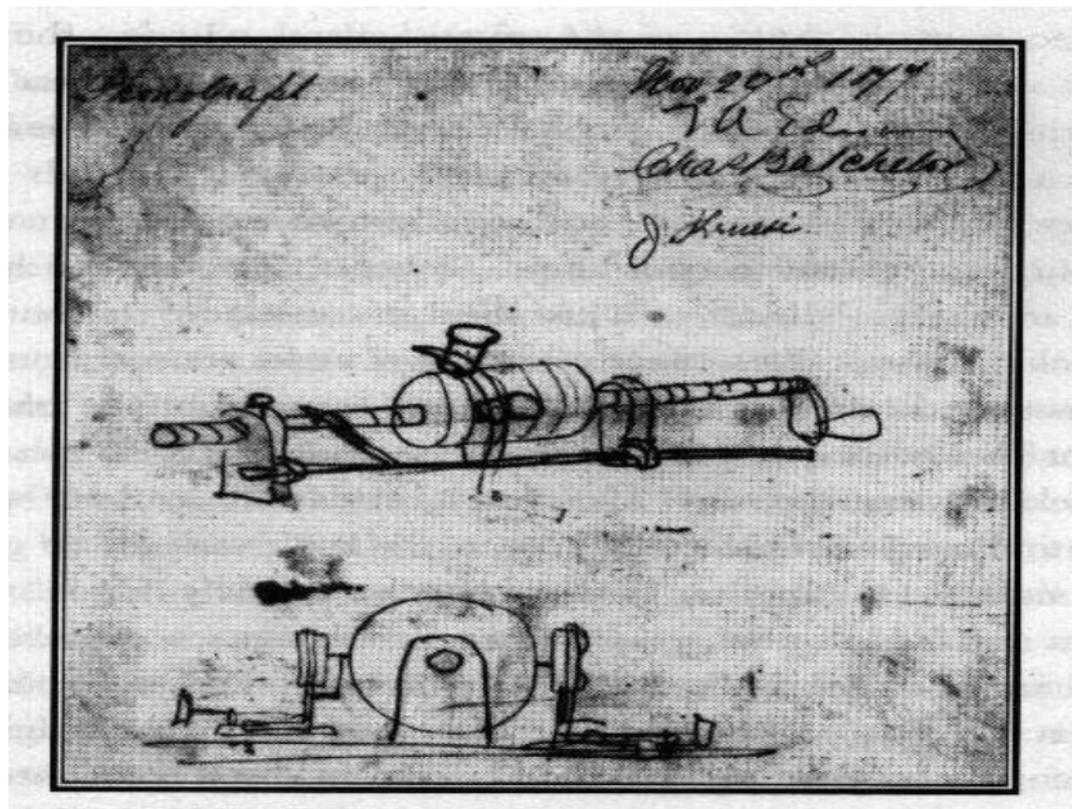


# 6.003: Signals and Systems

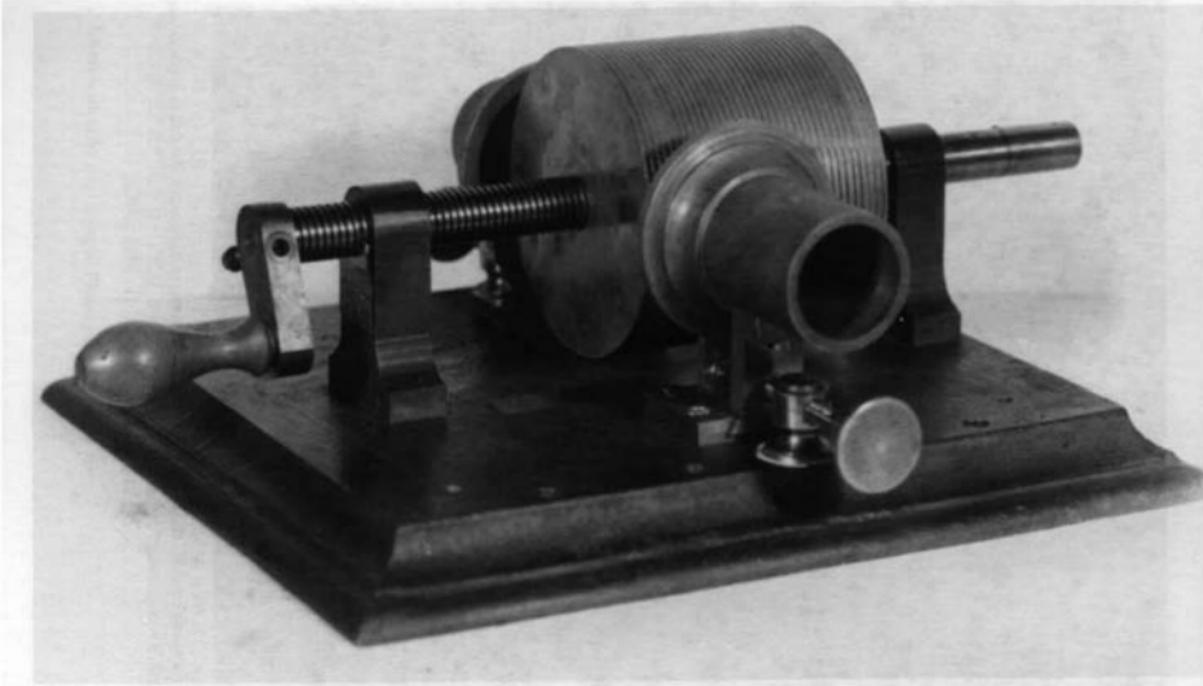
From LPs to CDs –  
and how 6.003 helps get you there

*December 8, 2011*

# Edison's Phonograph



# Edison's Phonograph



## Edison's Phonograph

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# Edison's Phonograph

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# Edison's Phonograph

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Image by [Infrogmation](#) on Wikimedia Commons.

# Edison's Phonograph

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Photo of Pioneer record player removed due to copyright restrictions.

# Edison's Phonograph

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# Edison's Phonograph

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Photo of Grado phono cartridge removed due to copyright restrictions.

## Edison's Phonograph

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LPs: 100 years of optimization → good fidelity, but

- fragile: easily scratched
- lots of distortions: e.g., wow and flutter
- expensive

CDs: much higher fidelity

- nearly indestructible
- very low distortion
- inexpensive

→ many of these advantages made possible by concepts from Signals and Systems!

# Edison's Phonograph

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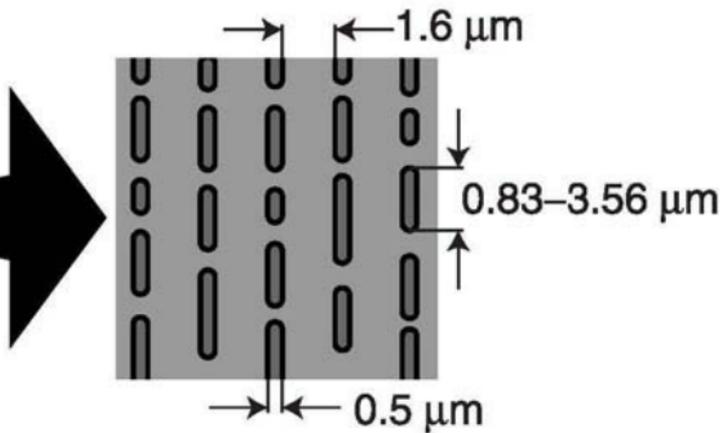


Image by [Dante Alighieri](#) on Wikimedia Commons.

# What's on a CD?



Image by [Dante Alighieri](#)  
on Wikimedia Commons.



## Edison's Phonograph

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LPs: 100 years of optimization → good fidelity, but

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CDs: much higher fidelity

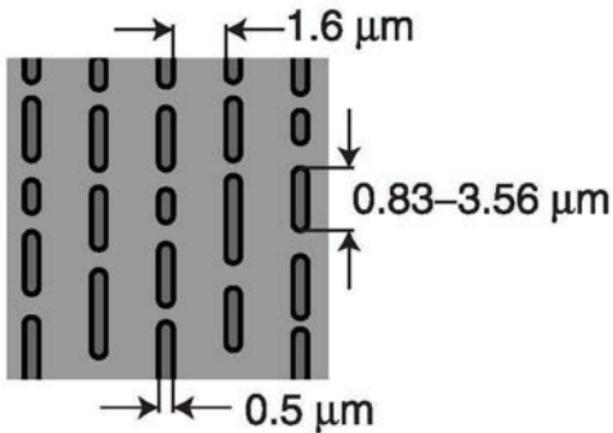
- nearly indestructible ✓
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- inexpensive

→ many of these advantages made possible by concepts from Signals and Systems!

# What's on a CD?



Image by [Dante Alighieri](#)  
on Wikimedia Commons.



## What's on a CD?

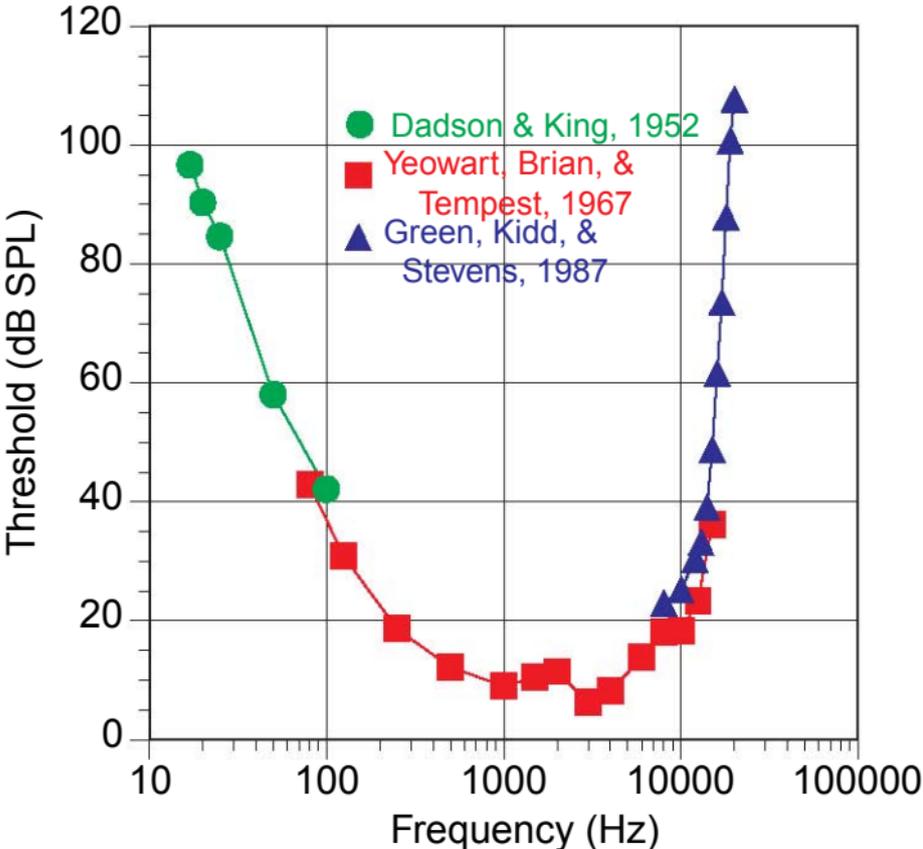
---

Continuous signal (audio)

Discrete storage (pits and lands)

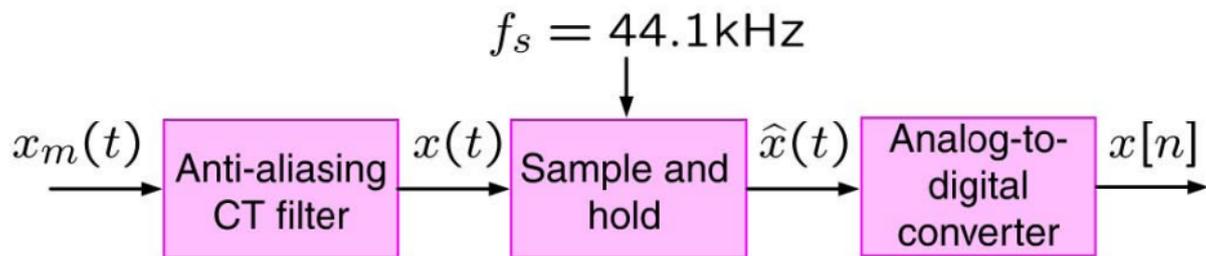
→ sampling!

# What's on a CD?



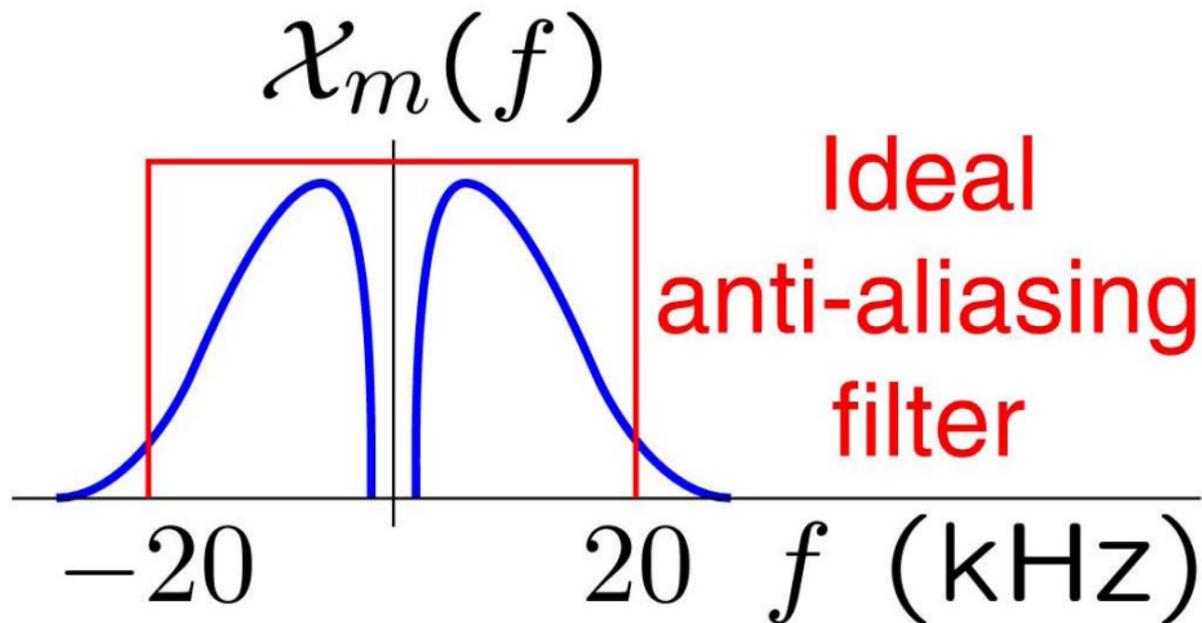
## What's on a CD?

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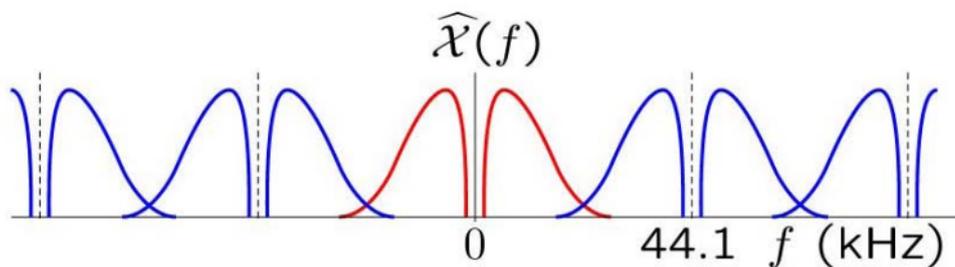


## What's on a CD?

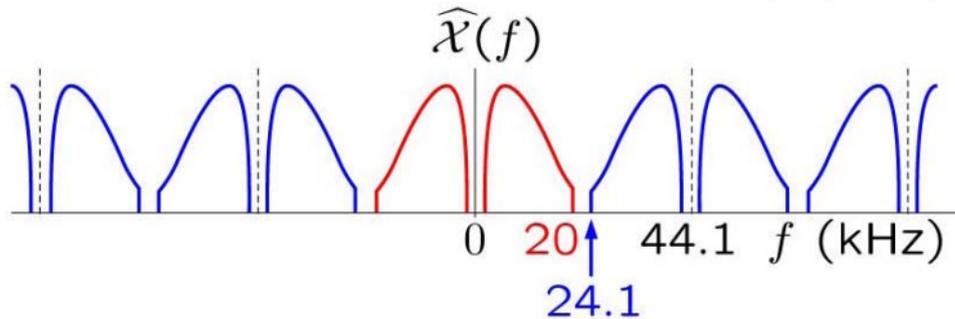
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# What's on a CD?

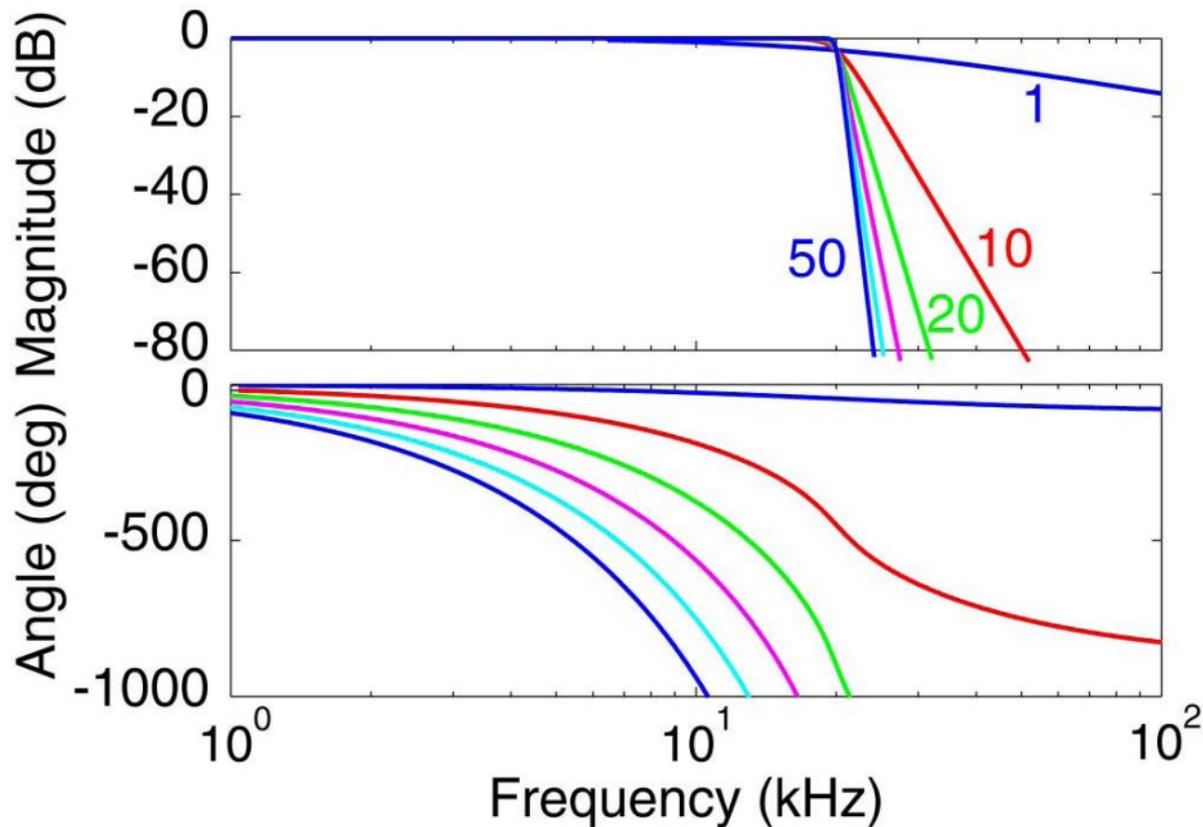


Without  
anti-aliasing  
filter



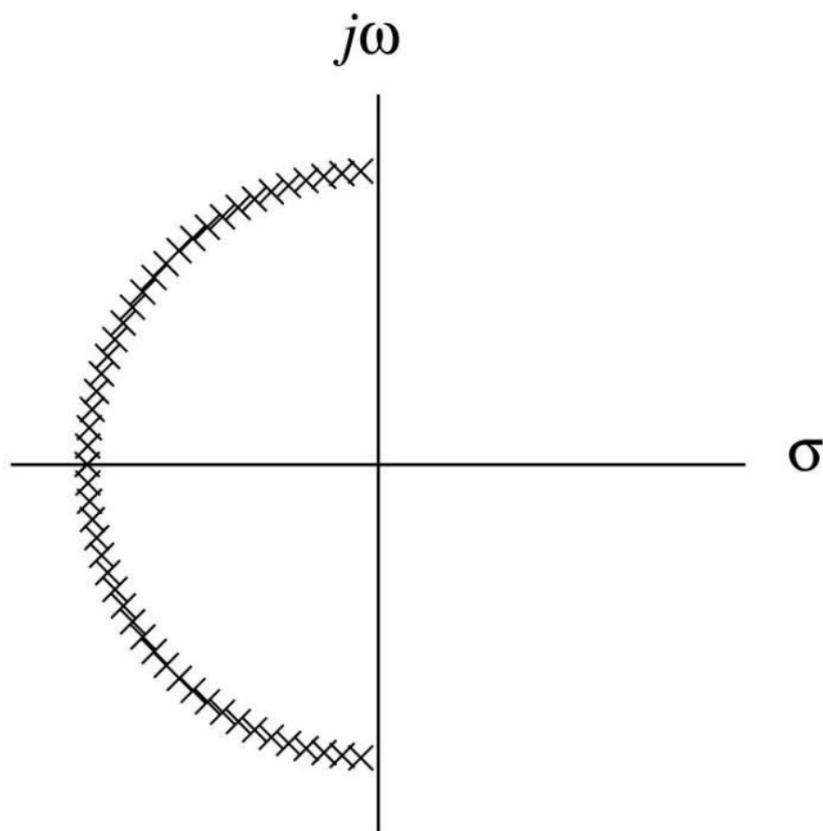
With ideal  
anti-aliasing  
filter

# What's on a CD?

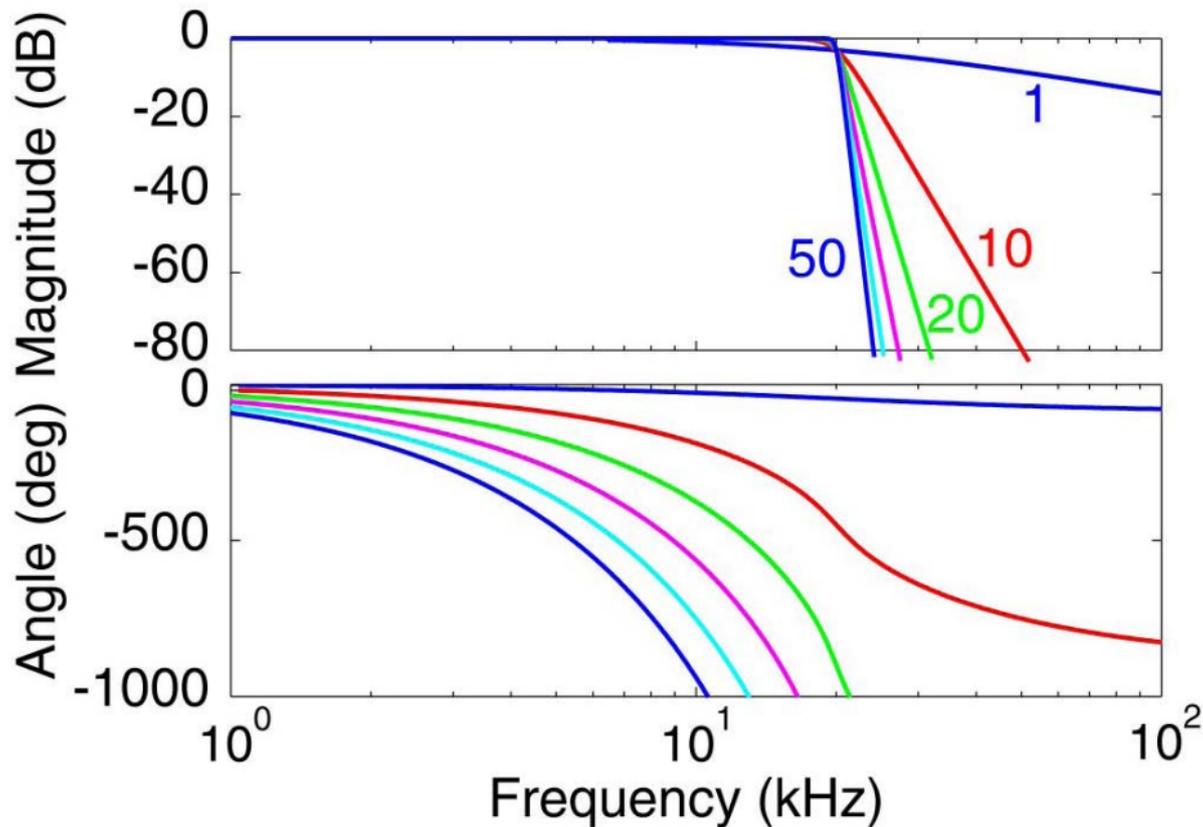


## What's on a CD?

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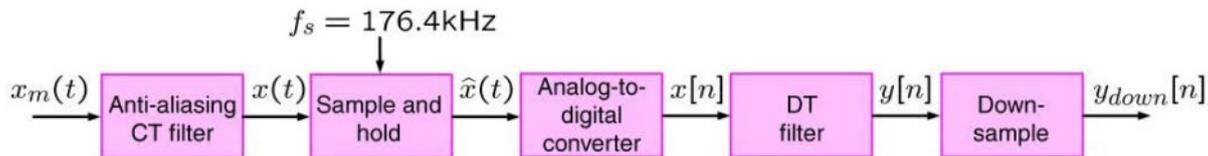


## What's on a CD?



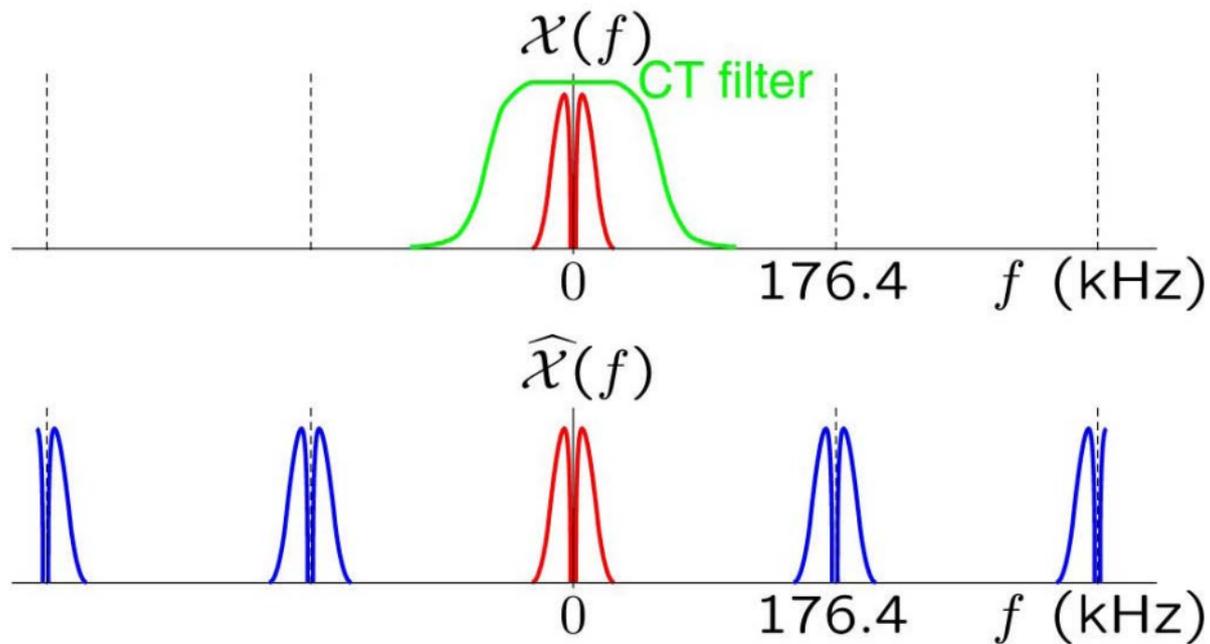
# What's on a CD?

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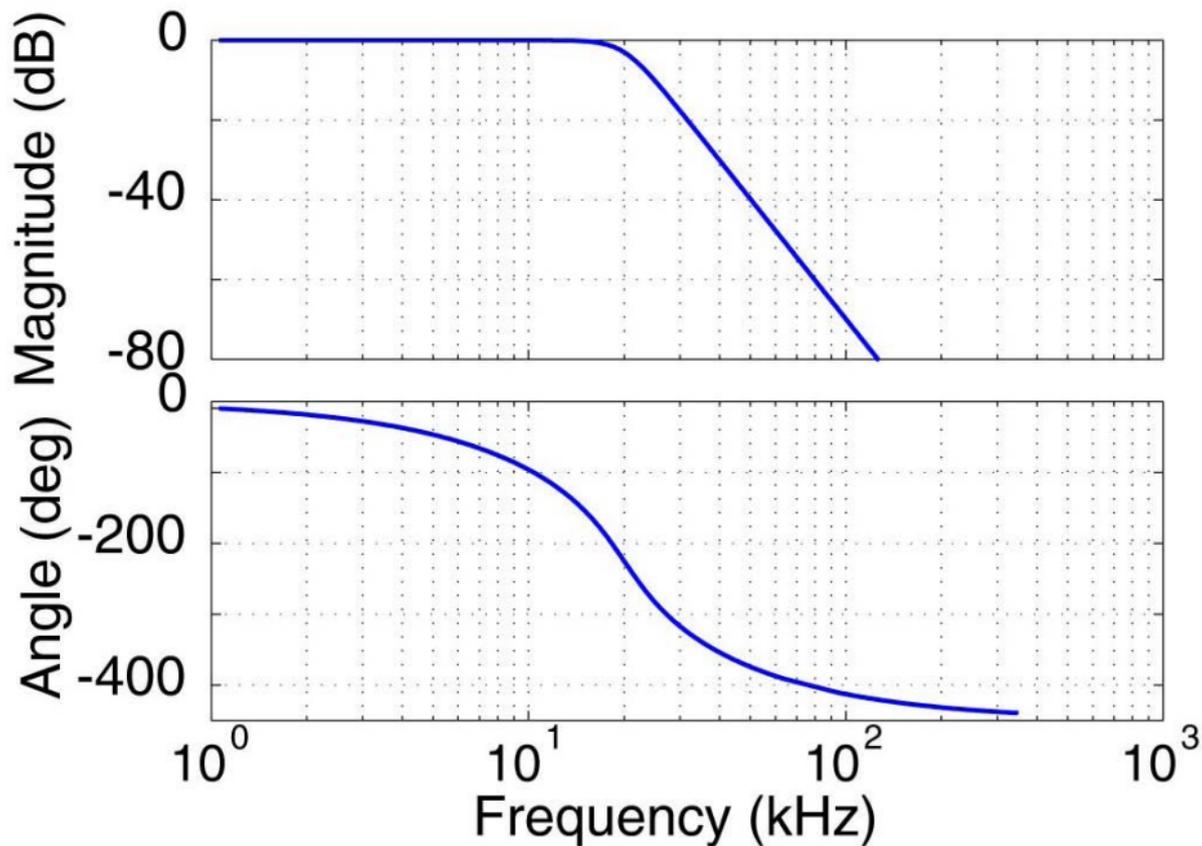


## What's on a CD?

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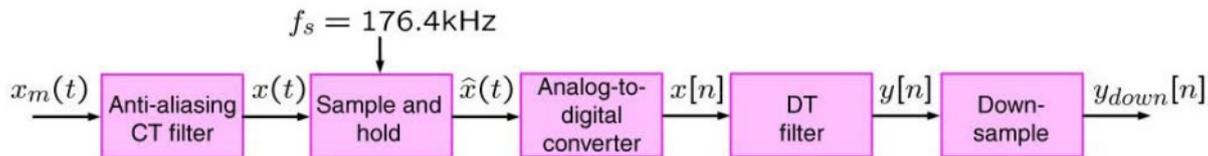


## What's on a CD?

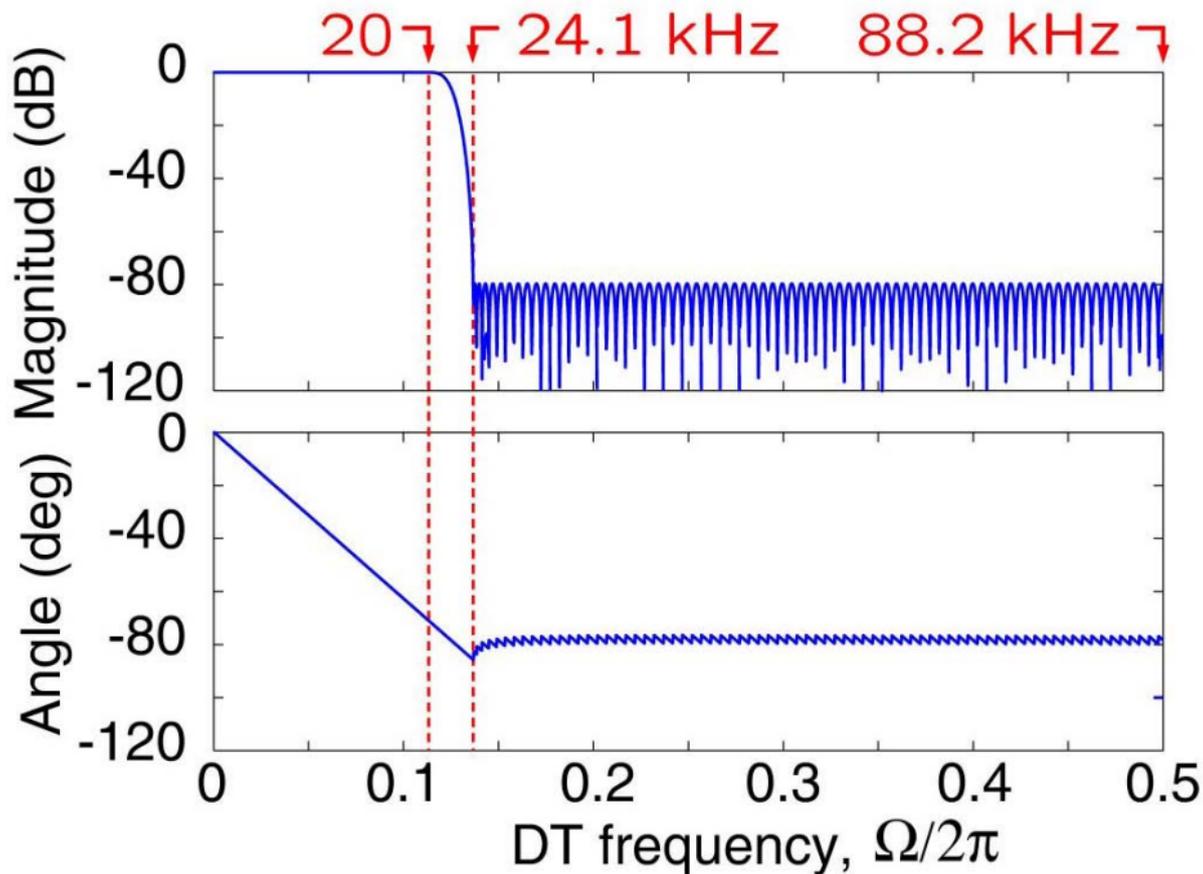


# What's on a CD?

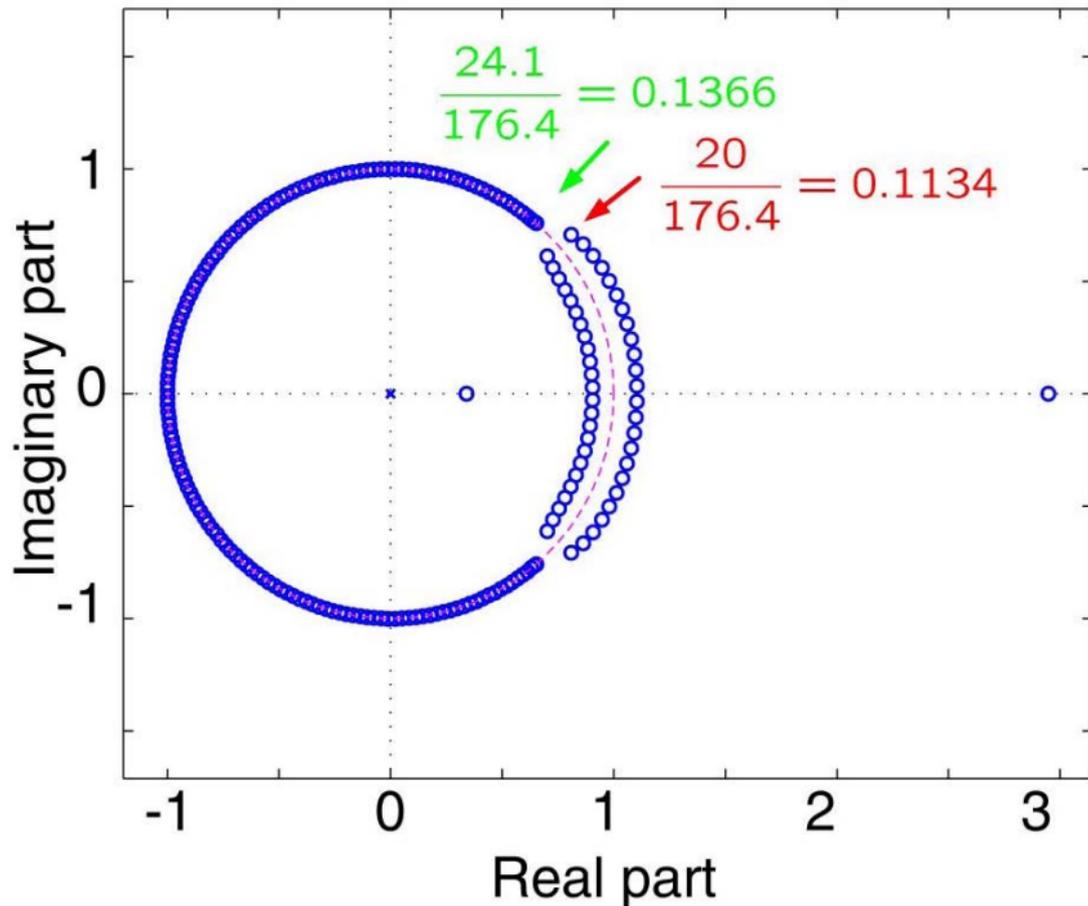
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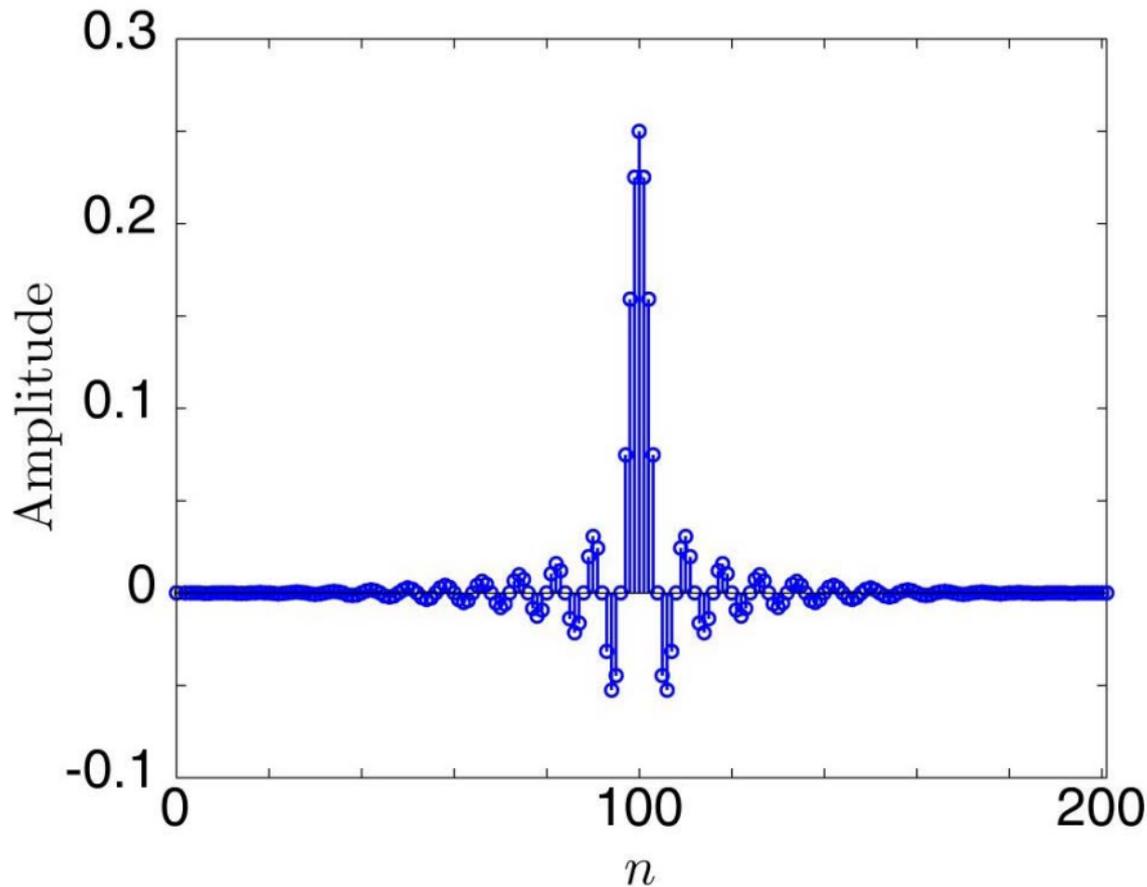
## What's on a CD?



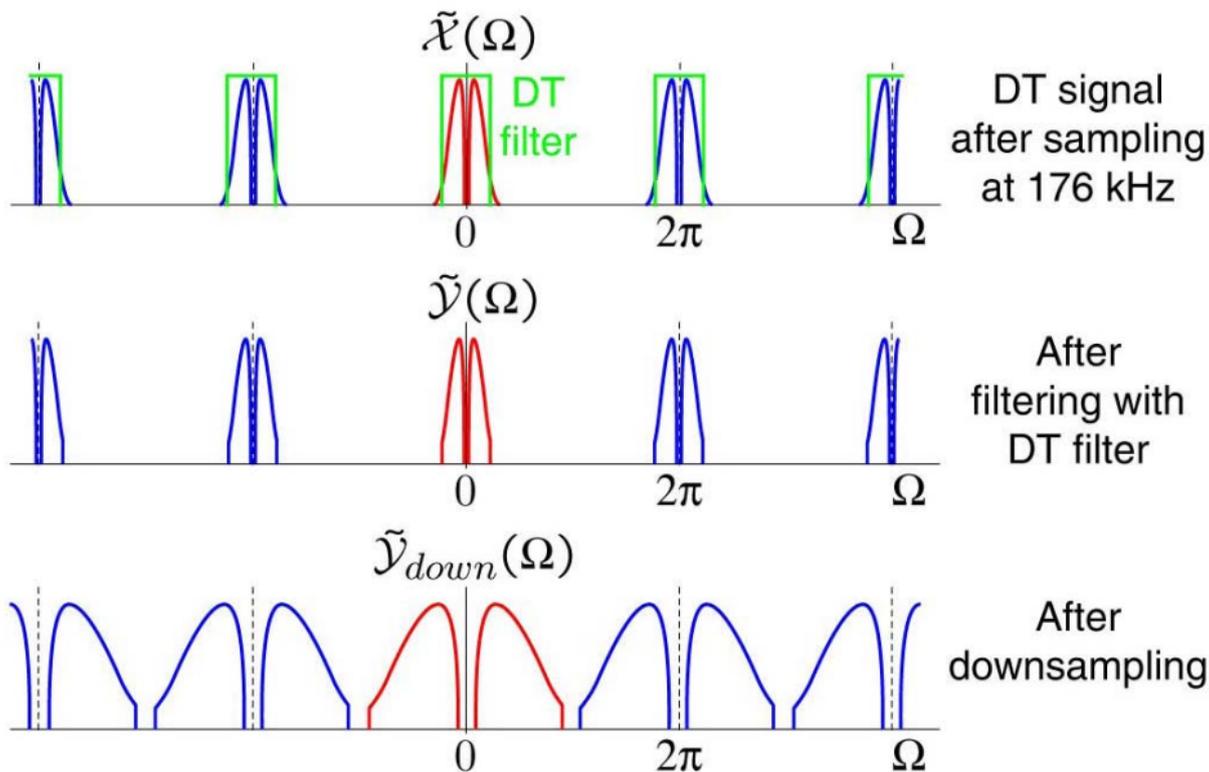
## What's on a CD?



## What's on a CD?



# What's on a CD?



## What's on a CD?

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LPs: 100 years of optimization, good fidelity, but

- fragile: easily scratched
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→ many of these advantages made possible by concepts from Signals and Systems!

## What's on a CD?

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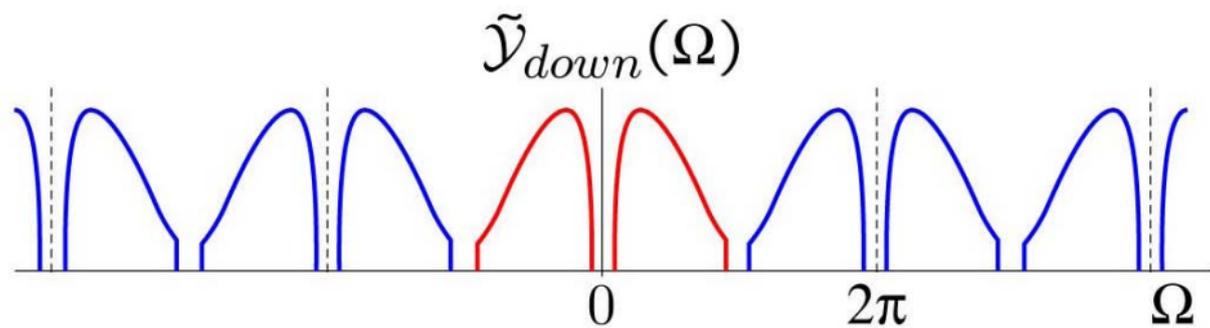
Audio  $\rightarrow$  bits:

- sampling
- filtering
- DT processing of CT signals
- downsampling

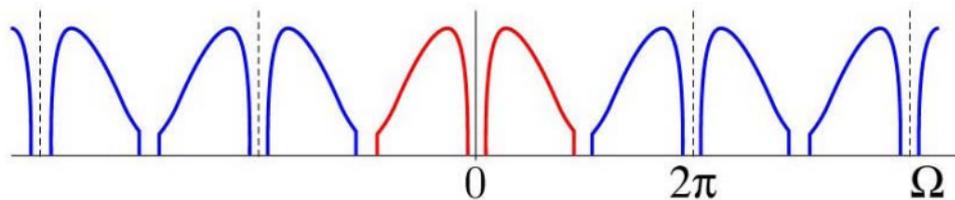
Next issue: how to you build a player?

## What's on a CD?

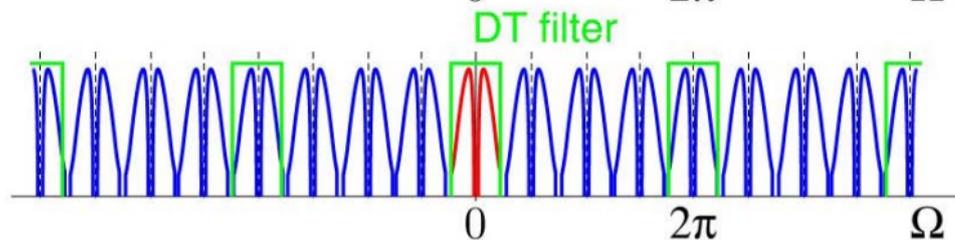
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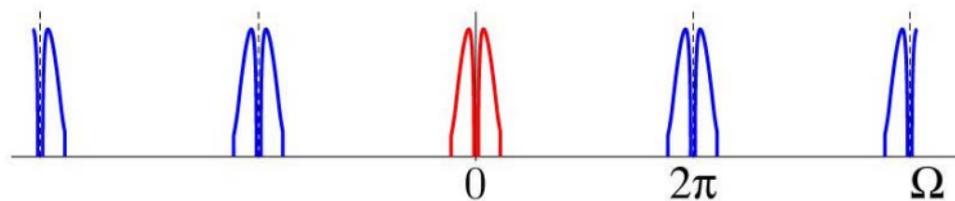
# What's on a CD?



Spectrum  
of samples  
on CD



Upsampled  
 $4 \times \bigcirc$

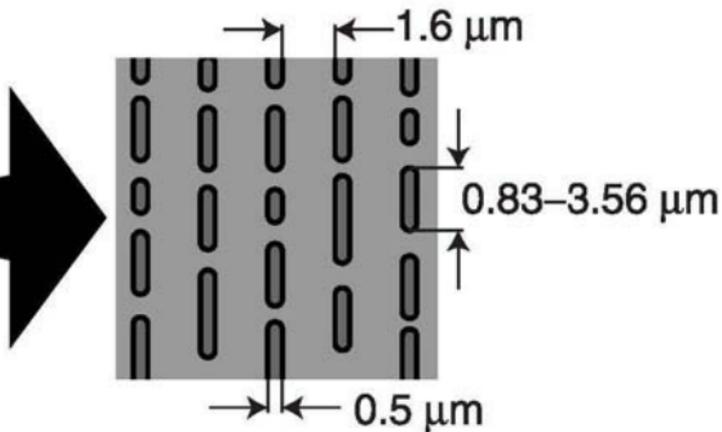


After  
filtering with  
DT filter

# What's on a CD?

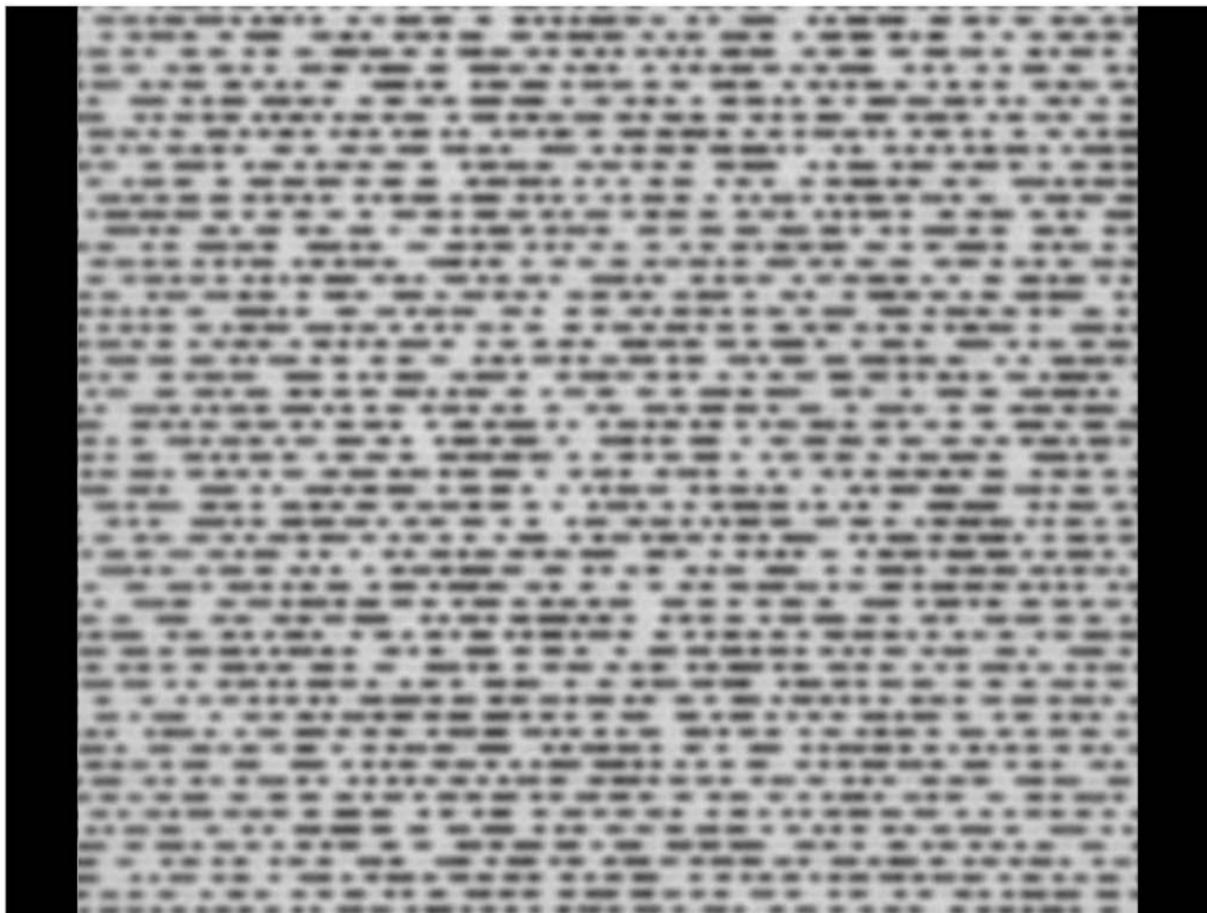


Image by [Dante Alighieri](#)  
on Wikimedia Commons.



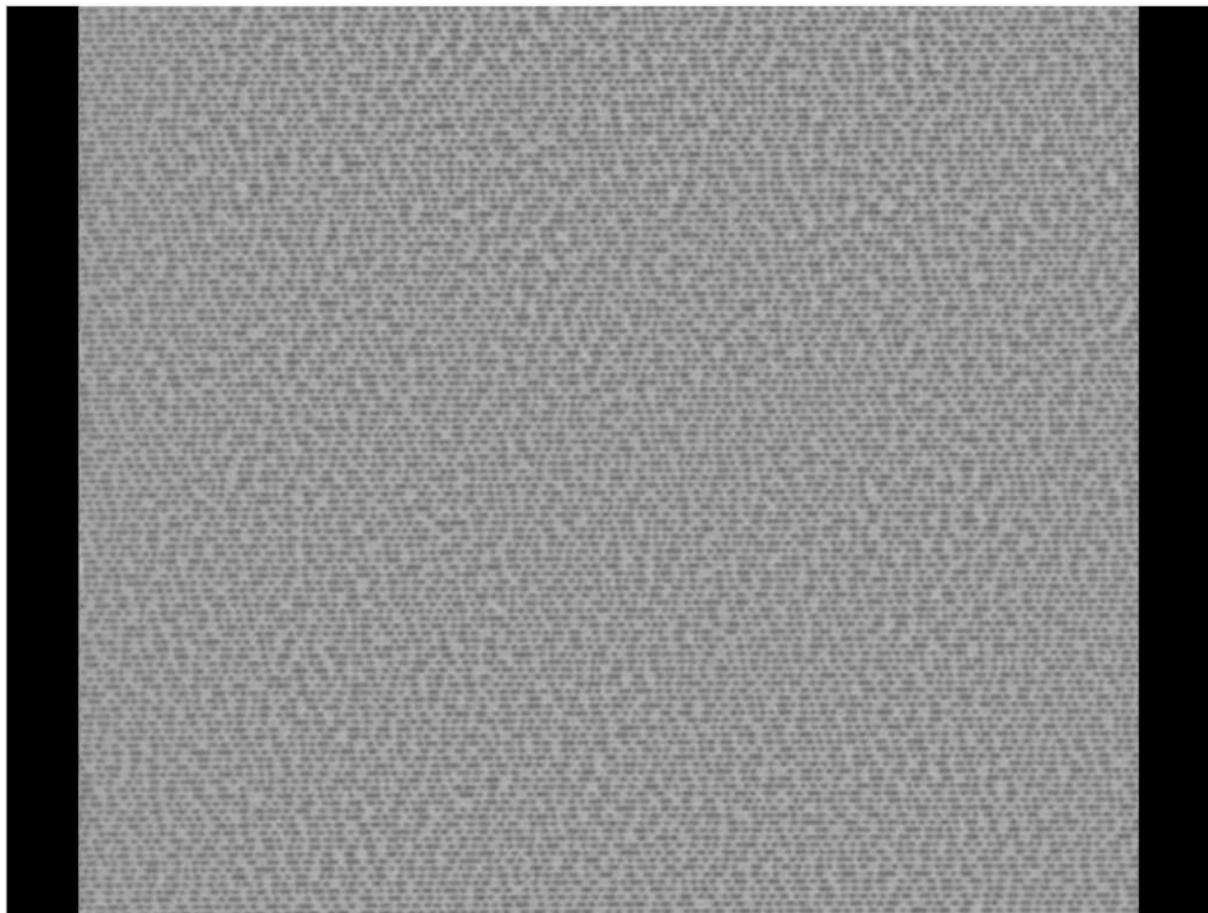
## What's on a CD?

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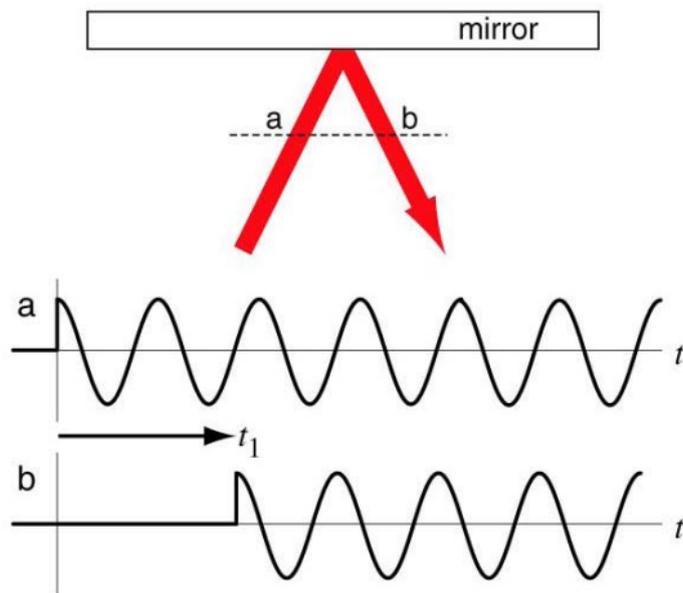
## What's on a CD?

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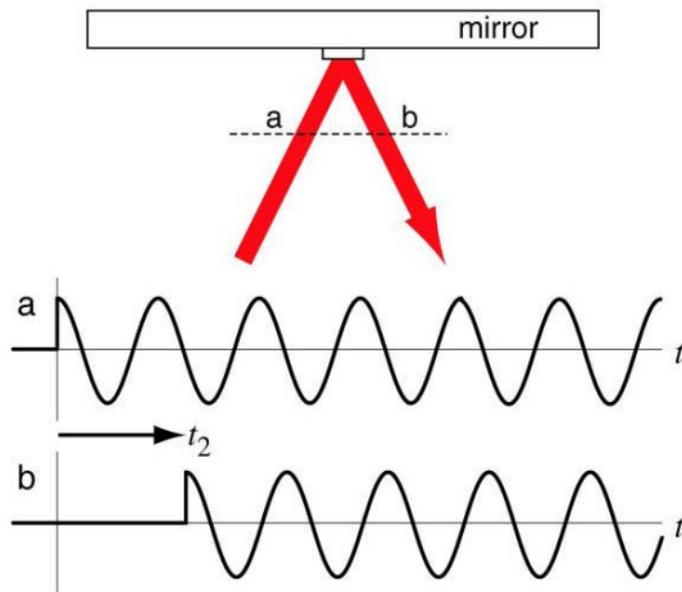
# What's on a CD?

Interferometric sensing: 6.003 explanation



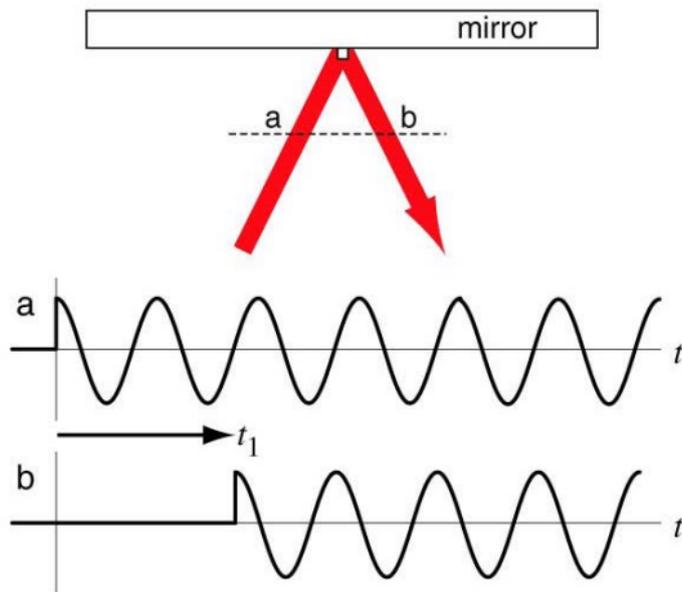
# What's on a CD?

Interferometric sensing: 6.003 explanation



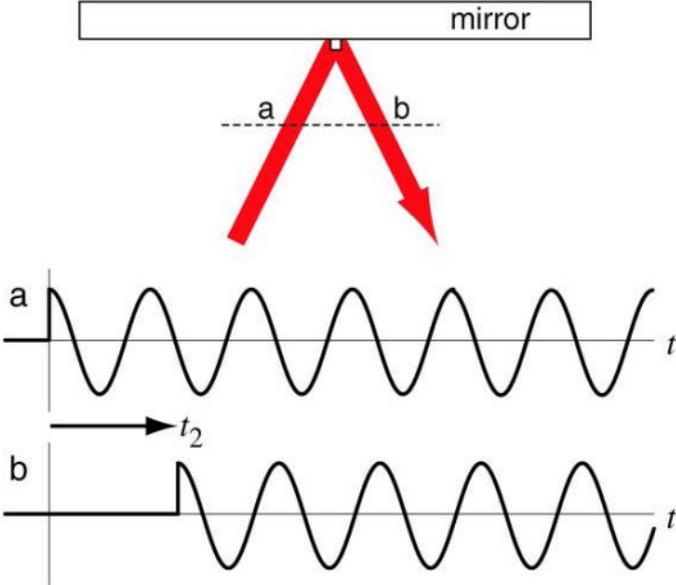
# What's on a CD?

Interferometric sensing: 6.003 explanation



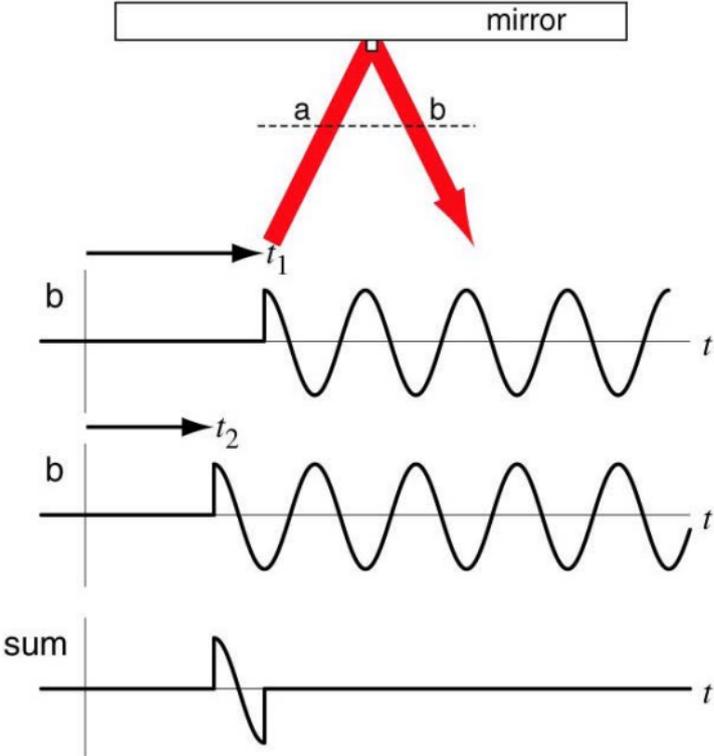
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Interferometric sensing: 6.003 explanation



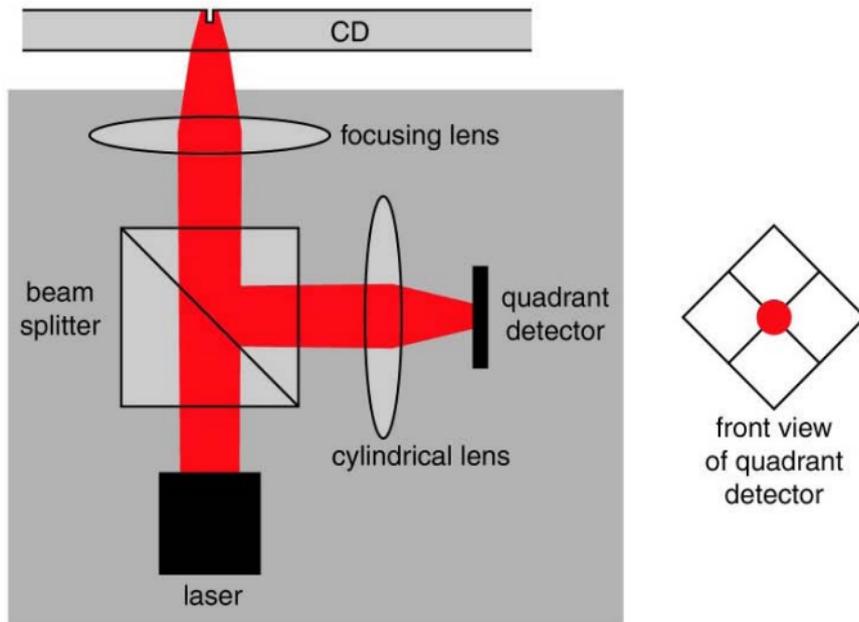
# What's on a CD?

Interferometric sensing: 6.003 explanation



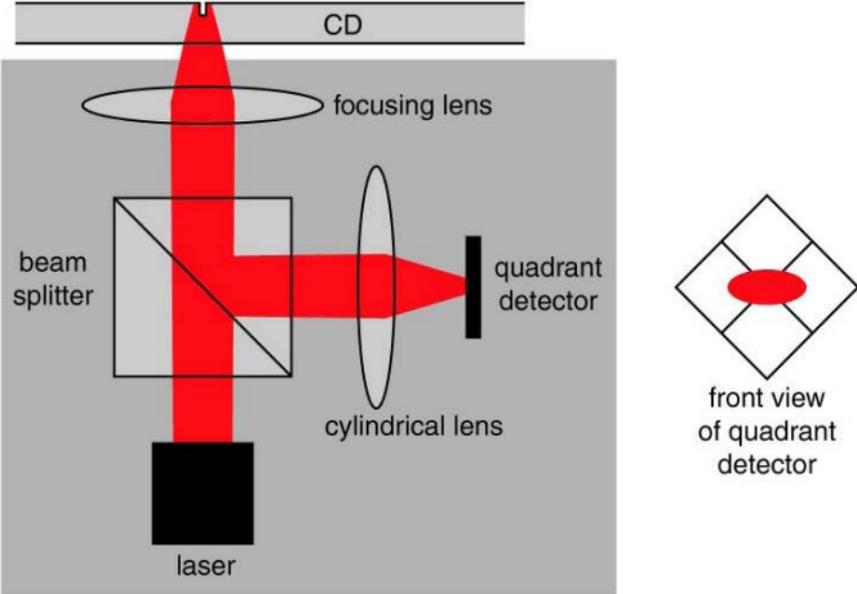
# What's on a CD?

## Focusing with feedback control



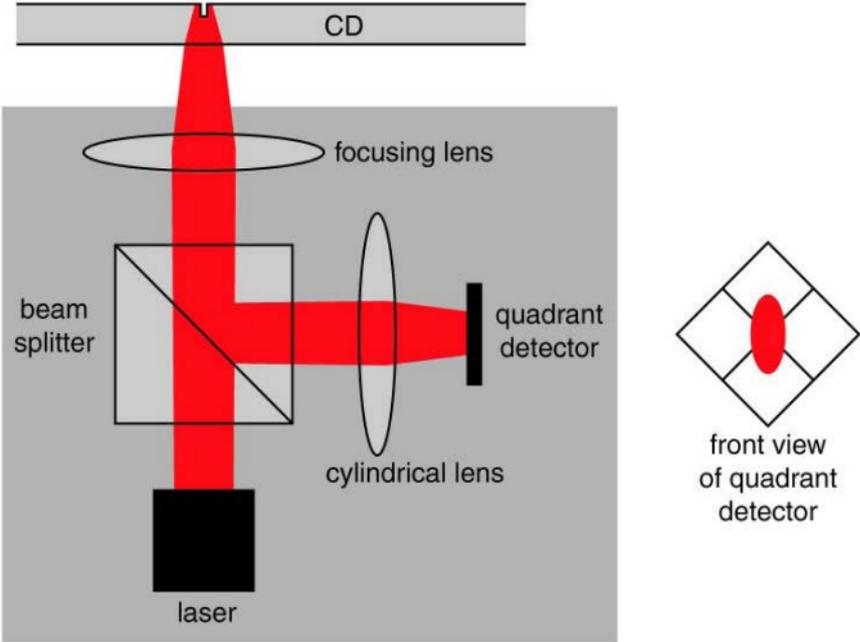
# What's on a CD?

## Focusing with feedback control



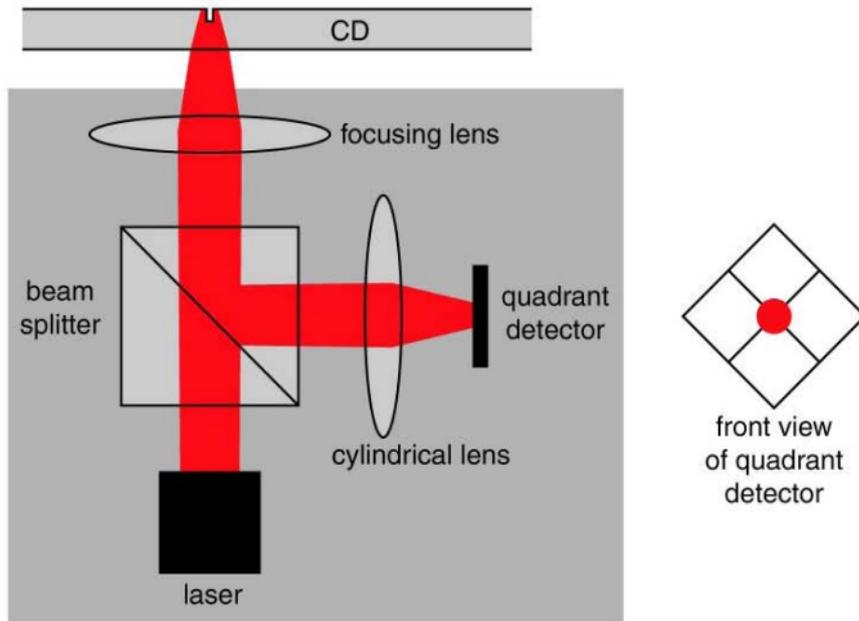
# What's on a CD?

## Focusing with feedback control



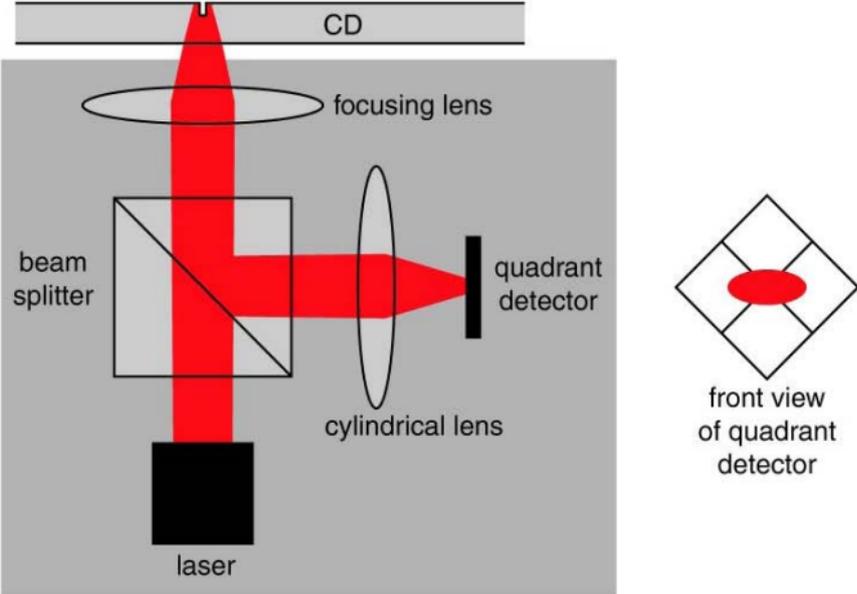
# What's on a CD?

## Focusing with feedback control



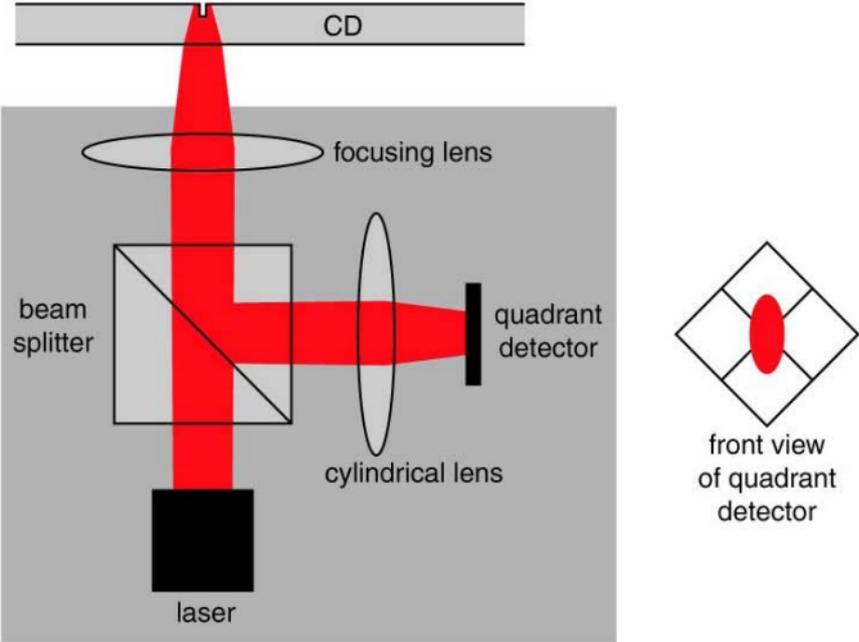
# What's on a CD?

## Focusing with feedback control



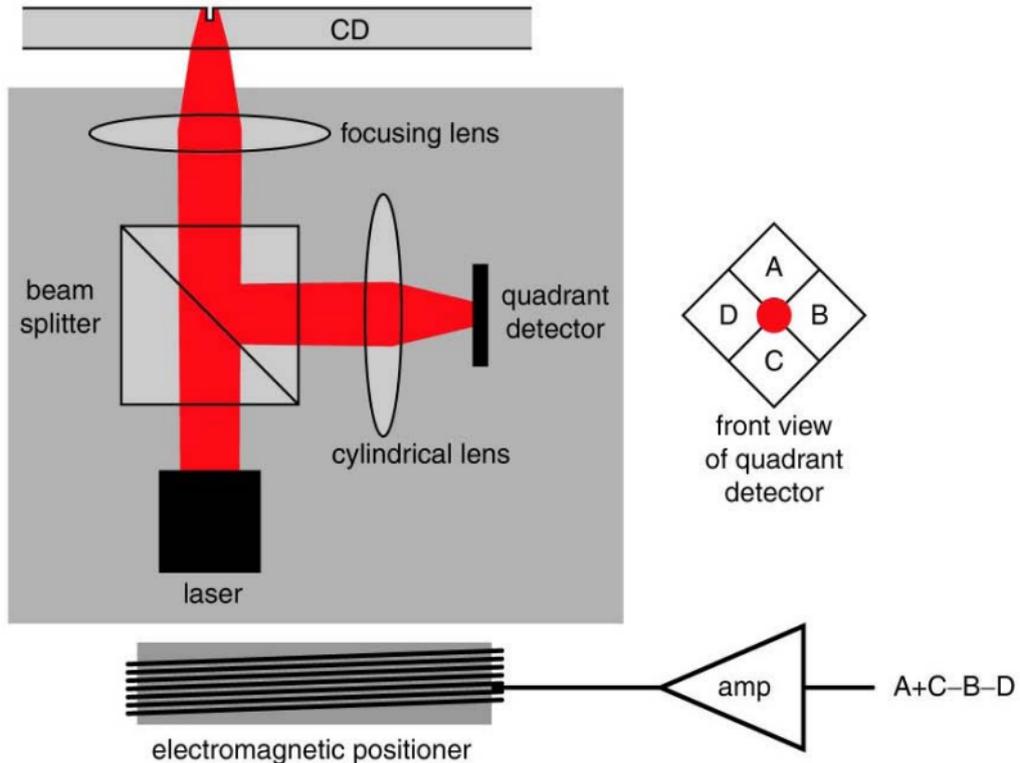
# What's on a CD?

## Focusing with feedback control



# What's on a CD?

## Focusing with feedback control



# What's on a CD?

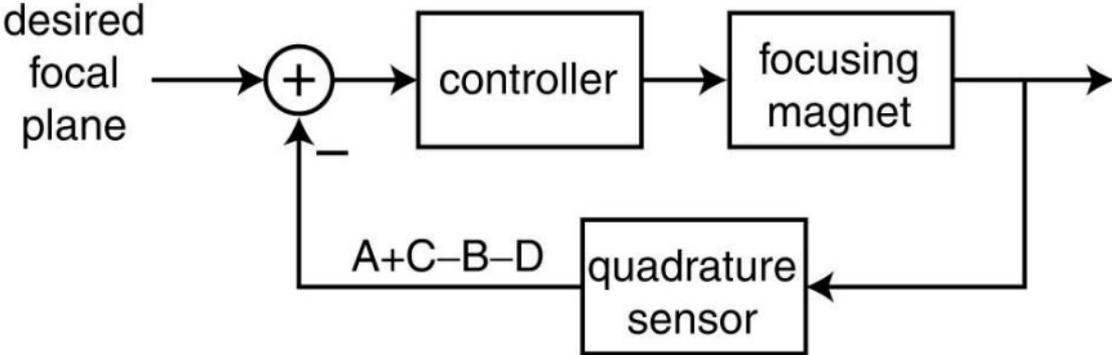
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Image removed due to copyright restrictions. Please see Brain, Marshall.  
"[How CDs Work: CD Player Components](#)." HowStuffWorks, April 2000.

# What's on a CD?

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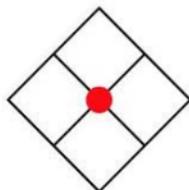
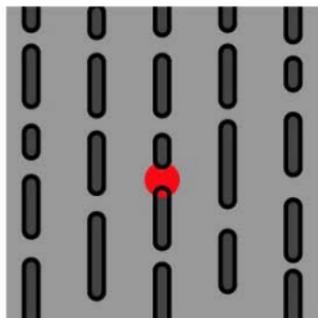
## Focusing with feedback



## What's on a CD?

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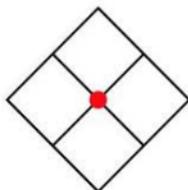
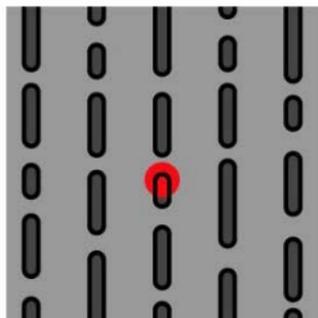
Translating pits to bits



## What's on a CD?

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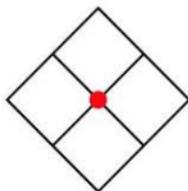
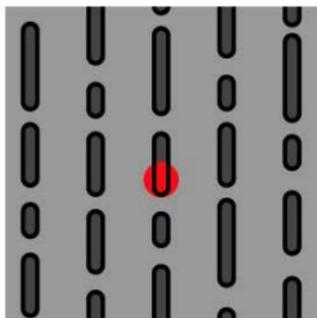
Translating pits to bits



## What's on a CD?

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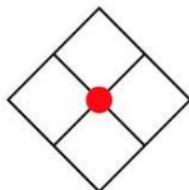
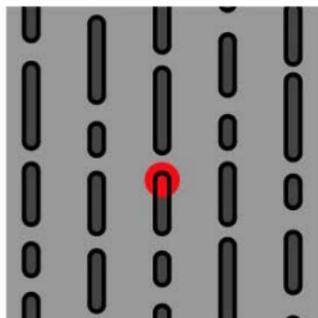
Translating pits to bits



## What's on a CD?

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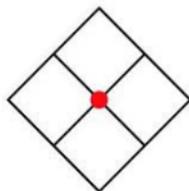
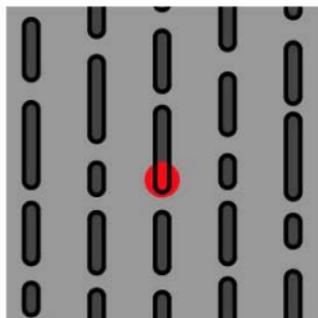
Translating pits to bits



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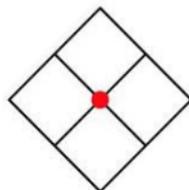
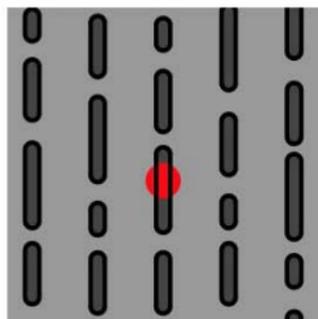
Translating pits to bits



## What's on a CD?

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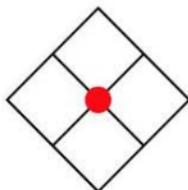
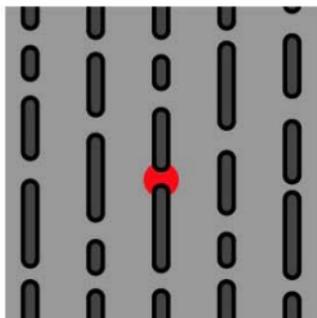
Translating pits to bits



## What's on a CD?

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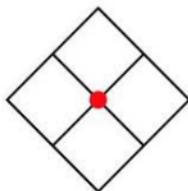
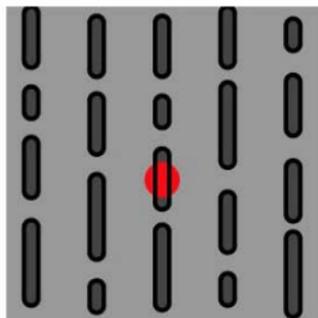
Translating pits to bits



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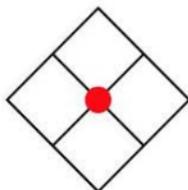
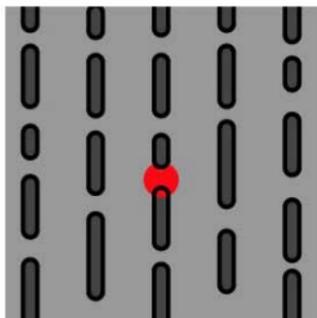
Translating pits to bits



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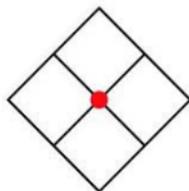
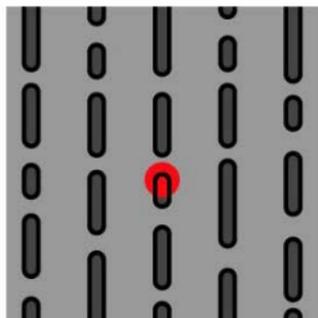
Translating pits to bits



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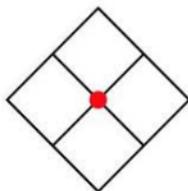
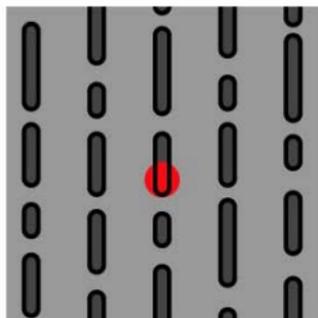
Translating pits to bits



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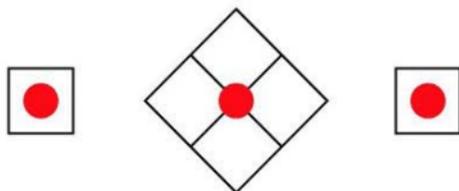
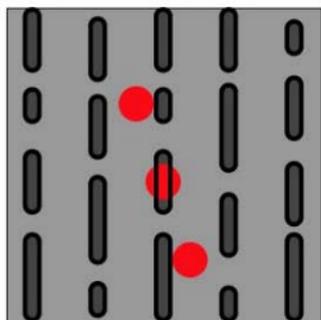
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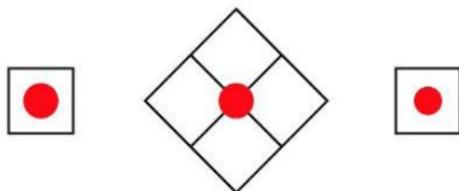
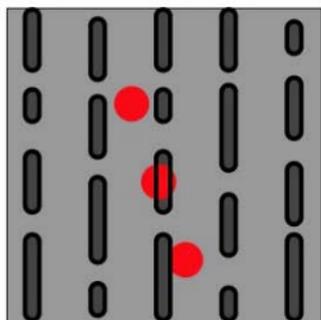
Tracking with feedback control



## What's on a CD?

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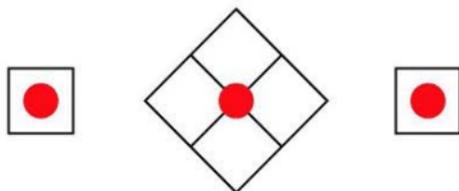
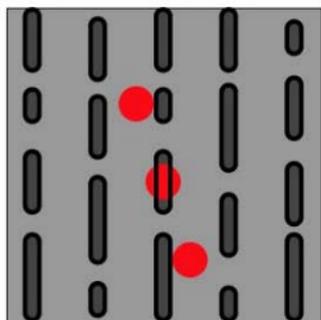
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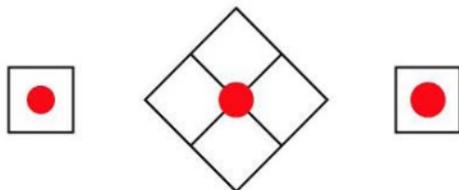
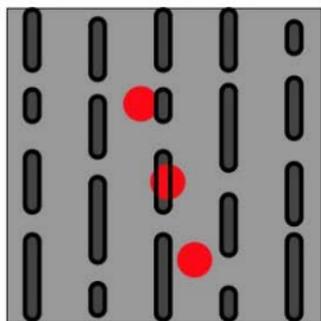
Tracking with feedback control



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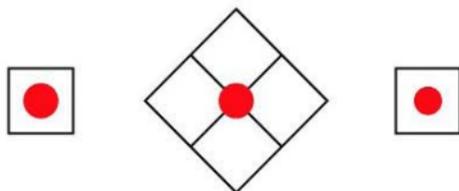
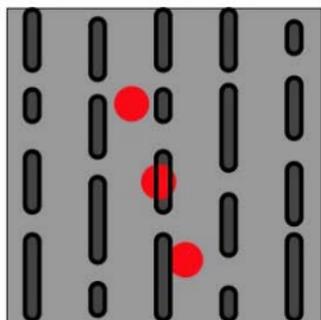
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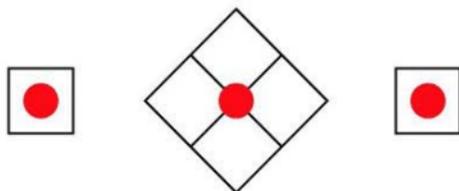
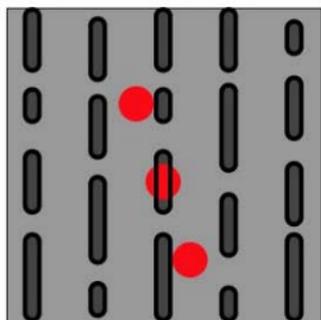
Tracking with feedback control



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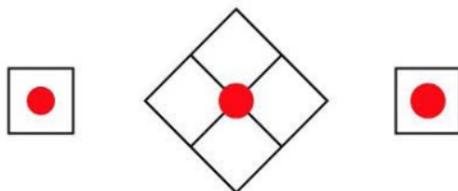
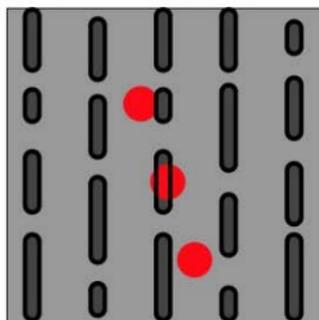
Tracking with feedback control



## What's on a CD?

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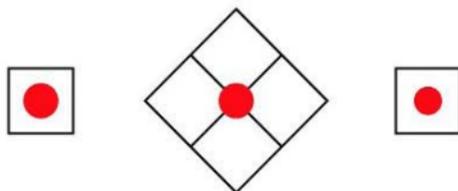
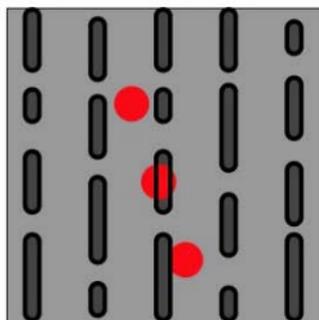
Tracking with feedback control



## What's on a CD?

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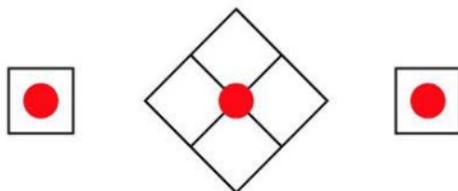
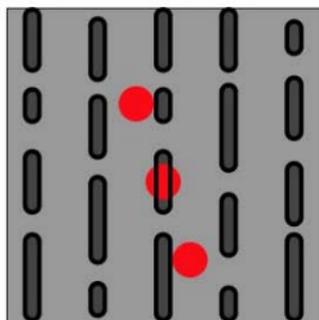
Tracking with feedback control



## What's on a CD?

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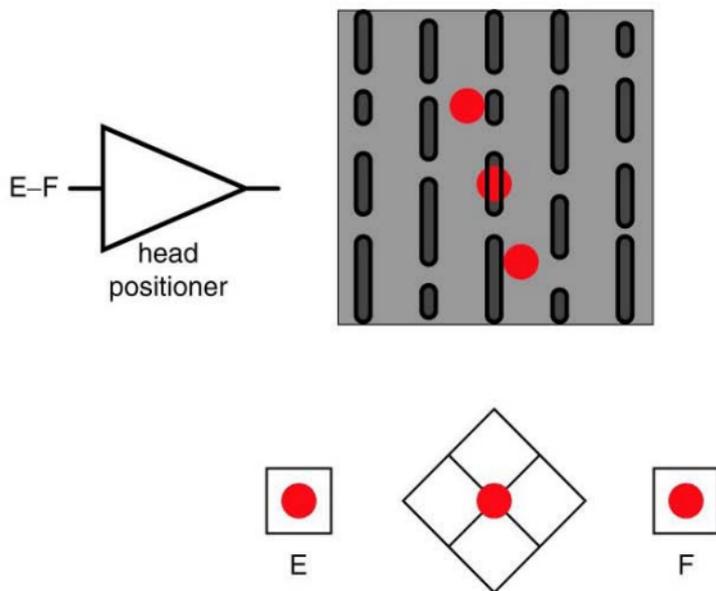
Tracking with feedback control



# What's on a CD?

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## Tracking with feedback control



# What's on a CD?

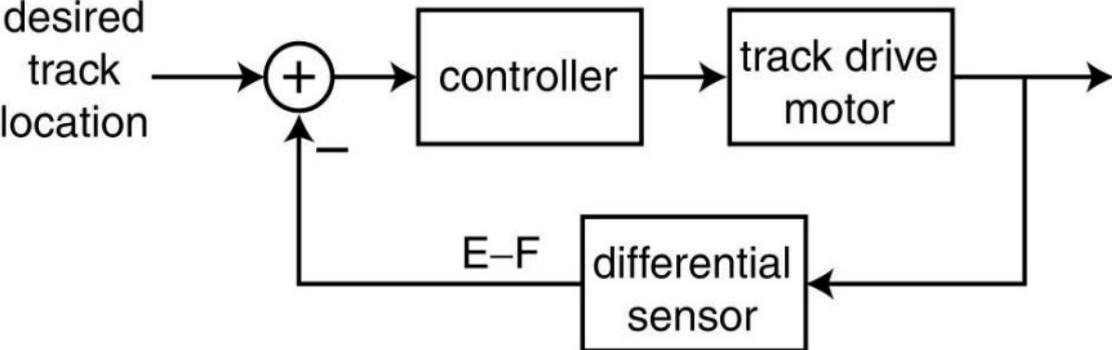
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Image removed due to copyright restrictions. Please see Brain, Marshall.  
"How CDs Work: CD Player Components." HowStuffWorks, April 2000.

# What's on a CD?

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Tracking the tracks with feedback



## What's on a CD?

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LPs: 100 years of optimization, good fidelity, but

- fragile: easily scratched
- lots of distortions: e.g., wow and flutter
- expensive

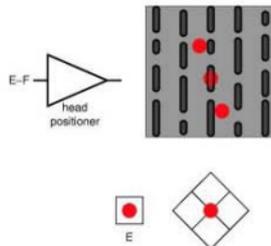
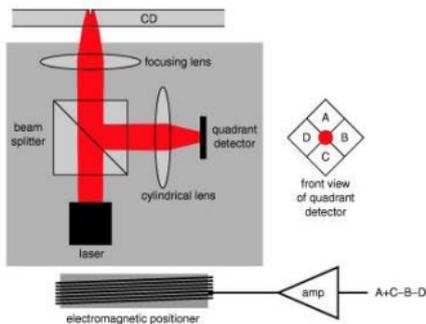
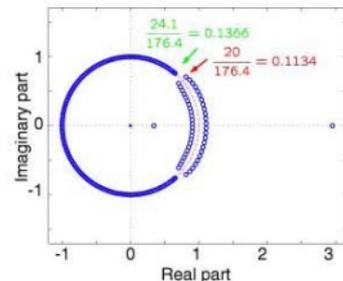
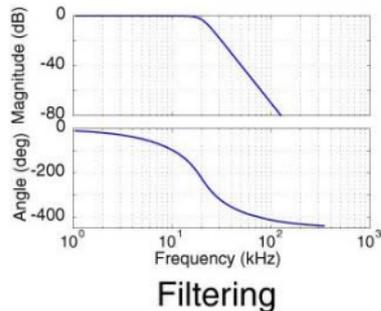
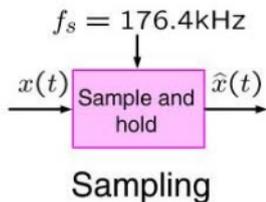
CDs: much higher fidelity

- nearly indestructible ✓
- very low distortion ✓
- very cheap ✓

→ many of these advantages made possible by concepts from Signals and Systems!

# What's on a CD?

From LPs to CDs –  
and how 6.003 helps get you there



Feedback

## What's on a CD?

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### References:

“The history of the Edison Cylinder Phonograph”

<http://memory.loc.gov/ammem/edhtml/edcyldr.html>

“Audio Compact Disk – An Introduction” by Kelin J. Kuhn

[http://audio18.stormloader.com/Audio/compact\\_disc/audioCD.htm](http://audio18.stormloader.com/Audio/compact_disc/audioCD.htm)

“How CDs Work” by Marshall Brain

<http://electronics.howstuffworks.com/cd.htm>

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## 6.003 Signals and Systems

Fall 2011

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