Iowa State University
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18th Century Work Still Vital in Modern Science

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Introduction

There is a myriad of scientific discoveries that were conceived long before the 21st or even the 20th century with a massive impact on today's society. After looking into three of these discoveries that are vital for Electrical Engineering, it became clear just how fundamental these were to the field as well as fields at first seemingly unrelated. Delving into their important works, and their reasons for researching them can offer insight into how discoveries of this importance are reached.

Laplace(1749-1827)

- The Laplace Transform is heavily in Electrical Engineering
- Vital for system analysis
- Undergraduates first interact with LT when analyzing circuits with capacitors and inductors.

<u>Laplace's Use:</u>

$F(s) = L\{f(x)\} = \int_0^{\infty} e^{-st} f(x)dx = -f(0) + sF(x)$

- Transforms differential equations into to algebraic equations

<u>Derivation of Capacitive Impedance:</u>

Capacitors and Inductors after LT:

Capacitor: $I(t) = C\frac{dv_{cap}(t)}{dt}$

$$I(s) = L\{I(t)\} = L\left\{C\frac{dv_{cap}(t)}{dt}\right\} = C\big(sV(s) - v(0)\big) = sCV(s)$$

$$V(s) = L\{v(t)\}$$

$$Z(s) = \frac{V(s)}{I(s)} = \frac{V(s)}{sCV(s)} = \frac{1}{sC}$$

- In Laplace Domain all circuit analysis laws still apply
- In Laplace Domain inductors and capacitors result in impedance with units of Ohms
- Analog systems can be described from a transfer function, the result of taking output over input which is a ratio of polynomials of s

<u>Poles and Zeros:</u>

Assume we find $\frac{V_{out}}{V_{in}} = \frac{N(s)}{D(s)}$

Zeroes (where $N(s)$=0)

Poles (where $D(s) = 0 \; so \; \frac{V_{out}}{V_{in}} \to \infty$)

- Can choose poles and zeros to control the behavior of a system

Fourier(1768-1830)

- Fourier Series implies all periodic functions can be expressed as an infinite sum of harmonically related sinusoids
- Fourier Transform is a result of FS when the period extends to infinity and results in signals that are aperiodic
- Both are used to obtain the frequency spectrum of signals

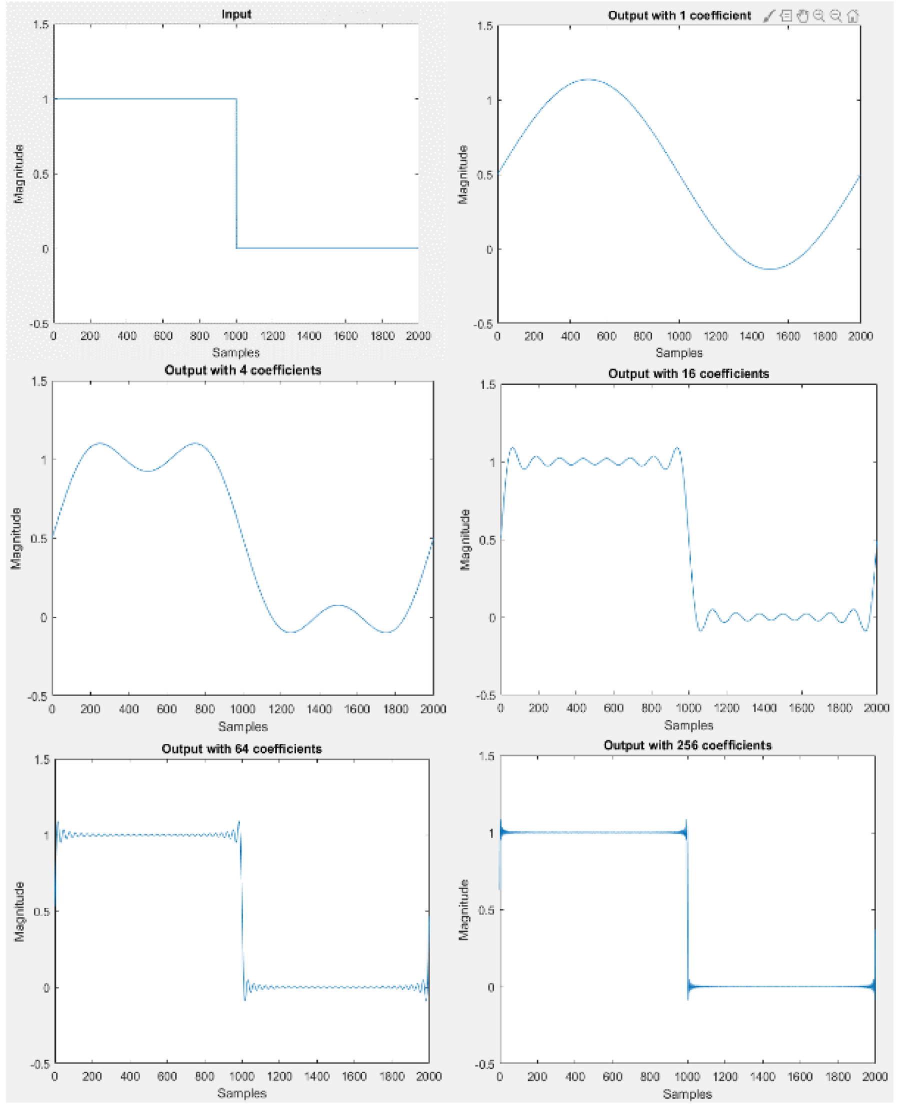
<u>Frequency Analysis:</u>

$f(t) = \sum_{k=1}^{\infty} \mathrm{F}[k]e^{jk\omega t}$; $F[k] = \frac{1}{T}\int_{t_0}^{t_0+T} f(t)e^{-jk\omega t}dt$;

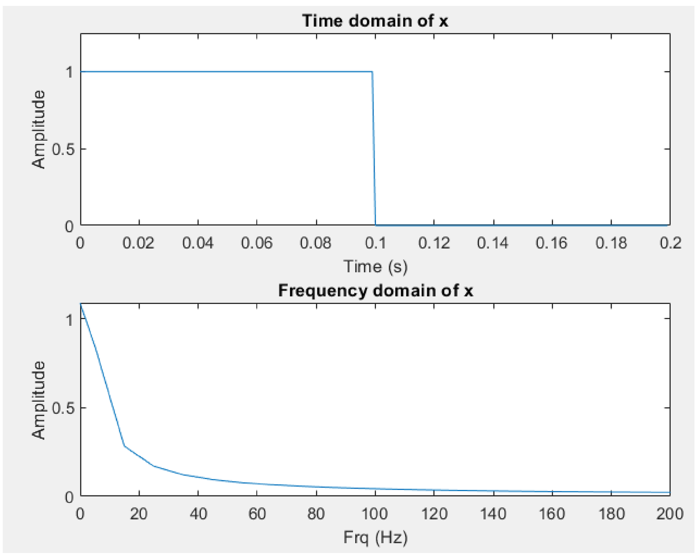
$F(\omega) = \mathcal{F}\{f(t)\} = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$; $f(t) = \int_{-\infty}^{\infty} \mathrm{F}(\omega)e^{j\omega t}d\omega$

Example where f(t) is a step-down signal. Each graph has 4 times more coefficients/frequencies.

Fourier Series:



Fourier Transform:



<u>Fourier Transform vs Laplace Transform:</u>

- Special case of the Laplace Transform ($s = \sigma + \omega j$ and then set $\sigma = 0$), we get:

$$\int e^{-st} f(x)dx = \int e^{-j\omega t} f(x)dx$$

Boole(1815-1864)

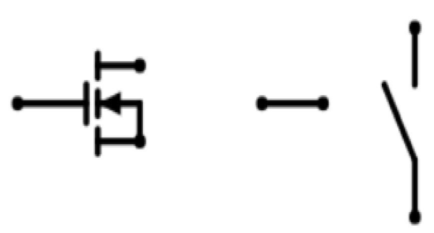
- George Boole published an outline for the algebraic description of processes using logical thought and reasoning: Boolean Algebra
- Defining two states, true or false. These are equivalent to "yes" and "no" or "1" and "0."
- Define different operators. For example "logical and," "logical or," and "not" denoted with the symbols for multiplication " · ", addition "+" and a tilde on the side or a bar on top respectively for each operator.
- Since then, there have been additions to the process, as well as conclusions and simplifications.

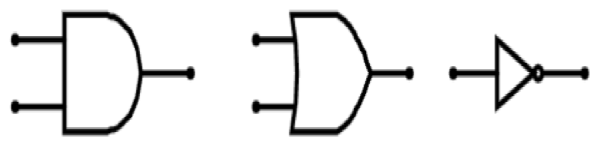
<u>Example</u>

"If it is cloudy and if I am not running late, I will take an umbrella." If we denote **C** as the variable for if there are clouds (1 for true, 0 for false), denote **L** for being late (1 for true and 0 for false) and **U** for whether I will take an umbrella, we can use an equation:

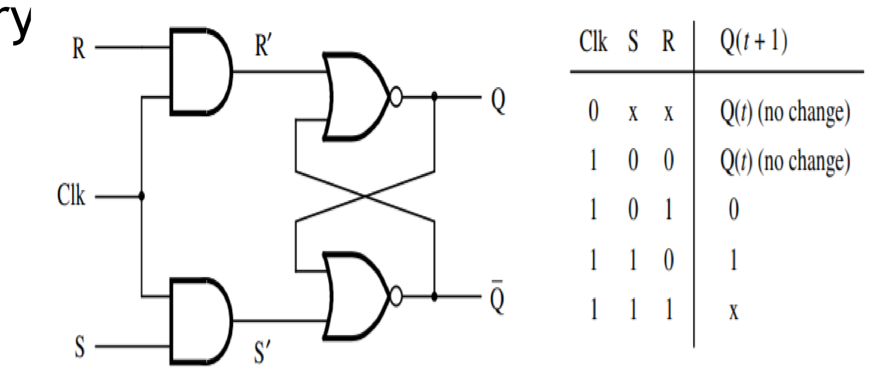
$$C \cdot (\bar{L}) = U$$

C	L	$\bar{L}$	C·$\bar{L}$
0	0	1	0
0	1	0	0
1	0	1	1
1	1	0	0





We have created components that can act as switches and apply Boolean algebra and Logic. We also use this for more complicated things like memory



(a) Circuit (b) Characteristic table

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