Ch. 6: Logarithmic Unit
The Decibel

Notes from EECE 281... "Ch. 6" refers to the EECE 281 book called "Electrical Engineering Uncovered"

<u>Logarithmic Scale</u>

- Engineers deal with data that can take on values over a **<u>HUGE</u>** range!!!

  i.e., Plotting Y vs. X

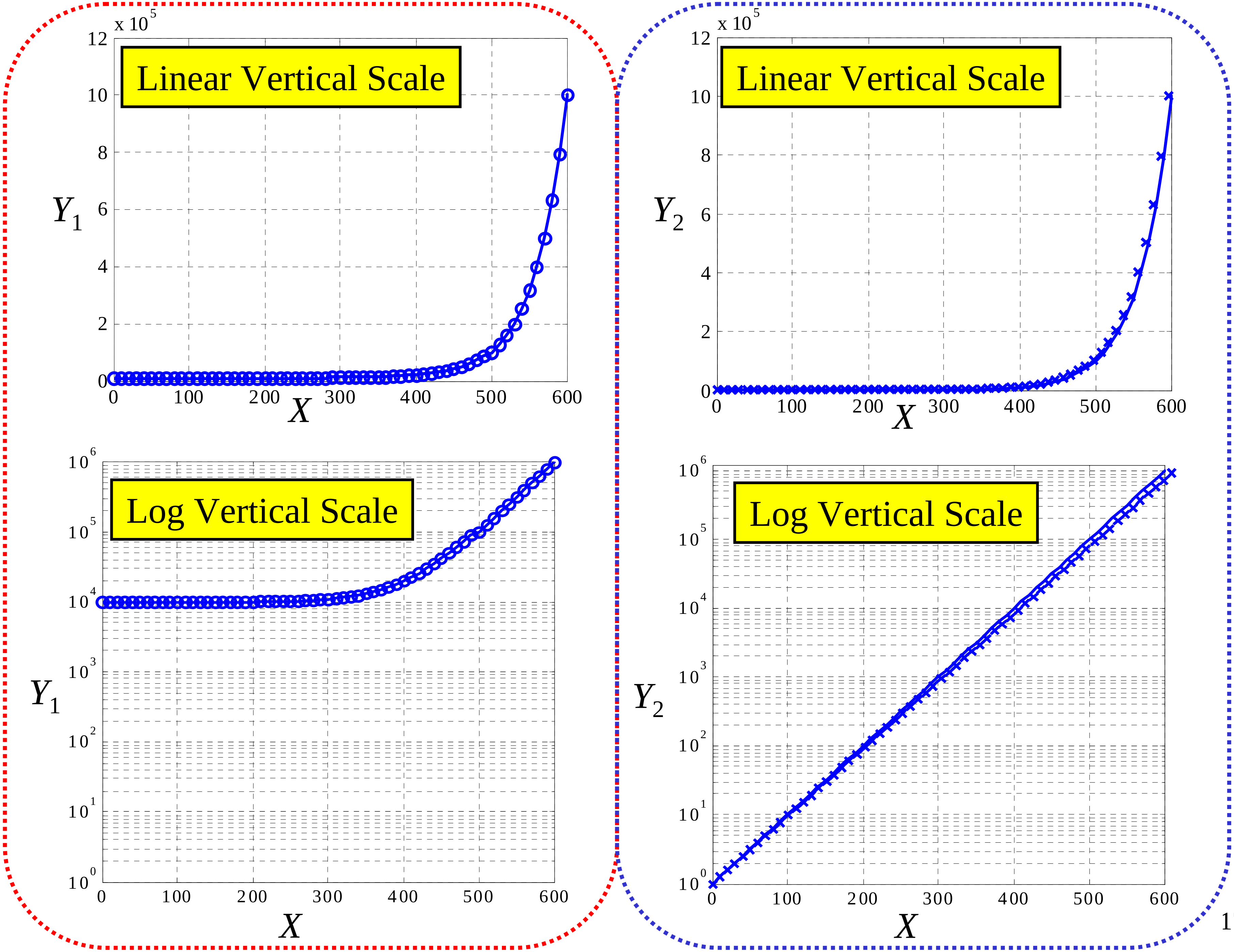
  – Plotting this on a "linear" scale doesn't show the data well

  – so use "logarithmic" <u>scale(s)</u>

  - Y on **log** axis vs. X on **linear** axis, or
  - Y on **linear** axis vs. X on **log** axis, or
  - Y on **log** axis vs. X on **log** axis,

    … depends on data

  – The following plots illustrate this!
    - Two sets of data that are very different, but you can't see it on the linear scale!!!

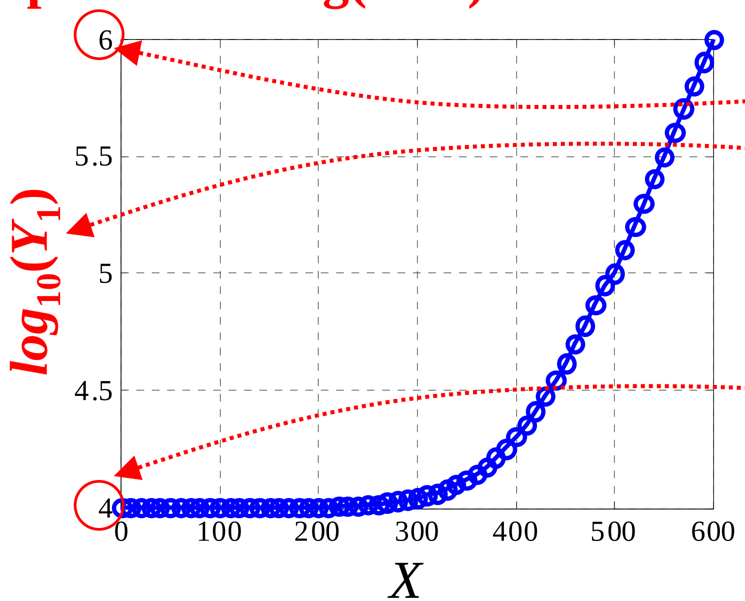

Linear Vertical Scale
Log Vertical Scale
Linear Vertical Scale
Log Vertical Scale
Y_1
Y_2
X
x 10^5

Logarithmic Scale

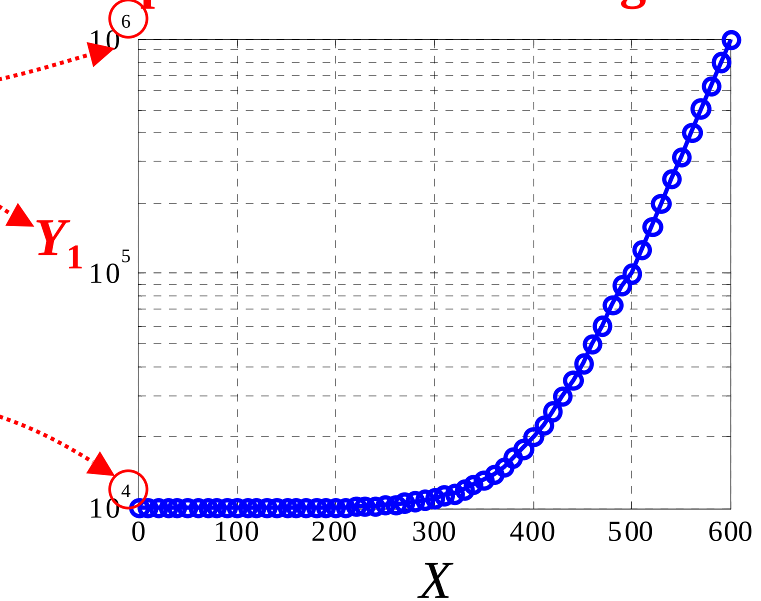
- Instead of using a logarithmic ***axis***…
- **First… take log of data;**
  then… plot on linear axis

- log(Y) vs. X, or
- Y vs. log(X), or
- log(Y) vs. log(X)

Option: Plot log(data) on linear axis



Option: Plot data on log axis



Defining the Decibel

- Building on this $log_{10}(data)$ idea…
- **Definition**: use "decibels" as a **logarithmic unit** of measure for a **ratio** between **two powers**

$$\underbrace{10\underbrace{\log_{10}\left(\frac{P_1}{P_2}\right)}_{\text{bel}}}_{\text{decibel}}$$

P_1/P_2 (non-dB)	P_1/P_2 (dB)
$1000 = 10^{3}$	30 dB
$100 = 10^{2}$	20 dB
$10 = 10^{1}$	10 dB
$1 = 10^{0}$	0 dB
$0.1 = 10^{-1}$	–10 dB
$0.01 = 10^{-2}$	–20 dB
$0.001 = 10^{-3}$	–30 dB

Know These

Powers of 10 are easy to convert to dB!!

Another "Rule" to Know!!

$P_1/P_2 = 2$ ➔ ~ 3 dB

"Extending" the Decibel

- Even though dB is defined for power we can extend it for use with voltages and currents:
  - assume voltages to be compared are across same resistance

$$10\log_{10}\left(\frac{P_1}{P_2}\right) = 10\log_{10}\left(\frac{V_1^2/R}{V_2^2/R}\right)$$

$$= 10\log_{10}\left(\frac{V_1^2}{V_2^2}\right)$$

$$= 20\log_{10}\left(\frac{V_1}{V_2}\right)$$

$$10\log_{10}\left(\frac{P_1}{P_2}\right) = 10\log_{10}\left(\frac{I_1^2 R}{I_2^2 R}\right)$$

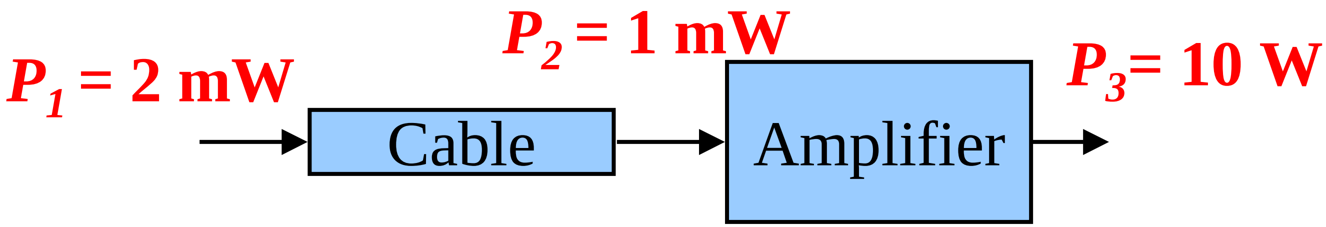
$$= 10\log_{10}\left(\frac{I_1^2}{I_2^2}\right)$$

$$= 20\log_{10}\left(\frac{I_1}{I_2}\right)$$

Use "20" for V & I, but use "10" for P

Using the Decibel

- Comparing two quantities in system(s)



$$10\log_{10}\left(\frac{P_2}{P_1}\right) = 10\log_{10}\left(\frac{1}{2}\right) = -3\,\text{dB}$$

The Cable has a **Gain** of –3 dB

$$10\log_{10}\left(\frac{P_3}{P_2}\right) = 10\log_{10}\left(\frac{10}{10^{-3}}\right) = 40\,\text{dB}$$

The Amplifier has a **Gain** of 40 dB

Negative dB gain = loss… "Cable has a 3 dB Loss"

$$10\log_{10}\left(\frac{P_3}{P_1}\right) = 10\log_{10}\left(\frac{10}{2\times 10^{-3}}\right) = 37\,\text{dB}$$

The System has a **Gain** of 37 dB

log(ab) = *log*(a) + *log*(b)

Gains in a "cascade" add in dB: –3 dB + 40 dB = 37 dB

Using the Decibel (2)

- Using decibels for amplifier gains
  - **MUST** disregard the "negative" for an inverting gain
  - Recall: Inverting Op Amp Gain = $-R_F/R_1$
  - In dB this is stated as: **"20log$_{10}$(R_F/R_1)   (inverting)"**
- Comparing a quantity in a system to a reference
  - Sometimes common arbitrary references are used
    - 1 W ➔ $10log_{10}(P/1W)$ **dBW**
    - 1 mW ➔ $10log_{10}(P/0.001W)$ **dBmW or just dBm**
  - Sometimes a physically meaningful reference is used
    - See table for sound pressure level

Sounds	Sound Pressure Level (μBar)	**Sound Pressure Level** (dB)
Jet Plane (@ 30 m)	2000	140
Threshold of Pain		130
	200	120
Chainsaw		110
Rock Concert/Club	20	100
		90
Busy Street	2	80
		70
Normal Speech	0.2	60
		50
	0.02	40
Quiet Room		30
Recording Studio	0.002	20
		10
Threshold of Hearing	0.0002	0

Not Power
➔ $20\log_{10}(SPL/y)$

What should "y" be?
A Reference Level!!

$$20\log_{10}\left(\frac{20}{0.0002}\right)$$

For Non-Power
Factor of 10
➔ 20 dB

Reference Level
➔ 0 dB