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# TRANSFORMING THE CIRCUIT MATH SO THAT TIME DISAPPEARS

# Transforming the Circuit Math So That Time Disappears

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**Abstract** – We know that every function can be written as a series of sine waves of various frequencies and magnitudes added together. The entire world can be constructed from sin waves. Here, one sine wave is looked at, the repeating nature ( $\omega$ ) is stripped away. What's left is a phasor. Since time is made of circles, and if we consider just one of these circles, we can move to a world where time doesn't exist and circles are "things". Instead of the word "world", use the word "domain" or "plane" as in two dimensions. Math in the Phasor domain is almost the same as DC circuit analysis. What is different is that inductors and capacitors have an impact that needs to be accounted for. The transform into the Phasors plane or domain and transforming back into time is based upon Euler's equation. It is the reason we studied imaginary numbers in past math class.

**Key words:** function, stripped away, phasor, domain, imaginary numbers.

## INTRODUCTION

In computer science and machine learning, **cellular neural networks (CNNs)** are a parallel computing paradigm similar to neural networks, with the difference that communication is allowed between neighbouring units only. Typical applications include image processing, analyzing 3D surfaces, solving partial differential equations, reducing non-visual problems to geometric maps, modelling biological vision and other sensory-motor organs. Due to number and variety of architectures, it is difficult to give a precise definition for a CNN processor. From an architecture standpoint, CNN processors are a system of a finite, fixed-number, fixed-location, fixed-topology, locally interconnected, multiple-input, single-output, nonlinear processing units. The nonlinear processing units are often referred to as neurons or cells. Mathematically, each cell can be modeled as a dissipative, nonlinear dynamical system where information is encoded via its initial state, inputs, and variables used to define its behavior. Dynamics are usually continuous, Continuous-Time CNN processors, but can be discrete, Discrete-Time CNN processors. Each cell has one output, by which it communicates its state with both other cells and external devices. Output is typically real-valued, but can be complex or even quaternion, i.e. Multi-Valued CNN. In most CNN processors, processing units are identical, but there are applications that require, Non-Uniform Processor CNN, (NUP-CNN) processor, consisting of different types of cells. In the original Chua-Yang CNN processor, the state of the cell was a weighted sum of the inputs and the output was a piecewise linear function. However, like the original perceptron-based neural networks, the functions it could perform

were limited: specifically, it was incapable of modeling non-linear functions, such as XOR. If this is a problem, more complex functions are achievable via Non-Linear, (NL-CNN) processors.

## REVIEW OF LITERATURE:

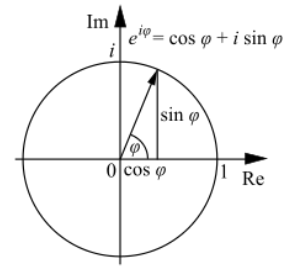
The idea of CNN processors was introduced by Leon Chua and Lin Yang's two-part, 1988 article, "Cellular Neural Networks: Theory" and "Cellular Neural Networks: Applications" in IEEE Transactions on Circuits and Systems. Leon Chua is the same professor who pioneered nonlinear-circuit theory and unified it with linear-circuit theory using Kirchhoff laws and element laws. He was also responsible for introducing nonlinear dynamics and chaos theory to Electrical Engineering in the form of the Chua circuit, a simple, canonical, realizable electrical circuit that exhibits chaotic behavior. In these articles, Leon Chua and Lin Yang outline the underlying mathematics behind CNN processors. They use this mathematical model to demonstrate, for a specific implementation, that if the inputs are static, the processing units will converge, and can be used to perform useful calculations. They then suggest one of the first applications of CNN processors: image processing and pattern recognition, which is still the largest application to this date. Leon Chua is still active in research and publishes many of his articles in the International Journal of Bifurcation and Chaos, of which he is an editor. Both IEEE Transactions on Circuits and Systems and the International Journal of Bifurcation also contain a variety of useful articles on CNN processors authored by other knowledgeable researchers. The former tends to focus on new,

architectures and the latter more on the dynamical aspects of, processors. Another key article is Tamas Roska and Leon Chua's, 1993 article, "The, Universal Machine: An Analogic Array Computer", where the first algorithmically programmable, analog, processor was introduced to the engineering research community. The multi-national effort was funded by the Office of Naval Research, the National Science Foundation, and the Hungarian Academy of Sciences, and researched by the Hungarian Academy of Sciences and the University of California. This article proved that, processors were producible, and provided researchers a physical platform to test their, theories. After this article, companies started to invest into larger, more capable processors, based on the same basic architecture as the, Universal Processor. Tamas Roska is another key contributor to Cellular Neural Networks. His name is often associated with biologically inspired information processing platforms and algorithms, and he has published numerous key articles and has been involved with companies and research institutions developing, technology. There are several overviews of, processors. One of the better references is a paper, "Cellular Neural Networks: A Review" written for the Neural Nets WIRN Vietri 1993, by Valerio Cimagalli and Marco Balsi. This paper is beneficial because it provides definitions, types, dynamics, implementations, and applications in a relatively small, readable document. There is also a book, "Cellular Neural Networks and Visual Computing Foundations and Applications", written by Leon Chua and Tamas Roska. This reference is valuable because it provides examples and exercise to help illustrates points, which is uncommon in papers and journal articles. This book covers many different aspects of, processors and can serve as a textbook for a Masters or PhD course. These two references are invaluable since they manage to organize the vast amount of, literature into a coherent framework.

## MATERIAL AND METHOD

Phasors are a type of "transform." We are transforming the circuit math so that time disappears. Imagine going to a place where time doesn't exist. We know that every function can be written as a series of sine waves of various frequencies and magnitudes added together. (Look up fourier transform animation). The entire world can be constructed from sin waves. Here, one sine wave is looked at, the repeating nature ( $\omega$ ) is stripped away. What's left is a phasor. Since time is made of circles, and if we consider just one of these circles, we can move to a world where time doesn't exist and circles are "things". Instead of the word "world", use the word "domain" or "plane" as in two dimensions. Math in the Phasor domain is almost the same as DC circuit analysis. What is different is that inductors and capacitors have an impact that needs to be accounted for. The transform into the Phasors plane or domain and transforming back into time is based upon Euler's equation. It is the reason we studied imaginary numbers in past math class.

## Euler's Equation



## Euler's Formula

Euler started at these three series. Obviously there is a relationship:

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \dots$$

He did the following:

$$e^{ix} = 1 + ix + \frac{i^2 x^2}{2!} + \frac{i^3 x^3}{3!} + \frac{i^4 x^4}{4!} + \frac{i^5 x^5}{5!} + \dots$$

$$e^{ix} = 1 + ix - \frac{x^2}{2!} - i\frac{x^3}{3!} + \frac{x^4}{4!} + i\frac{x^5}{5!} - \frac{x^6}{6!} - i\frac{x^7}{7!} \dots$$

$$e^{ix} = (1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots) + i(x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots)$$

$$e^{ix} = \cos(x) + i \sin(x)$$

Set  $x = \pi$  and:

$$e^{i\pi} = -1$$

Euler's formula is ubiquitous in mathematics, physics, and engineering. The physicist Richard Feynman called the equation "our jewel" and "one of the most remarkable, almost astounding, formulas in all of mathematics."

A more general version of Euler's equation is:

$$Me^{j(\omega t + \phi)} = M \cos(\omega t + \phi) + jM \sin(\omega t + \phi)$$

This equation allows us to view sinusoids as complex exponential functions. A cyclic function represented as a voltage, current or power given in terms of radial frequency and phase angle turns into an arrow having length  $\mathbb{C}$ (magnitude) and angle  $\phi$ (phase) in the phasor domain/plane or a point having both a real ( $X$ ) and imaginary ( $Y$ ) coordinate in the complex domain/plane.

Generically, the phasor  $\mathbb{C}$ , (which could be voltage, current or power) can be written:

$$\mathbb{C} = X + jY \text{ (Rectangular coordinates)}$$

$$\mathbb{C} = M_v \angle \phi \text{ (Polar coordinates)}$$

We can graph the point (X, Y) on the complex plane and draw an arrow to it showing the relationship between X, Y,  $\mathbb{C}$  and  $\phi$ .

Using this fact, we can get the angle from the origin of the complex plane to out point (X, Y) with the function:

### Angle equation

$$\theta_C = \arctan\left(\frac{Y}{X}\right)$$

And using the Pythagorean Theorem, we can find the magnitude of C -- the distance from the origin to the point (X, Y) -- as:

### Pythagorean Theorem

$$M_C = |\mathbb{C}| = \sqrt{X^2 + Y^2}.$$

### Phasor Symbols

Phasors don't account for the frequency information, so make sure you write down the frequency some place safe.

Suppose in the time domain:

$$v(t) = M_v e^{j(\omega t + \phi)}$$

In the phasor domain, this voltage is expressed like this:

$$\mathbb{V} = M_v \angle \phi$$

The radial velocity  $\omega$  disappears from known functions (not the derivate and integral operations) and reappears in the time expression for the unknowns.

### CONCLUSION

Contrary to the statement made in this heading, phasors (phase vectors), are vectors. Phasors form a vector space with additional structure, hence they have some properties that are not common to all vector spaces; these additional properties exist because phasors form a field - thus you also get division.

For more details see [http://en.wikipedia.org/wiki/Phasor\\_\(electronics\)](http://en.wikipedia.org/wiki/Phasor_(electronics))

Like many kinds of vectors they have additional structure. Phasors will always be written out either with a large bold letter (as above). They are not a vector. Vectors have two or more real axes that are not related by Euler, but are independent. They share some math in two dimensions, but this math diverges.

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