PHILIPS CTT Hogeschool van Utrecht

Systeem en Regeltechniek

FMT / Mechatronica

Deel 2: Basisbegrippen regeltechniek

Blok 4: Frequentie-domein beschrijving

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Cursus Systeem en Regeltechniek

Overzicht

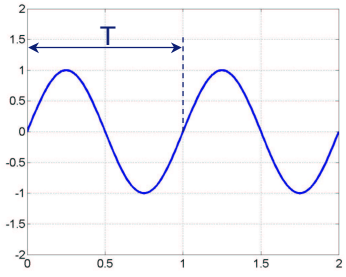
Deel 1	Blok 1.	Inleiding
Wo. 14-04	Blok 2.	Basisprincipes modelvorming massa-veersystemen
	Blok 3.	De regelaar als veer-demper combinatie
Deel 2	Blok 4.	Frequentie-domein beschrijving
Wo. 21-04	Blok 5.	Basisconcepten in de regeltheorie
Deel 3	**Vervolg regeltechniek**	
Wo. 28-04		
Deel 4	**Stabiliteit van regelsystemen**	
Wo. 12-05		
Deel 5	**Toepassing: PID regelaarontwerp**	
Wo. 19-05		
Deel 6	**Extra regeltechniek**	
Wo. 26-05		

What is a frequency domain description?

?

Intro Frequency Domain

What is frequency ?

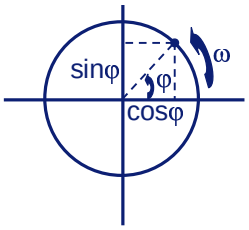


time [s]

$f = \frac{1}{T}$ [Hz]

smaller period → higher frequency

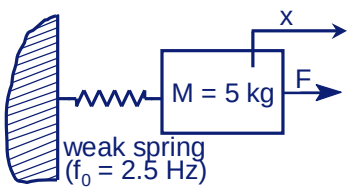
$\omega = 2\pi f$ [rad/s]



φ: phase angle

one period ⇔ one revolution
⇔ 360° degrees
⇔ 2π radians

From Time Domain to Frequency Domain



For sinusoidal excitation:

$$F(t) = 400\sin(2\pi 7t) \qquad \text{(f = 7 Hz)}$$

A linear system gives a sinusoidal response:

$$x(t) = \hat{x}\sin(2\pi 7t + \varphi) \qquad \hat{x}=?;\varphi=? \quad @\ f = 7\ Hz$$

Frequency Domain Response: **H(f)**

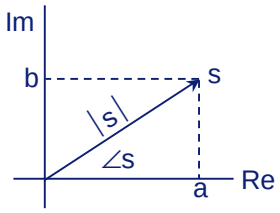
$$\rightarrow \hat{x}/\hat{F} = |H(7Hz)|$$
$$\rightarrow \varphi = \angle H(7Hz)$$

Intermezzo: complex numbers

s = a + bj $\qquad j^2 = -1$

Re(s) = a $\qquad |s| = \sqrt{a^2 + b^2}$

Im(s) = b $\qquad \angle s = \text{atan}\left(\frac{b}{a}\right)$



Define: $\varphi = \angle s$

Then: s = |s| [cos(φ) + j sin(φ)]

So: a = |s| cos(φ)
b = |s| sin(φ)

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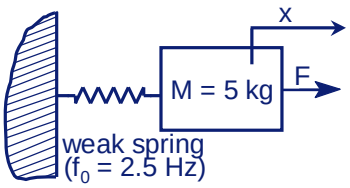
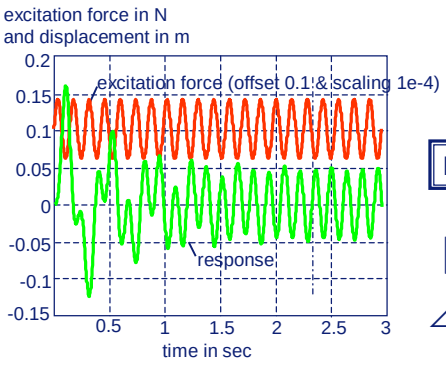
Frequency Domain Description

From Time Domain to Frequency Domain

$$F(t) = 400\sin(2\pi 7t)$$

$$x(t) = \hat{x}\sin(2\pi 7t + \varphi)$$





Frequency Domain Response: H(7*Hz*)

$$|H(7Hz)| \approx 0.045/400 = 1e-4m/N$$

$$\angle H(7Hz) \approx -180\,^{\circ}$$

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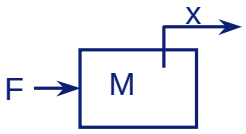
Frequency Domain Description

Frequency Domain solution for equation of motion

$$F = M\ddot{x}$$



1) Choose a sinusoidal input:

$$F = \hat{F}\sin(\omega t)$$

2) Then for a linear system:

$$x = \hat{x}\sin(\omega t + \varphi)$$

$$\dot{x} = \omega\hat{x}\cos(\omega t + \varphi)$$

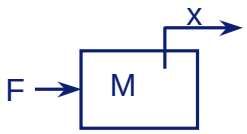
$$\ddot{x} = -\omega^2\hat{x}\sin(\omega t + \varphi)$$

$$\hat{x} = ?; \varphi = ?$$

Frequency Domain solution for equation of motion

$$F = M\ddot{x}$$

3) Solution:



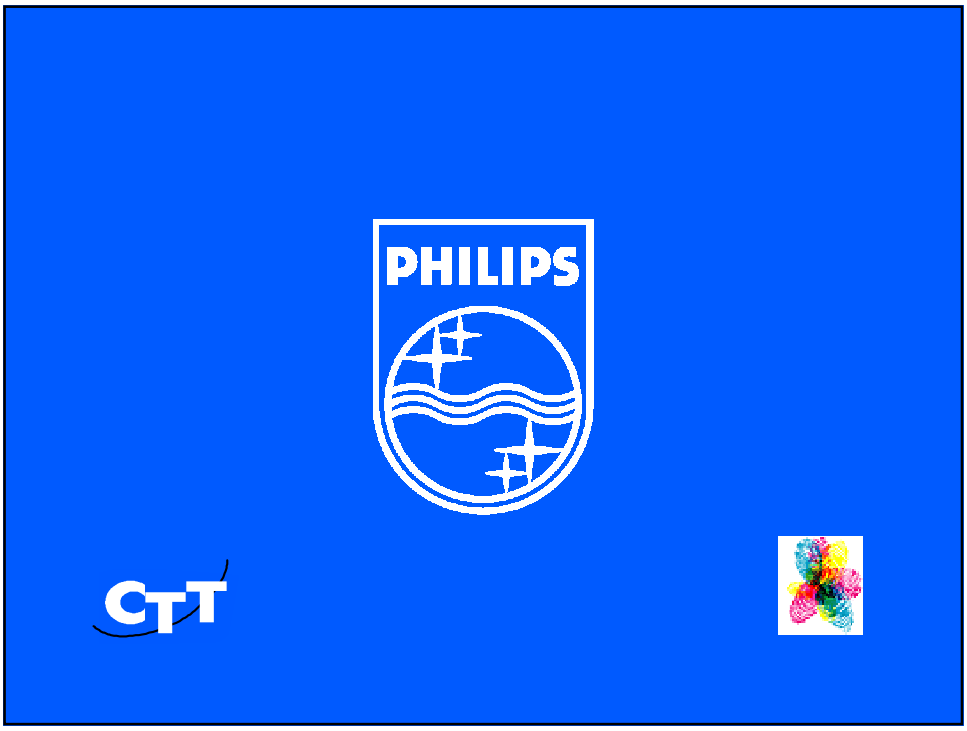
$$\hat{F}\sin(\omega t) = -M\omega^2\hat{x}\sin(\omega t + \varphi)$$

$$\varphi = \angle H = -180^\circ$$
$$\hat{x} = |H|\hat{F} = \frac{\hat{F}}{M\omega^2}$$

$$H = \frac{x}{F} = -\frac{1}{M\omega^2}$$ ⇐ **Frequency Response Function !**

Summary

- Frequency
- Frequency response H(f)
  - Amplitude
  - Phase
- Simple mass as example: $H = \frac{x}{F} = -\frac{1}{M\omega^2}$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