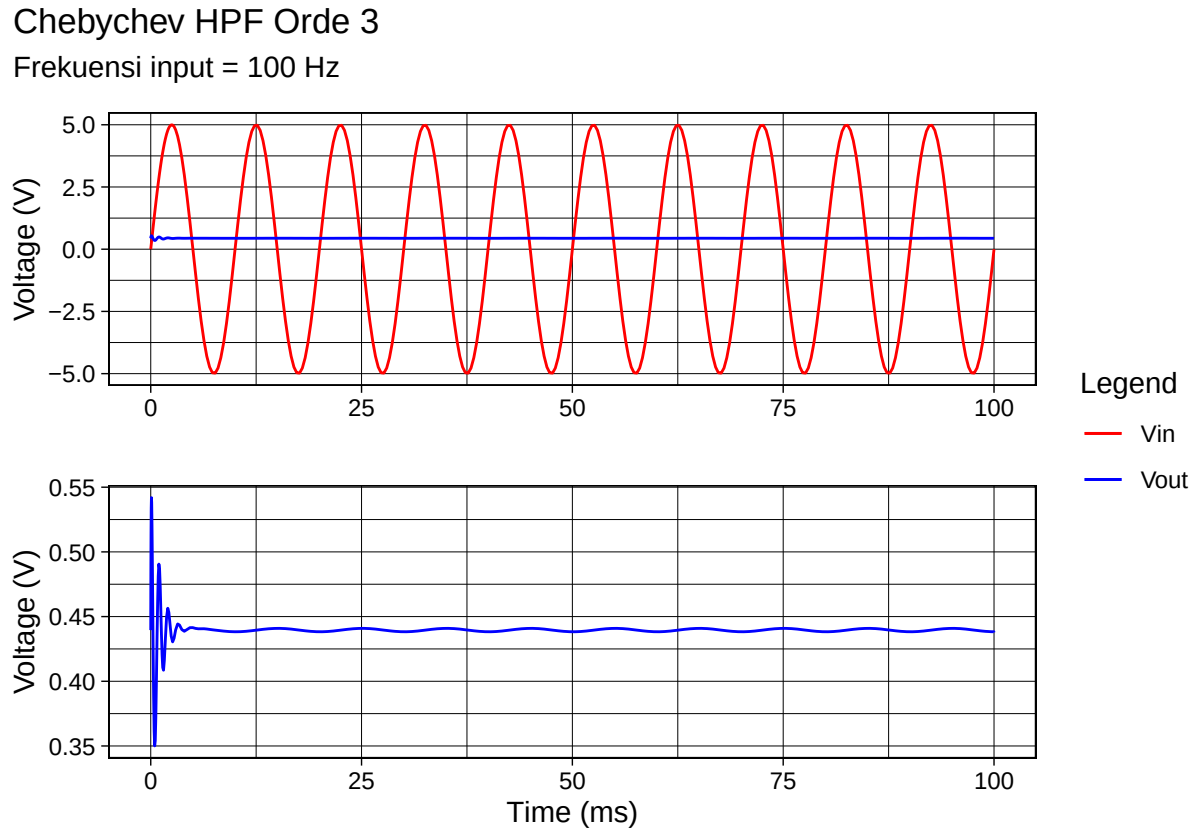
F = 100 Hz

Mengambil data untuk filter Chebychev orde 3.

```
cheby3_100Hz <- time_domain_100Hz %>%
  dplyr::select(TIME, Vin, Chebychev3)
```

Plot time domain.

```
# Plot Vout & Vin di stack
p1 <-
ggplot(cheby3_100Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev3, color = "vout")) +
  xlab("") +
  ylab("Voltage (V)") +

  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(cheby3_100Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev HPF Orde 3",
                  subtitle = "Frekuensi input = 100 Hz") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan cara melakukan subset data untuk t:

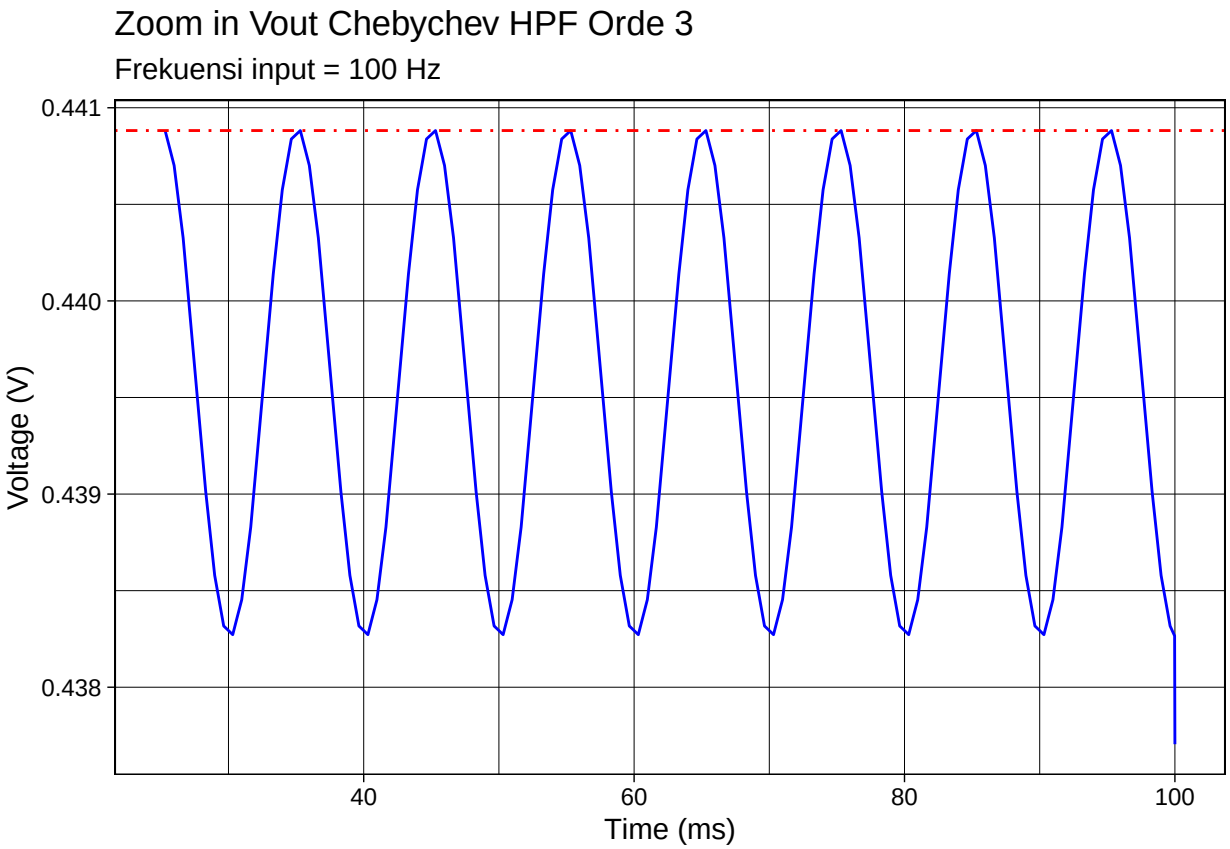
$$t > 25ms$$

Sekaligus mendapatkan V_{peak}:

```
cheby3_100Hz <- cheby3_100Hz %>%
  dplyr::filter(TIME * 1000 > 25)

vpeak <- max(cheby3_100Hz$Chebychev3)
vpeak
```

```
## [1] 0.440882
```

```
ggplot(cheby3_100Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot information
  labs(title = "Zoom in Vout Chebychev HPF Orde 3",
       subtitle = "Frekuensi input = 100 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Chebychev HPF Orde 3
Frekuensi input = 100 Hz
0.441
0.440
0.439
0.438
Voltage (V)
40
60
80
100
Time (ms)

F = 1000 Hz

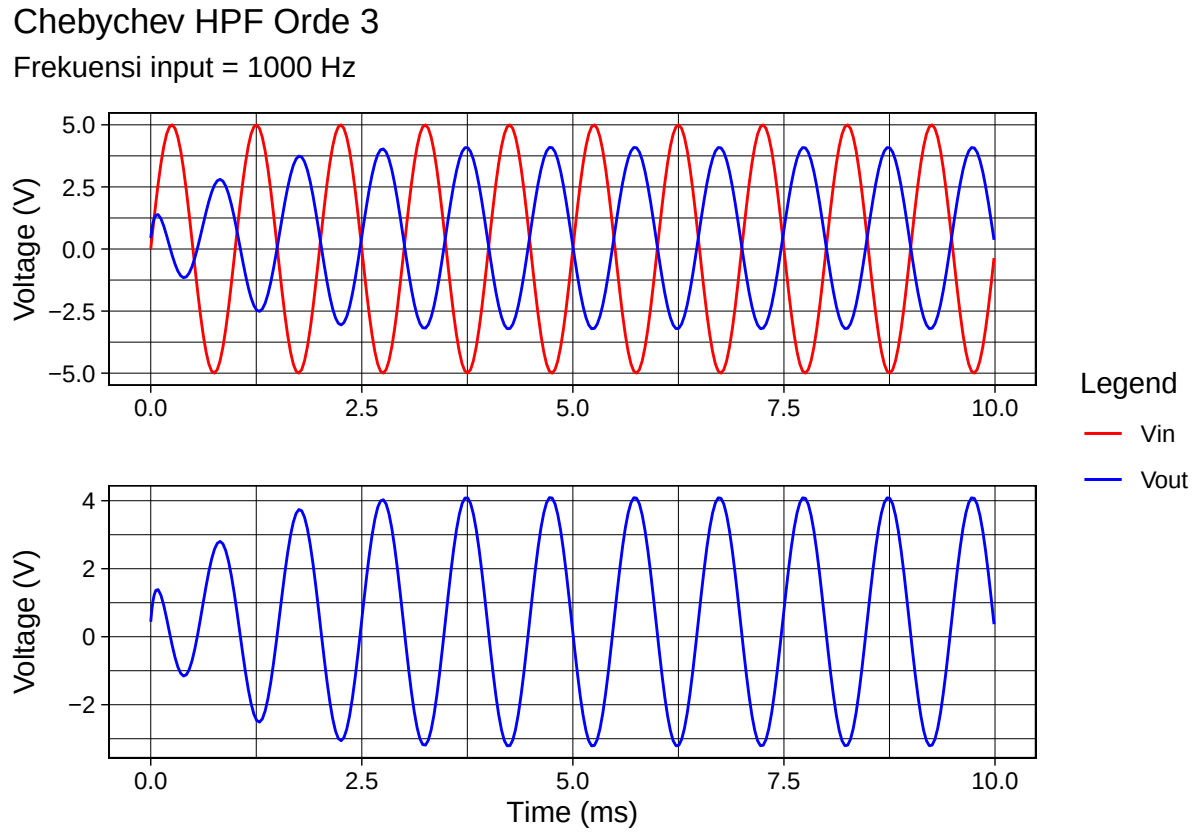
Mengambil data untuk filter Chebychev orde 3, dengan syarat t:

$$t < 10ms$$

```
cheby3_1000Hz <- time_domain_1000Hz %>%
  dplyr::select(TIME, Vin, Chebychev3) %>%
  dplyr::filter(TIME * 1000 < 10)
```

Plot time domain.

```
# Plot Vout & Vin di stack
p1 <-
ggplot(cheby3_1000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev3, color = "vout")) +
  xlab("") +
  ylab("Voltage (V)") +

  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(cheby3_1000Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev HPF Orde 3",
                  subtitle = "Frekuensi input = 1000 Hz") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan cara melakukan subset data untuk t:

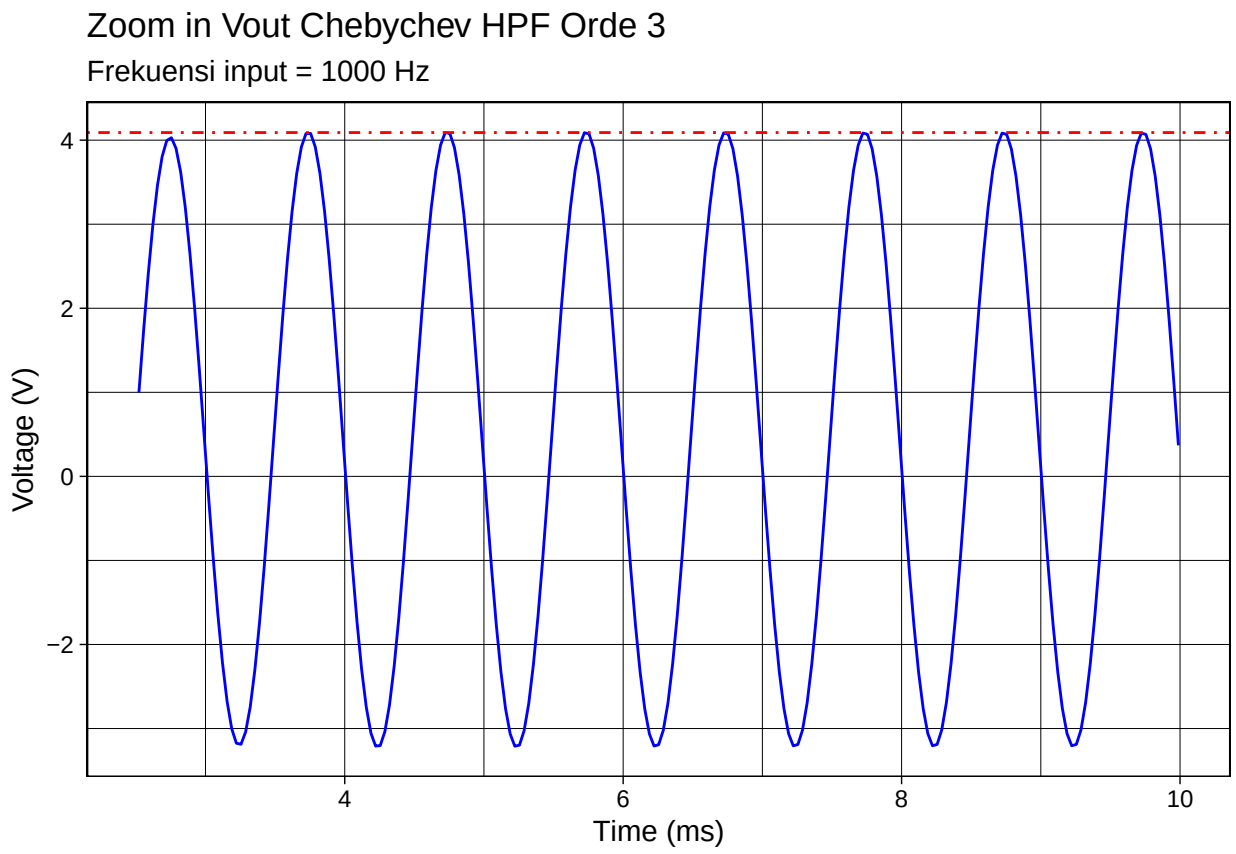
$$t > 2.5ms$$

Sekaligus mendapatkan V_{peak}:

```
cheby3_1000Hz <- cheby3_1000Hz %>%
  dplyr::filter(TIME * 1000 > 2.5)

vpeak <- max(cheby3_1000Hz$Chebychev3)
vpeak
```

```
## [1] 4.09061
```

```
ggplot(cheby3_1000Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot information
  labs(title = "Zoom in Vout Chebychev HPF Orde 3",
       subtitle = "Frekuensi input = 1000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```


Zoom in Vout Chebychev HPF Orde 3
Frekuensi input = 1000 Hz
Voltage (V)
4
2
0
−2
4
6
8
10
Time (ms)

F = 10000 Hz

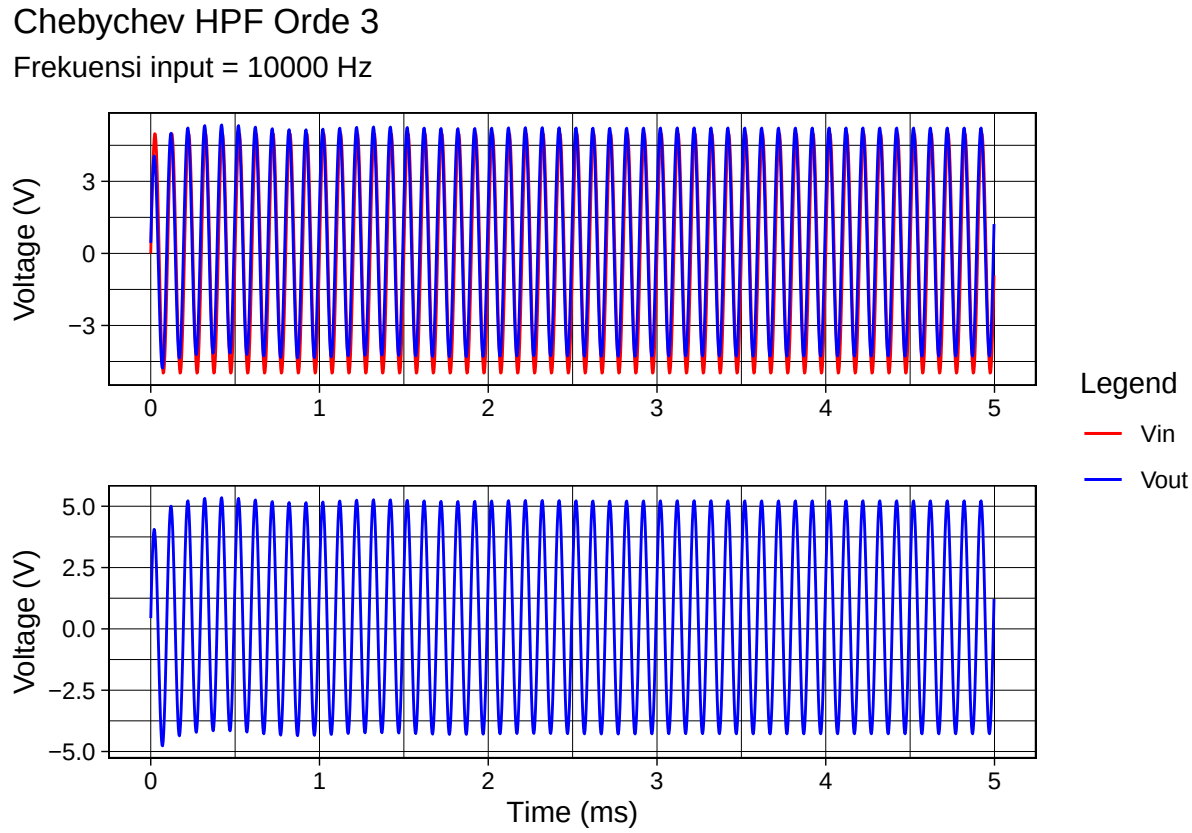
Mengambil data untuk filter Chebychev orde 3, dengan syarat t:

$$t < 5ms$$

```
cheby3_10000Hz <- time_domain_10000Hz %>%
  dplyr::select(TIME, Vin, Chebychev3) %>%
  dplyr::filter(TIME * 1000 < 5)
```

Plot time domain.

```
# Plot Vout & Vin di stack
p1 <-
ggplot(cheby3_10000Hz) +
  geom_line(aes(TIME * 1000, Vin, color = "vin")) +
  geom_line(aes(TIME * 1000, Chebychev3, color = "vout")) +
  xlab("") +
  ylab("Voltage (V)") +

  scale_color_manual(name = "Legend",
                     values = c("vin" = "red", "vout" = "blue"),
                     labels = c("Vin", "Vout"))

# Plot Vout saja
p2 <-
ggplot(cheby3_10000Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  xlab("Time (ms)") +
  ylab("Voltage (V)")

p1 / p2 +
  plot_layout(guides = "collect") +
  plot_annotation(title = "Chebychev HPF Orde 3",
                  subtitle = "Frekuensi input = 10000 Hz") &
  theme_linedraw()
```



Zoom in ke V_{out} dengan cara melakukan subset data untuk t:

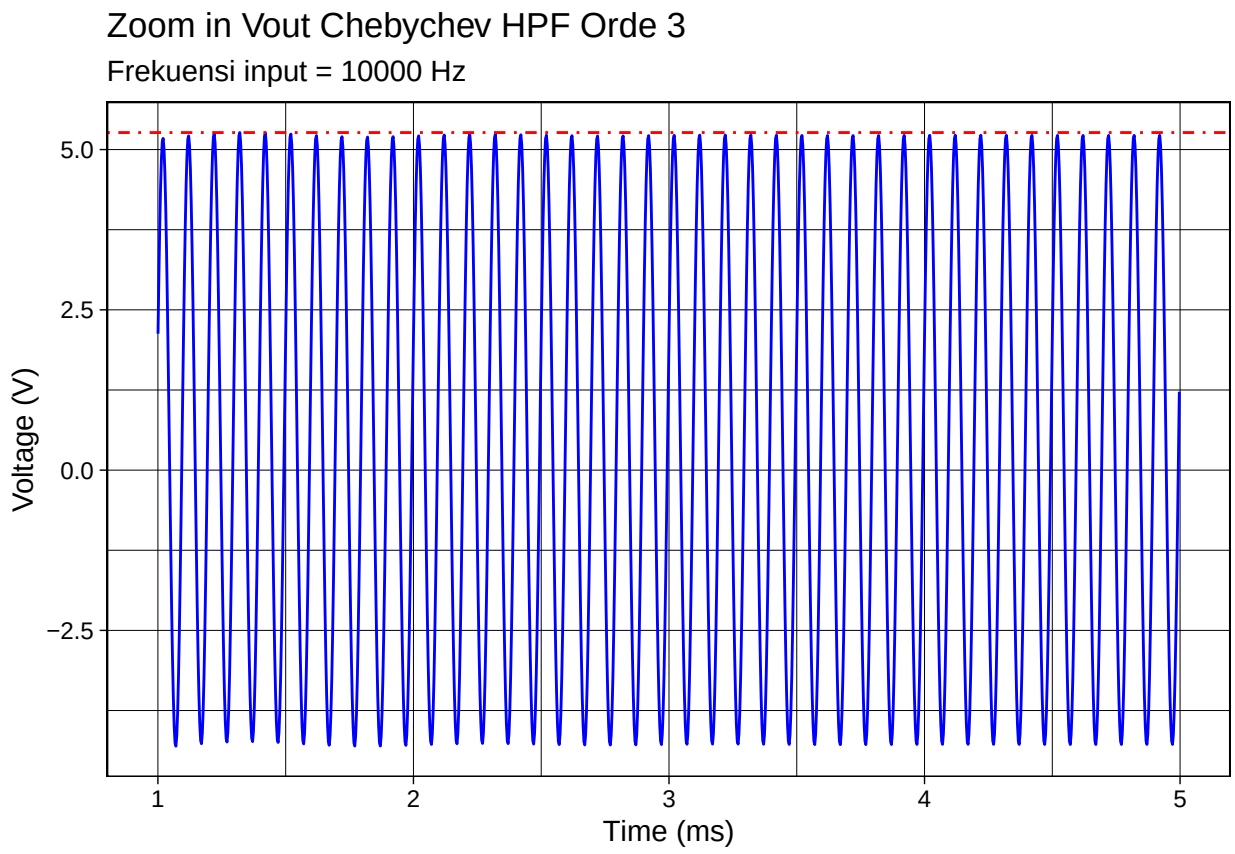
$$t > 1ms$$

Sekaligus mendapatkan V_{peak}:

```
cheby3_10000Hz <- cheby3_10000Hz %>%
  dplyr::filter(TIME * 1000 > 1)

vpeak <- max(cheby3_10000Hz$Chebychev3)
vpeak
```

```
## [1] 5.26553
```

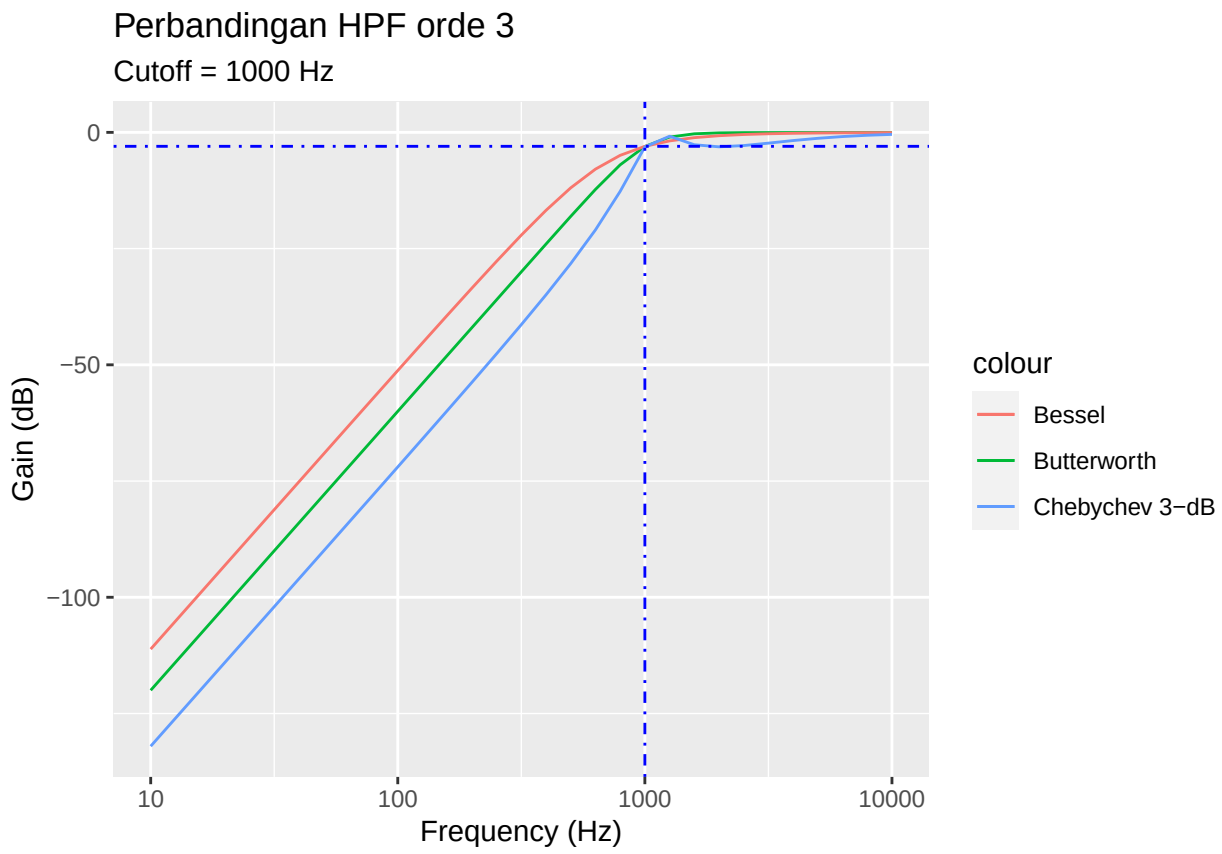
```
ggplot(cheby3_10000Hz) +
  geom_line(aes(TIME * 1000, Chebychev3), color = "blue") +
  geom_hline(yintercept = vpeak, color = "red", linetype = 4) +

  # plot information
  labs(title = "Zoom in Vout Chebychev HPF Orde 3",
       subtitle = "Frekuensi input = 10000 Hz",
       x = "Time (ms)",
       y = "Voltage (V)") +
  theme_linedraw()
```



4.2.4 Perbandingan Respon Frekuensi

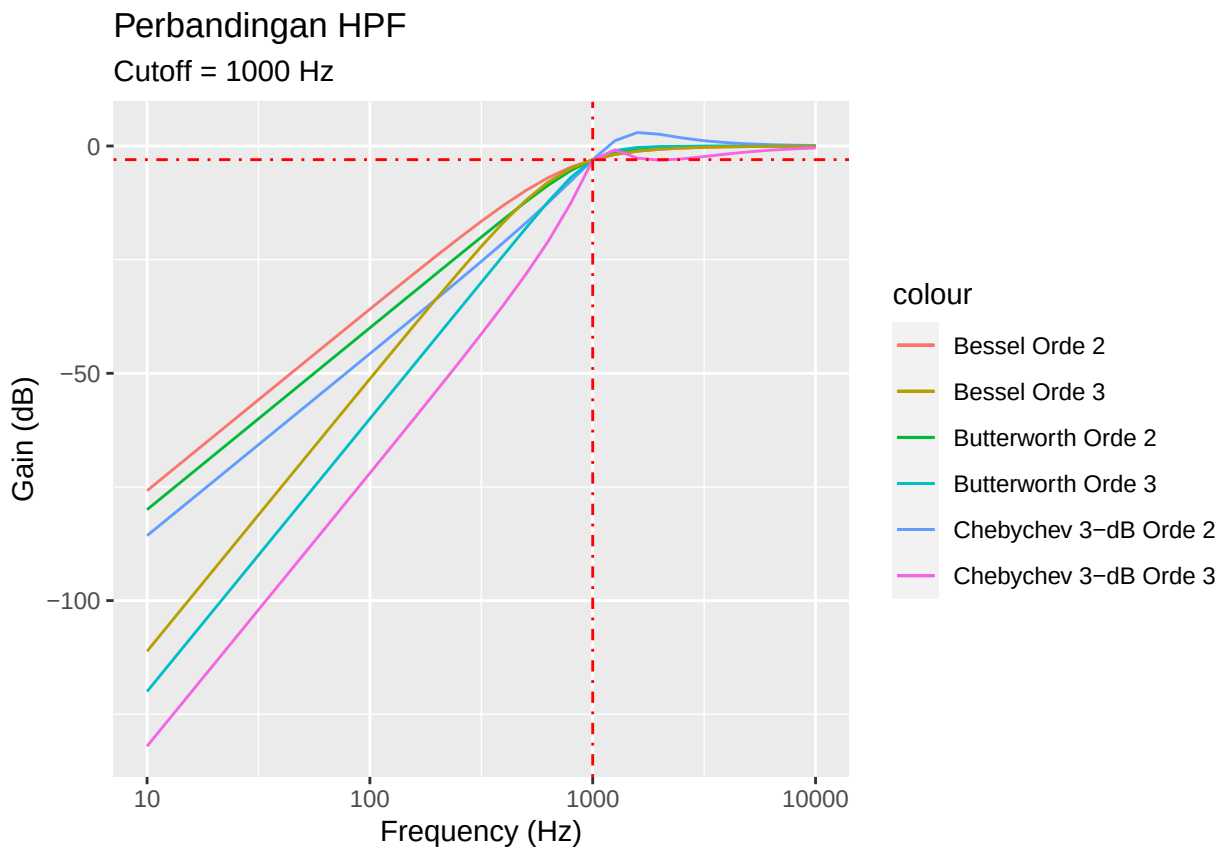
Plot frequency response ketiga filter orde 3, sumbu-x logaritmis, juga disertakan garis bantu untuk frekuensi cutoff & lokasi gain 3 dB.

```
ggplot(freq_resp) +
  scale_x_log10() +
  geom_line(aes(FREQ, Butterworth3, color = "Butterworth")) +
  geom_line(aes(FREQ, Bessel3, color = "Bessel")) +
  geom_line(aes(FREQ, Chebychev3, color = "Chebychev 3-dB")) +

  # Garis bantu
  geom_hline(yintercept = -3, color = "blue", linetype = 4) +
  geom_vline(xintercept = 1000, color = "blue", linetype = 4) +

  # plot information
  labs(title = "Perbandingan HPF orde 3",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)")
```



Perbandingan Semua Filter

```
ggplot(freq_resp) +
  scale_x_log10() +
  geom_line(aes(FREQ, Butterworth2, color = "Butterworth Orde 2")) +
  geom_line(aes(FREQ, Bessel2, color = "Bessel Orde 2")) +
  geom_line(aes(FREQ, Chebychev2, color = "Chebychev 3-dB Orde 2")) +
  geom_line(aes(FREQ, Butterworth3, color = "Butterworth Orde 3")) +
  geom_line(aes(FREQ, Bessel3, color = "Bessel Orde 3")) +
  geom_line(aes(FREQ, Chebychev3, color = "Chebychev 3-dB Orde 3")) +

  # Garis bantu frekuensi cutoff & -3dB point
  geom_hline(yintercept = -3, color = "red", linetype = 4) +
  geom_vline(xintercept = 1000, color = "red", linetype = 4) +

  # plot information
  labs(title = "Perbandingan HPF",
       subtitle = "Cutoff = 1000 Hz",
       x = "Frequency (Hz)",
       y = "Gain (dB)")
```


Perbandingan HPF
Cutoff = 1000 Hz
0
−50
−100
Gain (dB)
10
100
1000
10000
Frequency (Hz)
colour
Bessel Orde 2
Bessel Orde 3
Butterworth Orde 2
Butterworth Orde 3
Chebychev 3−dB Orde 2
Chebychev 3−dB Orde 3