Basic Electrical Engineering
ECS 203

Asst. Prof. Dr. Prapun Suksompong

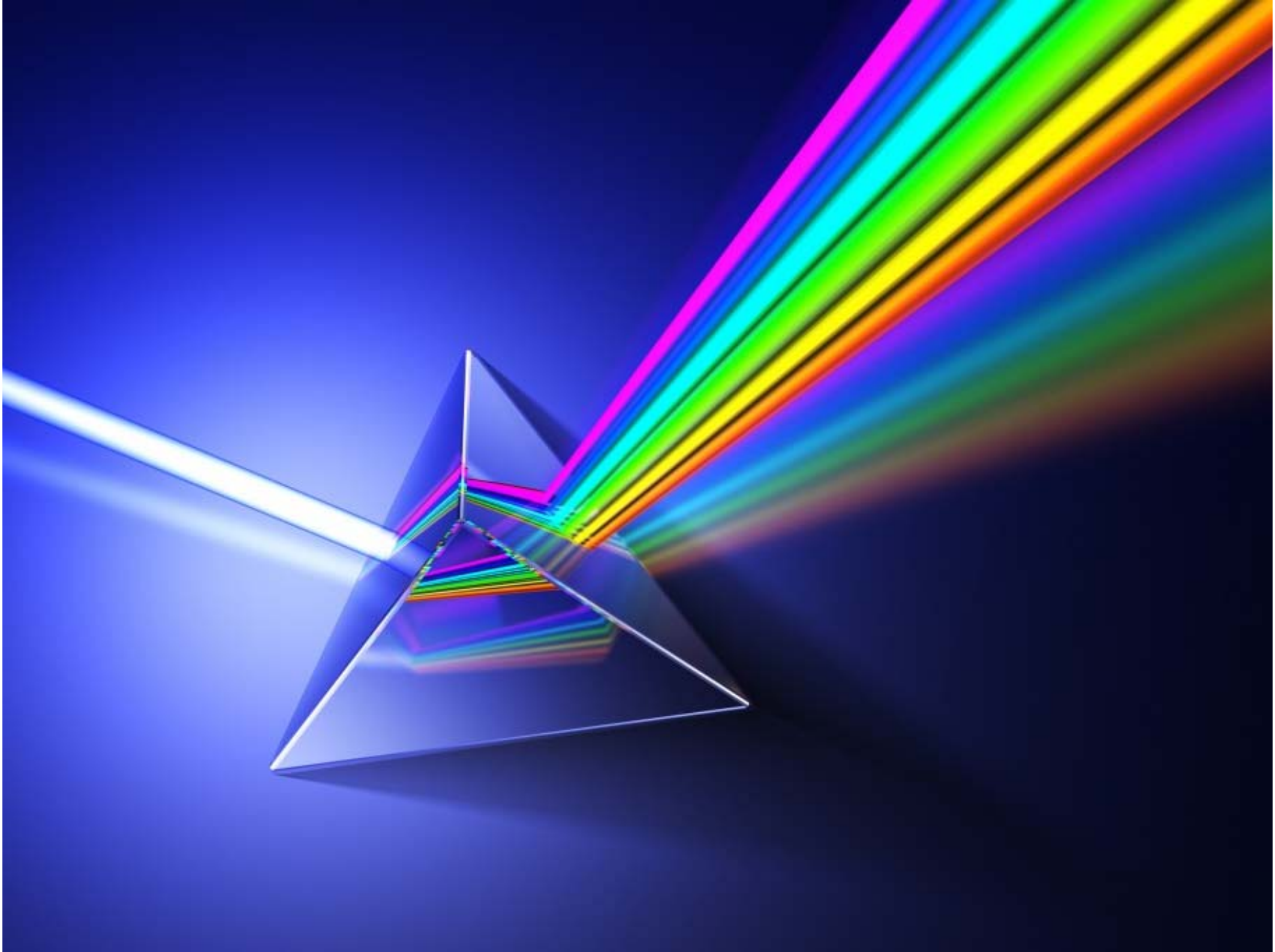
prapun@siit.tu.ac.th

7. Sinusoids and Phasors

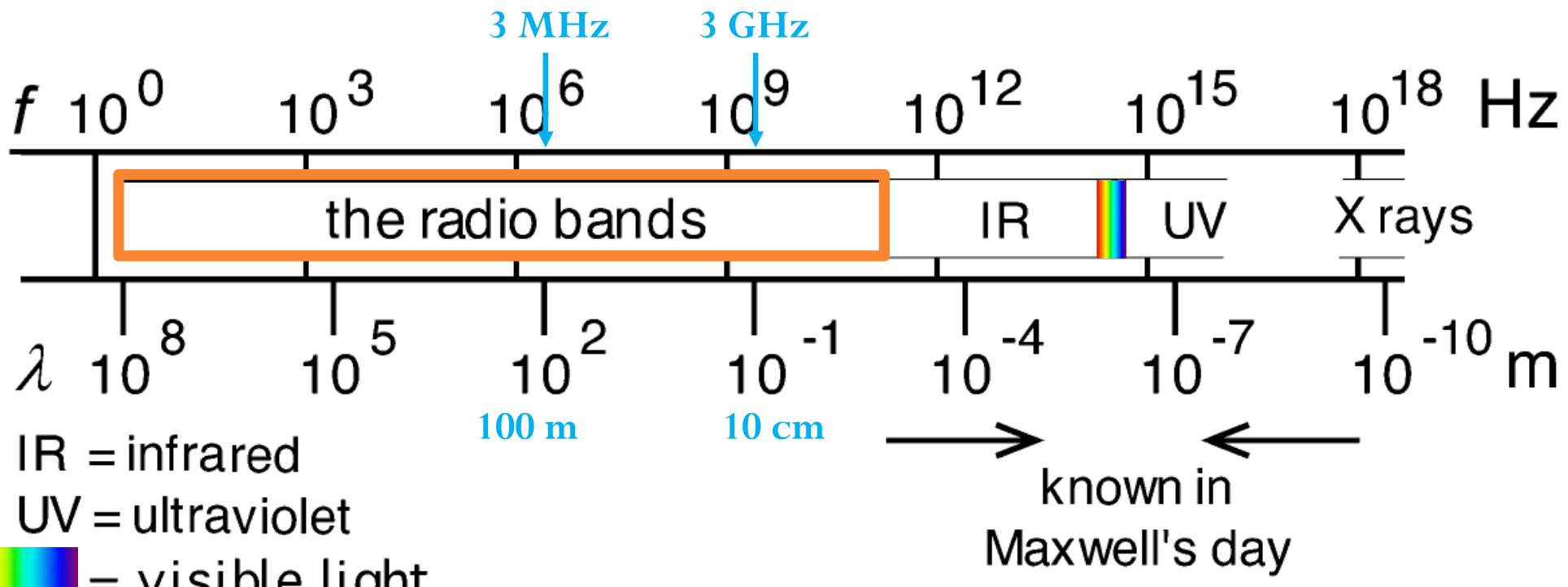
Office Hours:

BKD, 4th floor of Sirindhralai building

Monday	**14:00-16:00**
Thursday	**10:30-11:30**
Friday	**12:00-13:00**



Electromagnetic Spectrum

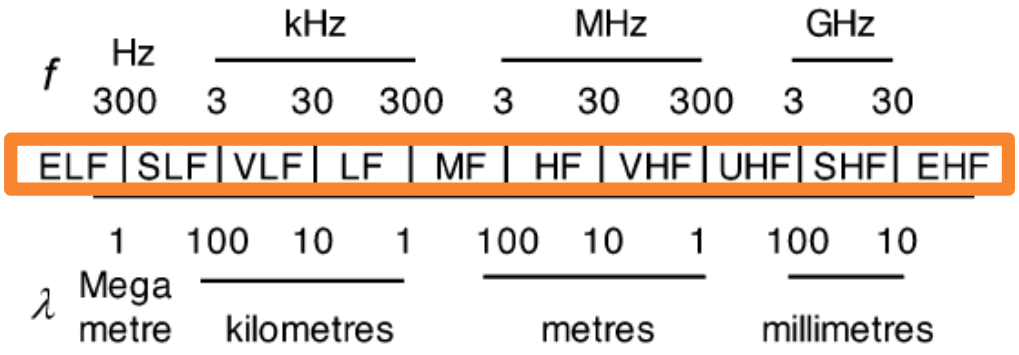


IR = infrared

UV = ultraviolet

= visible light

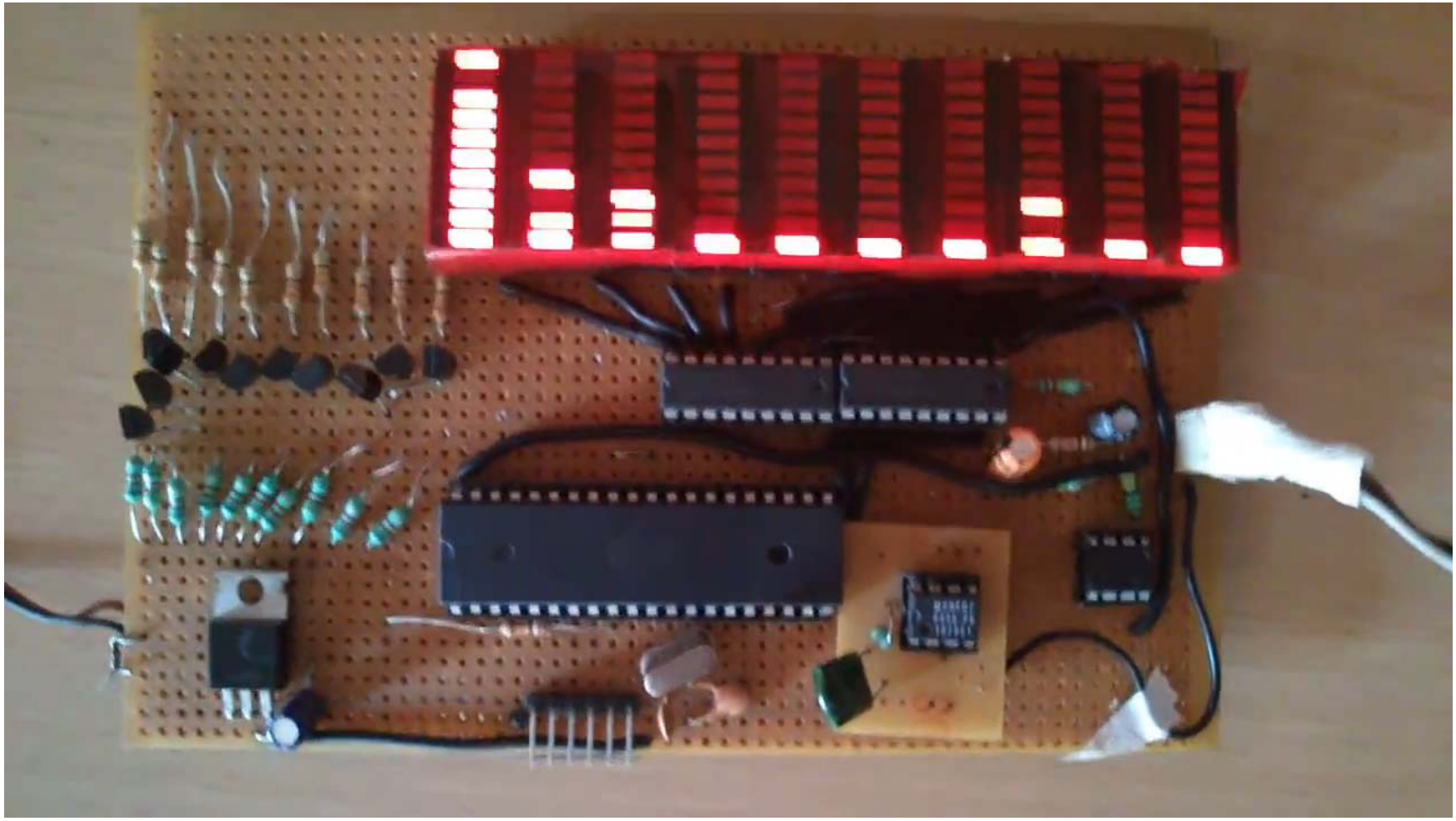
[Gosling , 1999, Fig 1.1 and 1.2]



$$c = f\lambda$$

3×10^8 m/s — Wavelength — Frequency

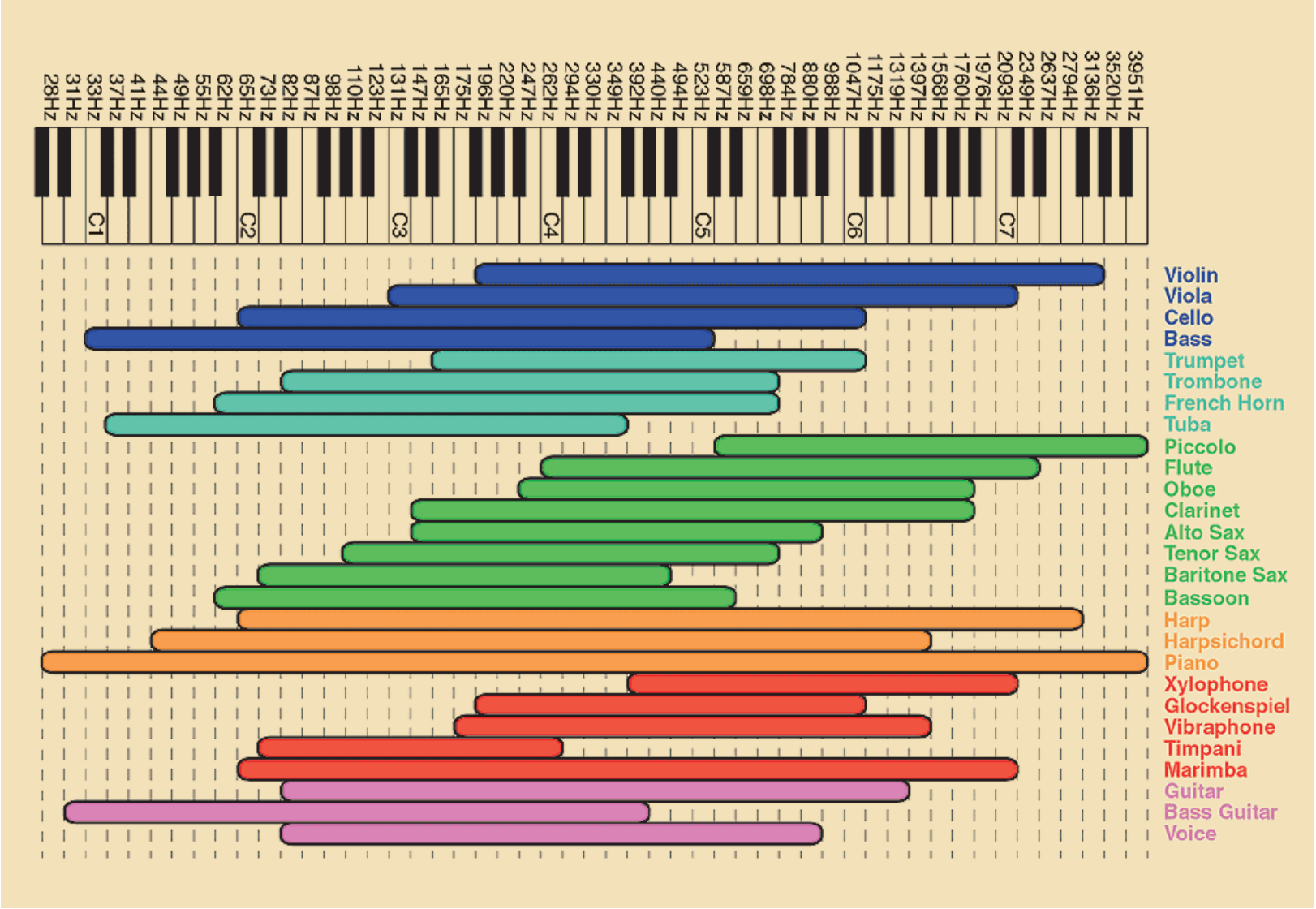
LED Audio Spectrum Analyzer



[http://www.instructables.com/id/100-LED-10-band-Audio-Spectrum-atmega32-MSGEQ7-wit/]

The (Fundamental) Frequencies of Musical Instruments

Note frequency



[http://www.psbspeakers.com/articles/The-Frequencies-of-Music]

A440 on Different Instruments

"Same" timbre of a tuning fork ("pure" tone)

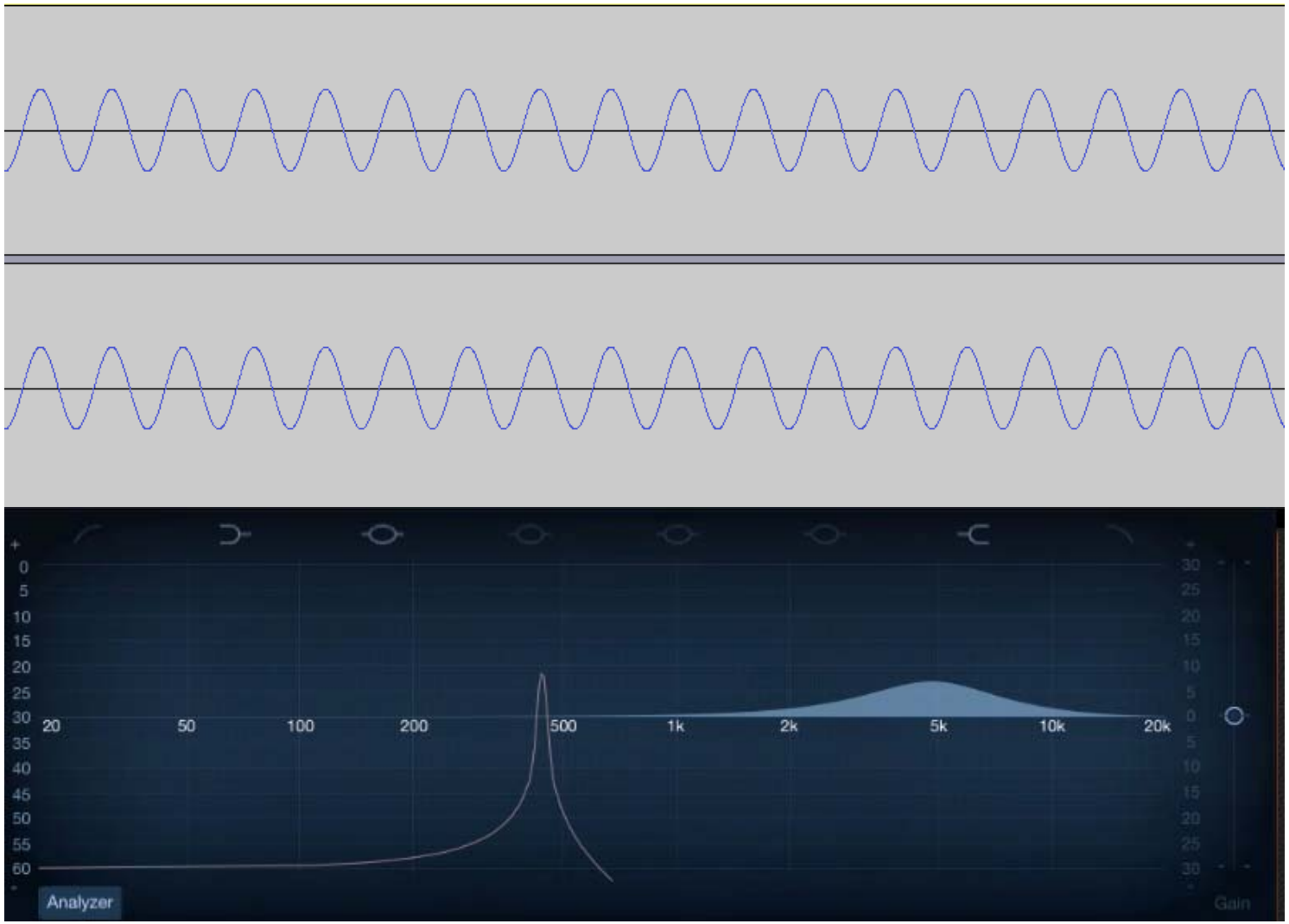
[GarageBand]

[https://www.youtube.com/watch?v=9iGjo2cd69s]
[http://www.philvarner.com/2015/01/27/why-does-a-tuning-fork-sound-different-than-a-piano-even-if-theyre-playing-the-same-note/]

A440 on a Cathedral Organ

Left track

Right track

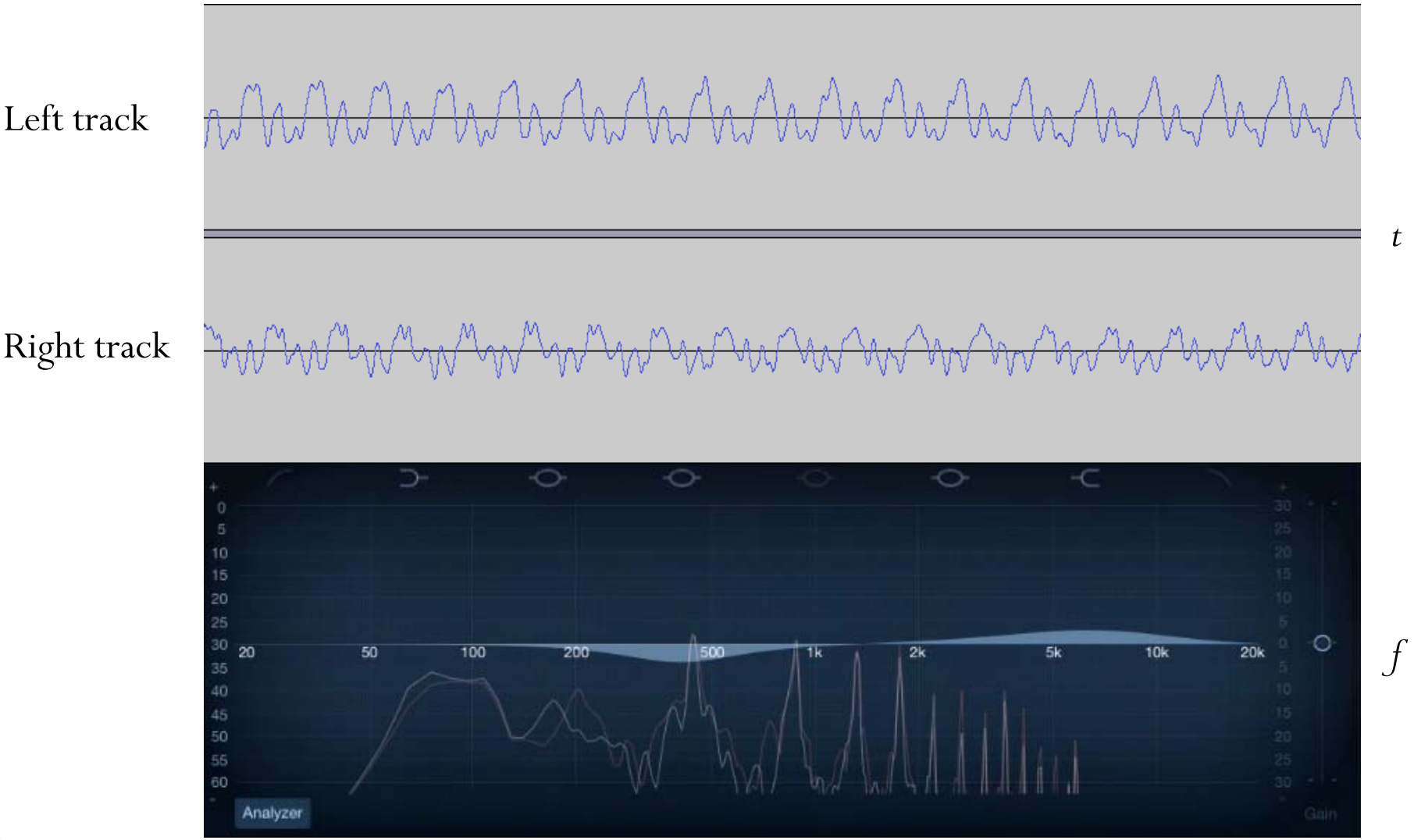


t

f

[http://www.philvarner.com/2015/01/27/why-does-a-tuning-fork-sound-different-than-a-piano-even-if-theyre-playing-the-same-note/]

A440 on a Grand Piano



[http://www.philvarner.com/2015/01/27/why-does-a-tuning-fork-sound-different-than-a-piano-even-if-theyre-playing-the-same-note/]

Tone Dialing

- Most modern telephones use a dialing system known as **Touch-Tone**.
  - **Dual-tone multifrequency** (**DTMF**) system.
- Use **pairs of audio** (voice-frequency) **tones** to create signals representing the numbers to be dialed.
- First developed in the **Bell System** in the United States, and became known under the trademark **Touch-Tone** for use in push-button telephones starting in 1963.
  - Replace the use of **rotary dial**.
- Standardized by ITU-T Recommendation Q.23.
  - Also known in the UK as MF4.

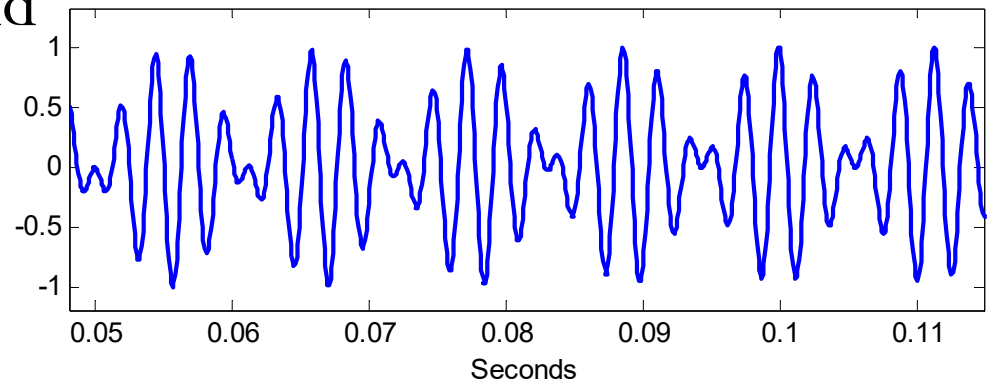
[http://samanthamyers.typepad.com/photos/telephones/b1964_touch_tone_telephone.html]

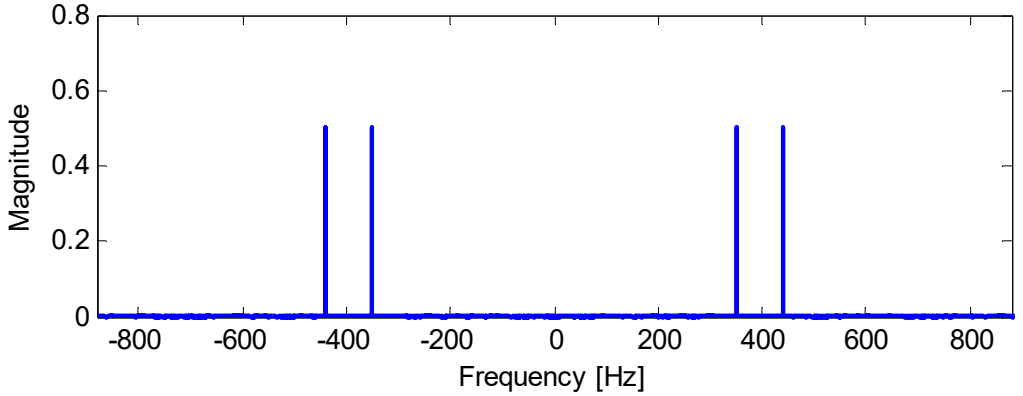
[http://blog.modernmechanix.com/pushbuttons-replace-dials-on-telephone/]

[Apr, 1964]

Dial Tone

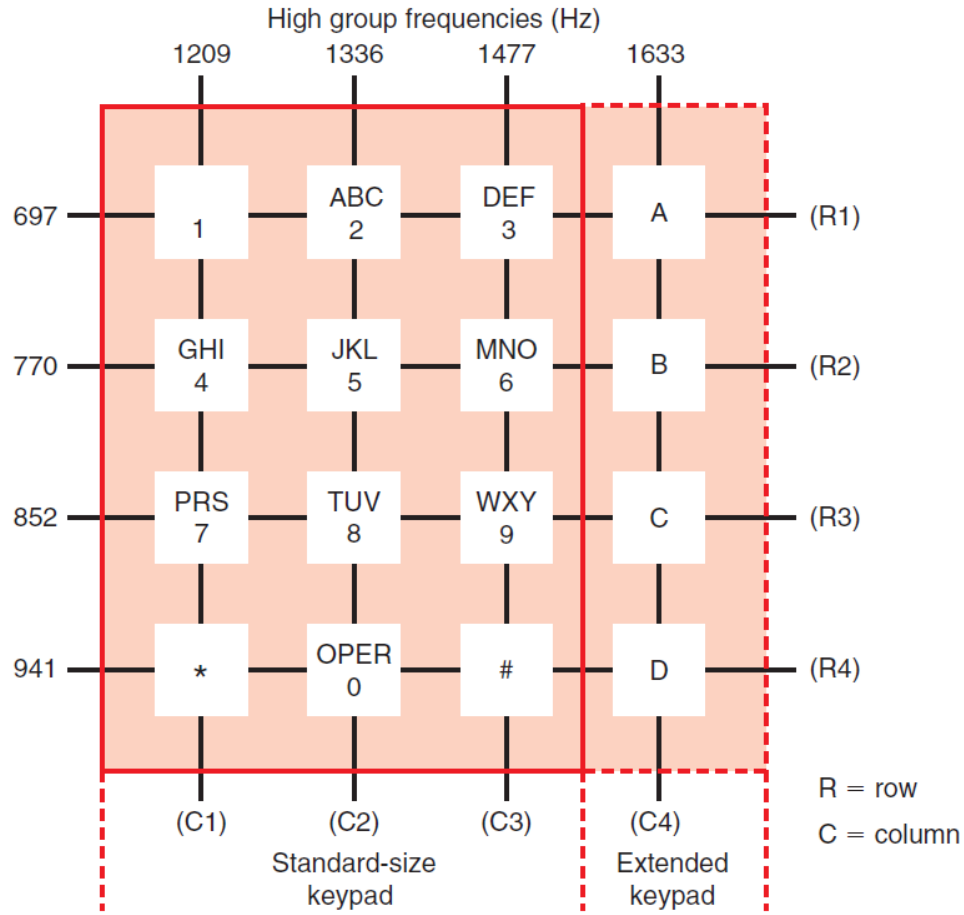
- North American and UK: A continuous mix of 350 Hz and 440 Hz
  - These two frequencies correspond to the standard concert pitch of A440, and approximately an “F”.
  - @ -12dBm
- Most of Europe: constant single tone (425 Hz)





Encoding

- Each number corresponds to a mix of two audio frequencies associated with each row and column of the corresponding pushbutton.

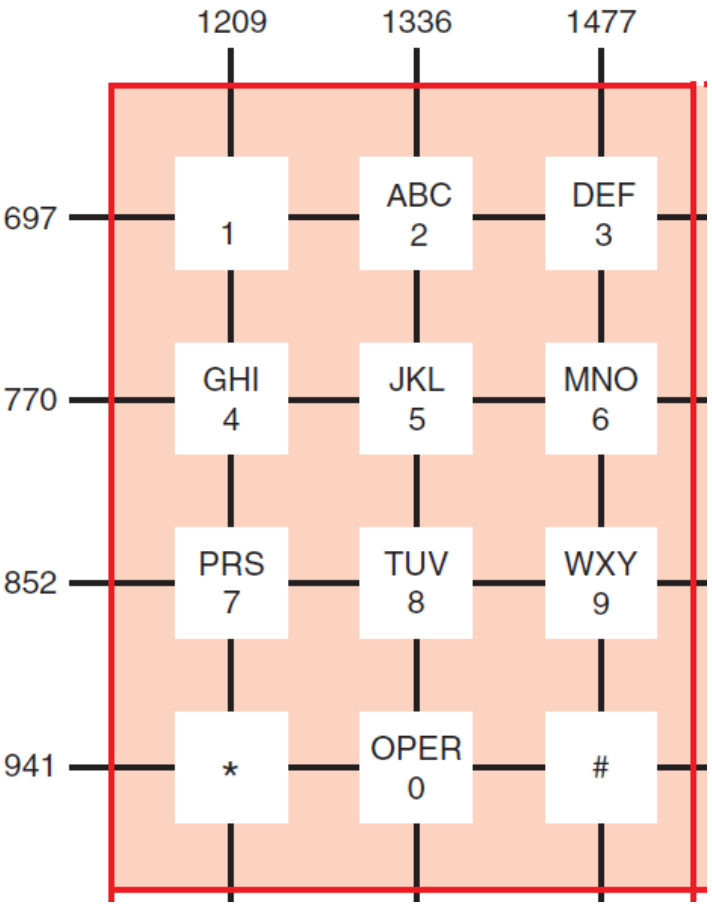


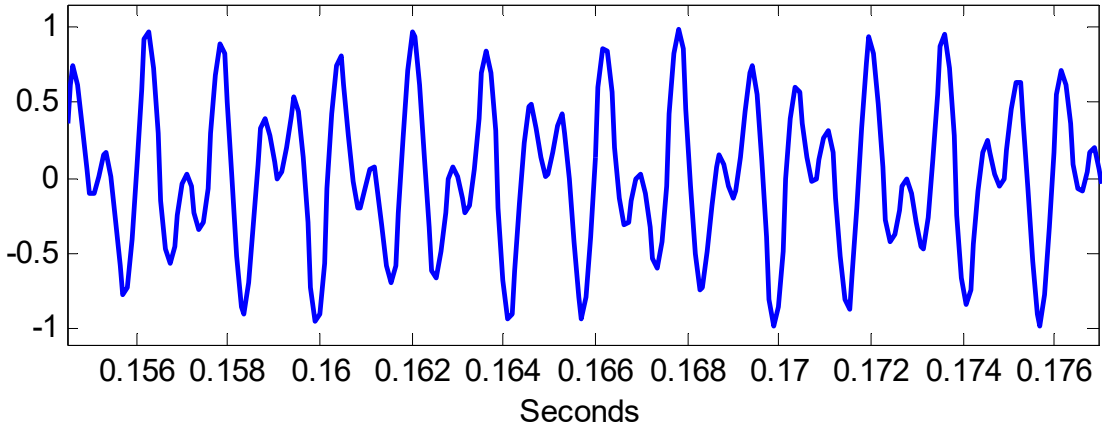
[Frenzel, 2016, Figure 18-5, p. 702]

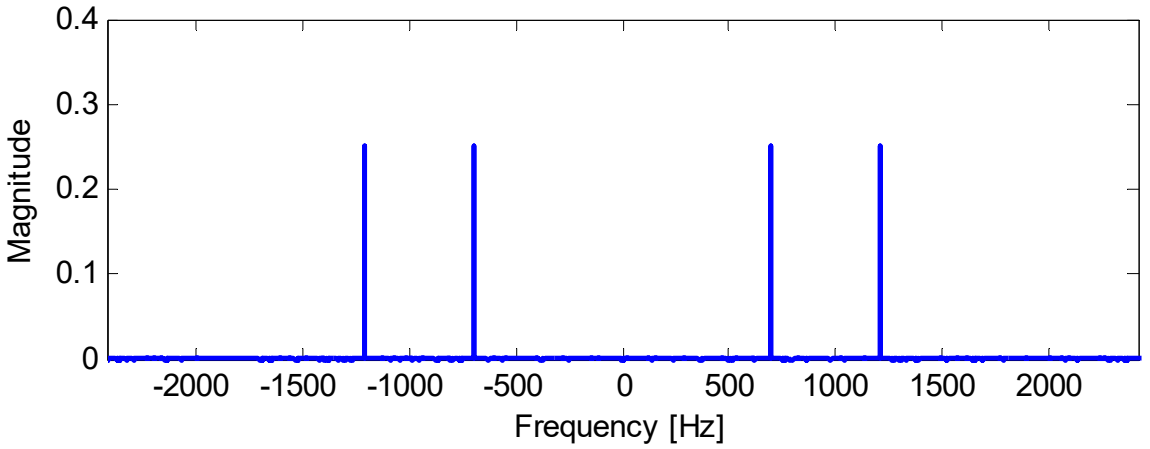
Most telephones use a standard keypad with 12 buttons or switches for the numbers 0 through 9 and the special symbols * and #.

Four additional keys for special applications.

The “1” tone

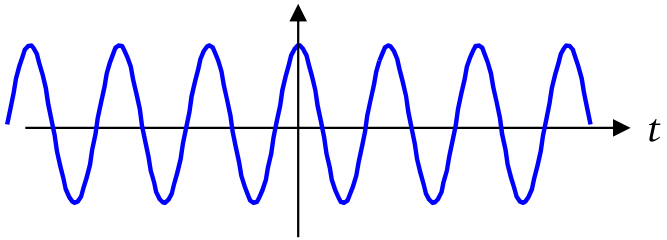

1209
1336
1477
697
770
852
941
1
ABC
2
DEF
3
GHI
4
JKL
5
MNO
6
PRS
7
TUV
8
WXY
9
*
OPER
0
#

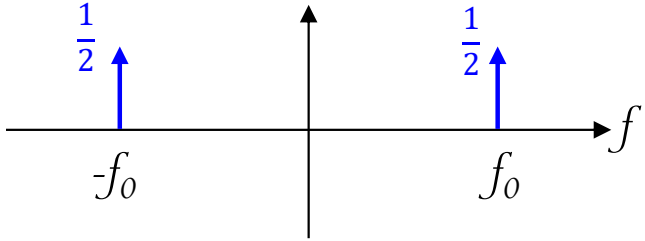

1
0.5
0
-0.5
-1
0.156 0.158 0.16 0.162 0.164 0.166 0.168 0.17 0.172 0.174 0.176
Seconds


0.4
0.3
0.2
0.1
0
Magnitude
-2000 -1500 -1000 -500 0 500 1000 1500 2000
Frequency [Hz]

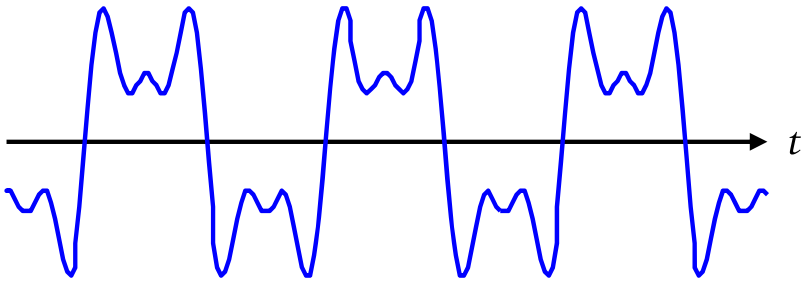
Fourier transform ($\mathcal{F}$)

- The Fourier transform is a **frequency domain representation** of the original signal.
- The term Fourier transform refers to both the frequency domain representation and the corresponding mathematical operation ($\mathcal{F}$).

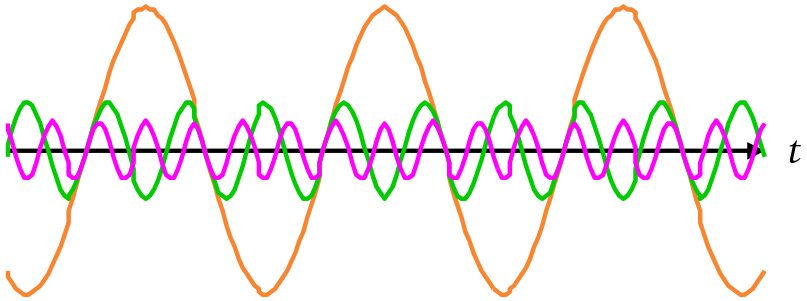




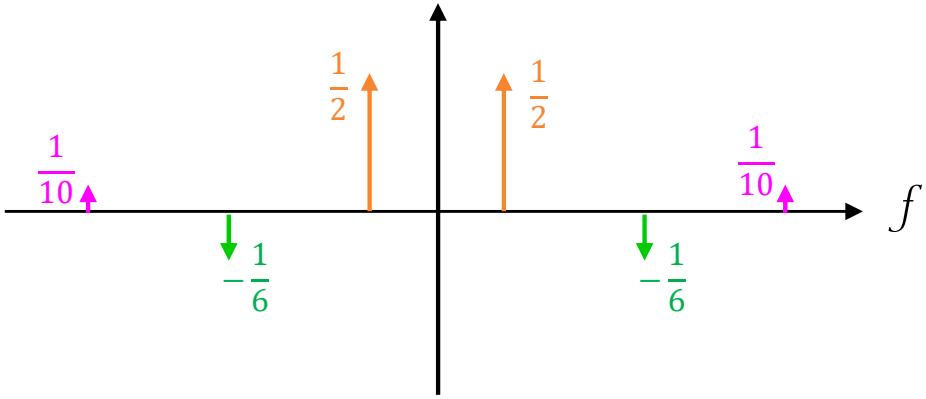
Fourier transform: Example



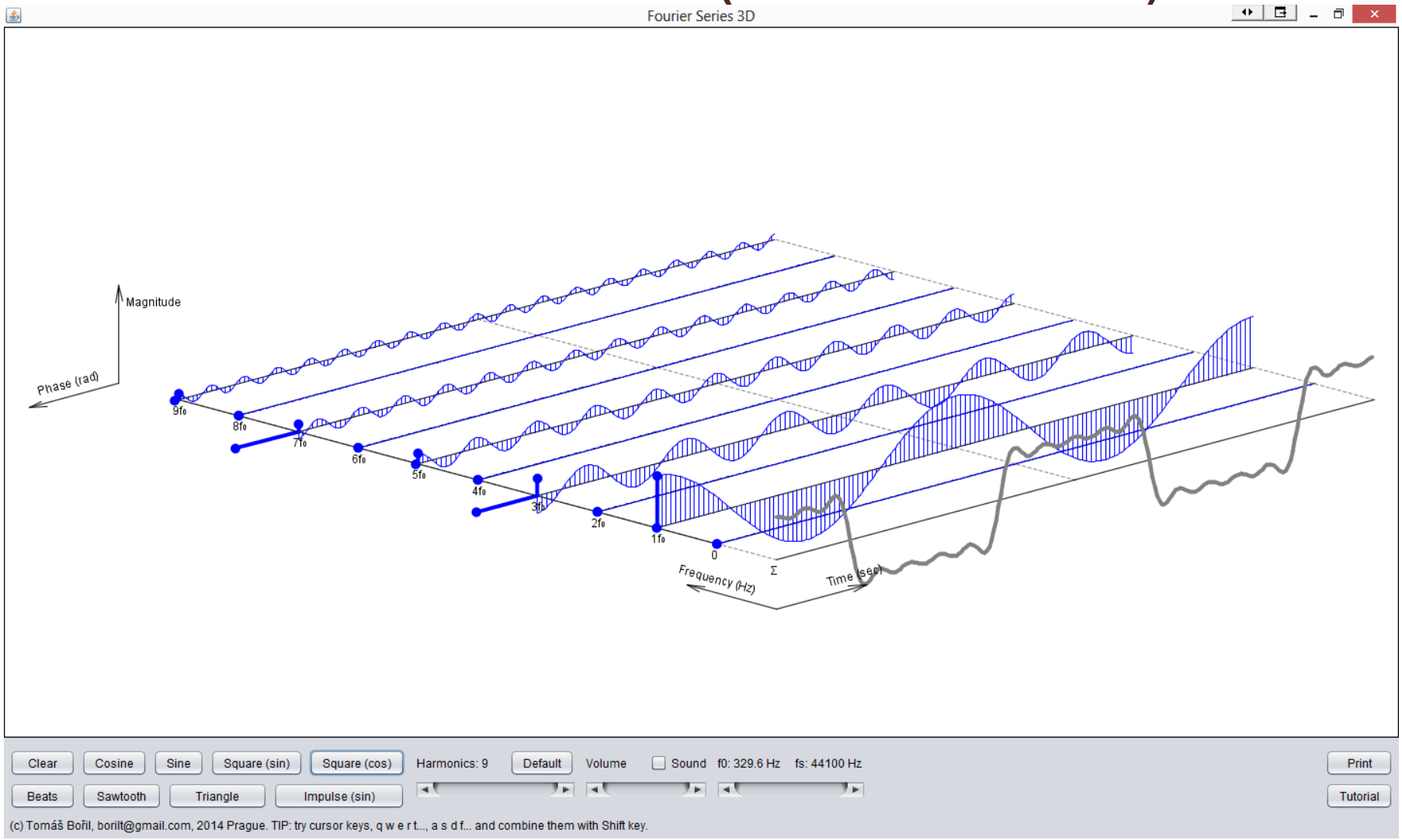
$$g(t) = \cos(t) - \frac{1}{3}\cos(3t) + \frac{1}{5}\cos(5t)$$



$\mathcal{F}$



Fourier Series: Ex (interactive)



ECS332_4_Amplitude_Modulation_Fourier_Ex1.jar

[http://www.tomasboril.cz/hobbies_programs_en.html]

Euler's Formula

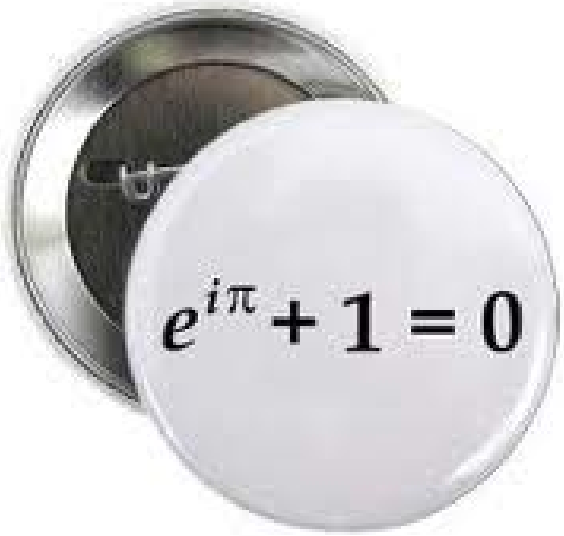
$$e^{j\theta} = \cos\theta + j\sin\theta$$

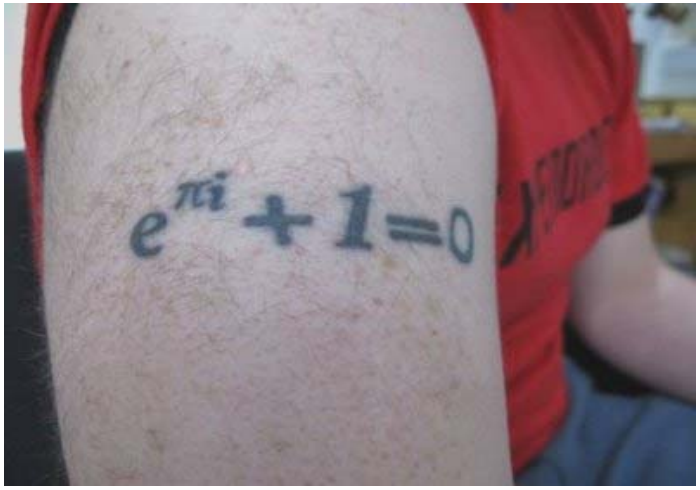
The Most Beautiful Equation

Euler's identity (Euler's equation)

Relate the three fundamental constants e, π and i.

Fact: When mathematicians describe equations as beautiful, they are not lying. Brain scans show that their minds respond to beautiful equations in the same way other people respond to great paintings or masterful music.





[http://www.scientificamerican.com/article/equations-are-art-inside-a-mathematicians-brain/]

Euler's Formula

$$e^{j\theta} = \cos\theta + j\sin\theta$$

Complex exponential

$$\cos(A) = \mathrm{Re}\{e^{jA}\} = \frac{1}{2}\left(e^{jA} + e^{-jA}\right)$$

$$\sin(A) = \mathrm{Im}\{e^{jA}\} = \frac{1}{2j}\left(e^{jA} - e^{-jA}\right)$$

$$\cos(-x) = \cos(x)$$

$$\cos\left(x - \frac{\pi}{2}\right) = \sin(x)$$

$$2\cos^2 x = 1 + \cos(2x)$$

$$2\sin^2 x = 1 - \cos(2x)$$

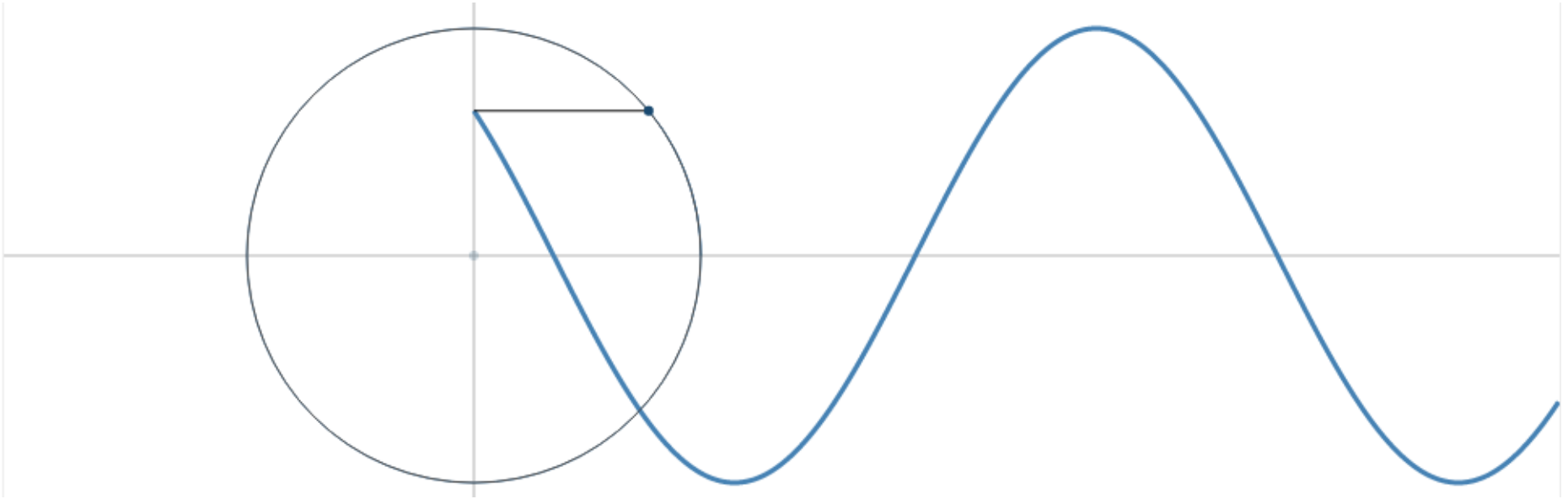
$$2\sin(x)\cos(x) = \sin(2x)$$

$$\frac{d}{dx}\sin x = \cos x$$

$$\cos(x)\cos(y) = \frac{1}{2}\left(\cos(x+y) + \cos(x-y)\right)$$

(product-to-sum formula)

$$\mathrm{Im}\{e^{j\theta}\} = \sin\theta$$



[http://bl.ocks.org/jinroh/7524988]