

LAPLACE TRANSFORMS AND ITS APPLICATIONS

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Abstract Laplace transform is a very powerful mathematical tool applied in various areas of engineering and science. With the increasing complexity of engineering problems, Laplace transforms help in solving complex problems with a very simple approach just like the applications of transfer functions to solve ordinary differential equations. This paper will discuss the applications of Laplace transforms in the area of physics followed by the application to electric circuit analysis. A more complex application on Load frequency control in the area of power systems engineering is also discussed.

I. INTRODUCTION

Laplace transform is an integral transform method which is particularly useful in solving linear ordinary differential equations. It finds very wide applications in various areas of physics, electrical engineering, control engineering, optics, mathematics and signal processing. The Laplace transform can be interpreted as a transformation from the time domain where inputs and outputs are functions of time to the frequency domain where inputs and outputs are functions of complex angular frequency.

In order for any function of time $f(t)$ to be Laplace transformable, it must satisfy the following Dirichlet conditions [1]:

- $f(t)$ must be piecewise continuous which means that it must be single valued but can have a finite number of finite isolated discontinuities for $t > 0$.
- $f(t)$ must be exponential order which means that $f(t)$ must remain less than $Se^{-\alpha_0 t}$ as t approaches ∞ where S is a positive constant and α_0 is a real positive number.

If there is any function $f(t)$ that satisfies the Dirichlet conditions, then,

$F(s) = \int_0^{\infty} f(t)e^{-st} dt$ written as $L\{f(t)\}$ is called the Laplace transformation of $f(t)$. Here, s can be either a real variable or a complex quantity.

The integral $\int_0^{\infty} f(t)e^{-st} dt$ converges if $\int_0^{\infty} |f(t)e^{-st}| dt < \infty, s = \sigma + j\omega$

A. Some Important Properties of Laplace Transforms

The Laplace transforms of different functions can be found in most of the mathematics and engineering books and hence, is not included in this paper. Some of the very important properties of Laplace transforms which will be used in its applications to be discussed later on are described as follows:[1][2]

• Linearity

The Laplace transform of the linear sum of two Laplace transformable functions $f(t) + g(t)$ is given by

$$L\{f(t) + g(t)\} = F(s) + G(s)$$

• Differentiation

If the function $f(t)$ is piecewise continuous so that it has a continuous derivative $f'(t)$ of order $n-1$ and a sectionally continuous derivative $f''(t)$ in every finite interval $0 \leq t \leq T$, then let, $f(t)$ and all its derivatives through $f^{(n-1)}(t)$ be of exponential order e^{at} as $t \rightarrow \infty$.

Then, the transform of $f''(t)$ exists when $Re(s) > c$ and has the following form:

$$L\{f''(t)\} = s^2 F(s) - s f'(0+) - f(0+) - \dots - s^{n-1} f^{(n-1)}(0+)$$

• Time delay

The substitution of $t - \lambda$ for the variable t in the transform $L\{f(t)\}$ corresponds to the multiplication of the function $F(s)$ by $e^{-s\lambda}$, that is

$$L\{f(t - \lambda)\} = e^{-s\lambda} F(s)$$

II. APPLICATIONS OF LAPLACE TRANSFORMS

This section describes the applications of Laplace transforms in the areas of science and engineering. At first, simple application in the area of Physics and Electric Circuit theory is presented which will be followed by a more complex application to power system which includes the description of Load Frequency Control (LFC) for transient stability studies.

A. Application in Physics

A very simple application of Laplace transform in the area of physics could be to find out the harmonic vibration of a beam which is supported at its two ends [3].

Let us consider a beam of length l and uniform cross section parallel to the yz plane so that the normal deflection $w(x,t)$ is measured downward if the axis of the beam is towards x axis. The basic equation defining this phenomenon is as given below:

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Fractional Calculus - From Theory to Applications Christos Volos, Jesus Manuel Munoz-Pacheco, 2025-05-28 Over the last decade research activity in the field of fractional calculus has surged resulting in applications across a wide range of scientific disciplines From the physics of diffusion and transport phenomena to control theory and financial systems fractional calculus has proven valuable in numerous domains capturing the interest of the scientific community Therefore this book comprises six chapters each with the purpose of providing a brief overview of the subject of fractional calculus and its recent developments in theory and applications This book aims to serve as an updated and handy reference for university professors graduate students laboratory researchers as well as physicists and applied mathematicians who are interested in studying fractional calculus and its applications

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The Laplace Transform Joel L. Schiff,2013-06-05 The Laplace transform is a wonderful tool for solving ordinary and partial differential equations and has enjoyed much success in this realm With its success however a certain casualness has been bred concerning its application without much regard for hypotheses and when they are valid Even proofs of theorems often lack rigor and dubious mathematical practices are not uncommon in the literature for students In the present text I have tried to bring to the subject a certain amount of mathematical correctness and make it accessible to undergraduate students To this end this text addresses a number of issues that are rarely considered For instance when we apply the Laplace transform method to a linear ordinary differential equation with constant coefficients any n an l why is it justified to take the Laplace transform of both sides of the equation Theorem A 6 Or in many proofs it is required to take the limit inside an integral This is always fraught with danger especially with an improper integral and not always justified I have given

complete details sometimes in the Appendix whenever this procedure is required IX X Preface Furthermore it is sometimes desirable to take the Laplace trans form of an infinite series term by term Again it is shown that this cannot always be done and specific sufficient conditions are established to justify this operation

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