

STUDENT FEEDBACK FORM-LLOYD DAVIES

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills		
Your work has shown that you researched adequately into the topic and you demonstrated a good understanding of the subject. If you had used other sources such as books, papers, magazines etc, rather than simply relying on the internet would have gained the highest score. The student has clearly shown that he has all-important skills needed to define the essential ideas from sufficient information. The quality of the references needs to be improved.	15	10
2. Knowledge and Understanding Skills		
The report shows good effort and good understanding of the topics covered. Good structure, detail and data presented in clear and appropriate format throughout.	20	18
3. Cognitive and Intellectual Skills		
Your work showed that you can summarise scientific facts into your own words without compromising academic style. There is a coherent flow in the writing and the reader can easily follow the simulations process and the analysis of the results. You have made it interesting to read and have also made attempts at drawing conclusions for the area you studied.	20	16
4. Practical Application Skills		
A good and appropriate application of established methods and techniques. The report clearly demonstrates the student has a clear understanding of studies to date and also shows the student's ability to work as an individual. Good detail provided throughout the report with all aspects being suitably and sufficiently carried out. All tables and figures presented are thoroughly discussed in the assignment. All aspects have been covered in excellent detail.	20	15
5. Transferable Skills for Life and Professional Practice		
Very weak use of language when analysing and discussing results. Little evidence of the skills for employment requiring the exercise of personal responsibility and decision-making.	25	5

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

64%

Lloyd Davies HND electrical and electronic engineering level 5

Course: HND in Electrical & Electronic Engineering

Course Code: BL1132FT1

Module: Electrical principles

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Assignment:

Name of Lecture: Dr Rabya Kadhim

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Introduction

In this report I will be investigating complex waveforms, to understand their harmonic content. Complex waveforms are common place in modern electrical engineering systems. I have been tasked with research in to Fourier's series and Fourier transform, in order to demonstrate my understanding. I am going to calculate the amplitude of the first 7 harmonics of a Fourier trigonometric series provided in the task. This will be achieved using spectral analysis, I will attempt to recreate my results by designing a circuit in daisy lab, a simulation software. I will then compare the amplitudes of the harmonics with the previously calculated values. My investigation will be analysed too see what variables had affected the accuracy of my findings.

Fourier series and transforms

Fourier series

Joseph Fourier (1768-1830) was a French mathematician most famous for his research of Fourier series and the applications. Fourier series is a method of representing the sum of infinite sine and cosine waves. It is an expansion of the periodic function;

$$f(x)$$

I will be carrying out what is known as harmonic analysis, the calculation and study of Fourier series, later on in this report. This is extremely useful to break down a periodic function into basic terms that can simply be plugged in, then solved individually. They are then recombined to calculate the original question, to the degree of accuracy you desire. The general equation for Fourier series is found by taking $f_1(x) \cos x$ and $f_2(x) \sin x$.

General Fourier series equation:

$$f(x) = a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$$

The main application of Fourier series is signal processing and analysis. Approximation theory uses Fourier's series to write functions in the form of a trigonometric polynomial. Fourier series can be used in control theory to predict some of the possible behaviour of the solution of differential equation. Dynamics of the solution can also be found.

(Kumar, 2016)

Fourier transforms

Fourier's transform is a linear transform which may be reversed. It has several important properties. Fourier transform is also usually denoted as

$f(x)$ and $f(a)$

Where the product of x and a is dimensionless. In most cases x is the time domain signal, used as a measure of time. S represents the time domain frequency, also known as the inverse time.

Fourier transforms are a large part of modern-day mathematics. It has several applications in engineering and physics. The counter part to Fourier transforms is the discrete Fourier transform (DFT). DFT is calculated using fast Fourier transform (FFT). These transforms have played a massive part in technological advancements over the years due to its applications in data processing, digital electronics and in many instruments (receivers spectrometers etc.).

definition of a Fourier transform

$$F(s) \equiv \int_{-\infty}^{\infty} f(x) e^{-2\pi i s x} dx ,$$

(forward transform)

And

$$f(x) \equiv \int_{-\infty}^{\infty} F(s) e^{2\pi i s x} ds ,$$

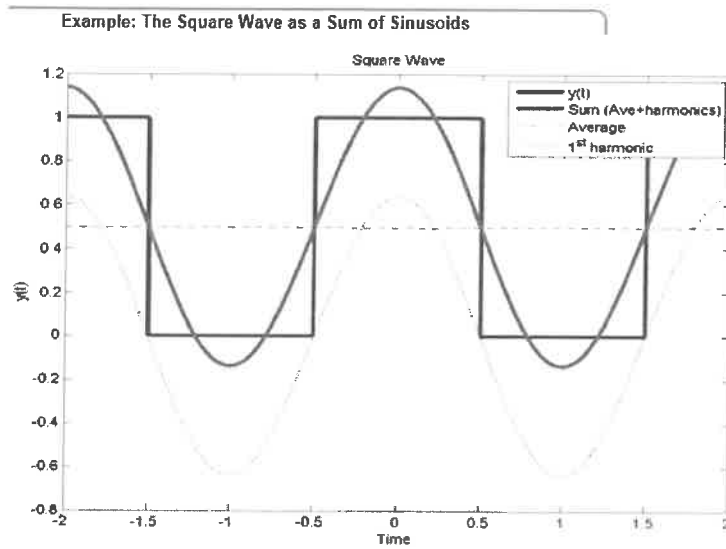
which is the *inverse transform*.

(cv.naro.edu, n.d.)

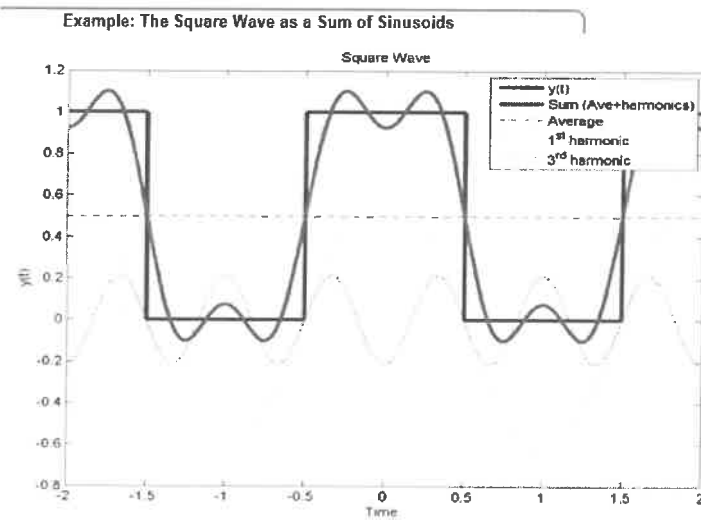
Fourier series square wave

Fourier expansion can be used to represent an ideal square wave as an infinite sum of sine functions. A square wave with only odd components is an ideal square wave. Square waves can be made of a sum of sinusoidal functions. Each sin wave is a harmonic, as more harmonics are added of higher frequency the closer to a perfect square wave it will get.

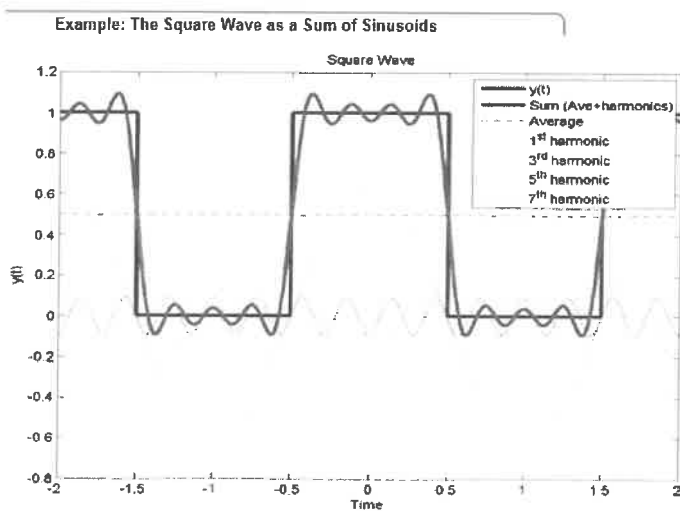
Average and first harmonic:



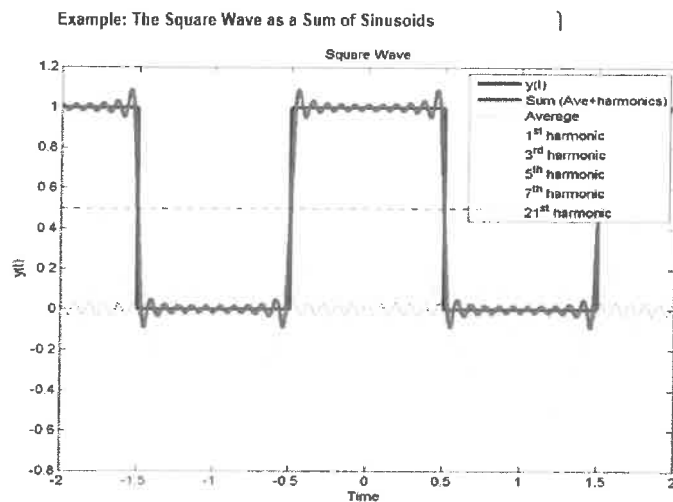
0-3rd harmonics:



0-7th harmonics:



0-21st harmonics:



Because of the shape of a sinusoidal wave a symmetry is created meaning only the odd harmonics are required to calculate the equation approximately. As you can see the more harmonics the closer to a square wave form that is created.

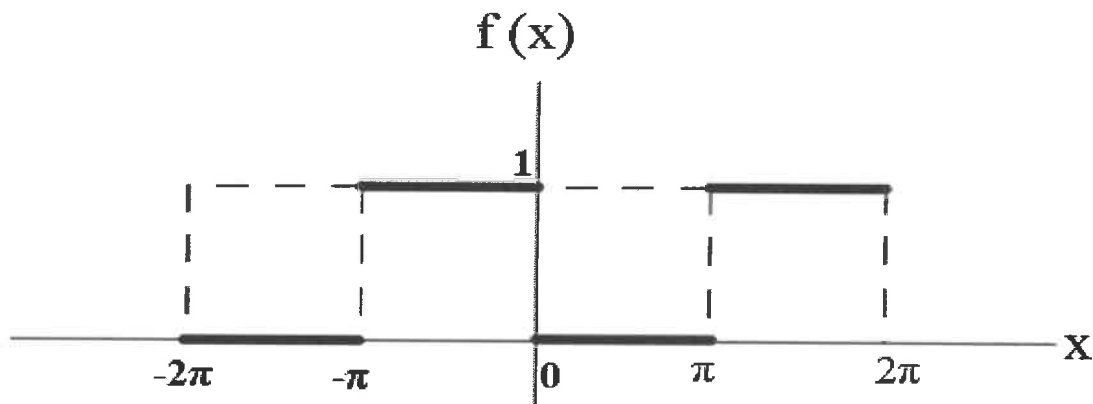
(Cheever, 2014)

Calculation of Fourier trigonometrical series

I have been tasked with producing a Fourier trigonometric series representation of a complex wave. The wave has a period of 2π .

$$f(x) = \begin{cases} 1, & -\pi < x < 0 \\ 0, & 0 < x < \pi \end{cases}$$

Here is the graph of $f(x)$ in the interval -2π to $+2\pi$:



Calculation of a_0

$$f(x) = a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$$

$$a_0 = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) dx$$

$$a_0 = \frac{1}{2\pi} \int_{-\pi}^0 f(x) dx + \frac{1}{\pi} \int_0^{\pi} f(x) dx$$

$$= \frac{1}{\pi} \int_{-\pi}^0 1 dx + \frac{1}{\pi} \int_0^{\pi} 0 dx$$

$$= \frac{1}{\pi} [x]_{-\pi}^0$$

$$= \frac{1}{\pi} (\pi)$$

$$a_0 = 1$$

$$a_0 = \frac{1}{2}$$

Calculation of a_n

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \cos nx dx$$

$$a_n = \frac{1}{\pi} \int_{-\pi}^0 f(x) \cos nx dx + \frac{1}{\pi} \int_0^{\pi} f(x) \cos nx dx$$

$$a_n = \frac{1}{\pi} \int_{-\pi}^0 1 \cos nx dx + \frac{1}{\pi} \int_0^{\pi} 0 \cos nx dx$$

$$= \frac{1}{\pi} \left(\left[\frac{\sin nx}{n} \right]_{-\pi}^0 \right)$$

$$= \frac{1}{nm} ([\sin nx]_{-\pi}^0)$$

$$= \frac{1}{nm} [\sin 0 - \sin(-n\pi)]$$

$$= \frac{1}{nm} [0 + \sin(n\pi)]$$

$$= \frac{1}{nm} [0 + 0]$$

$$a_n = 0$$

Calculation of b_n

$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin nx dx$$

$$\begin{aligned}
 b_n &= \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin nx \, dx + \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin nx \, dx \\
 &= \frac{1}{\pi} \int_{-\pi}^{\pi} 1 \sin nx \, dx + \frac{1}{\pi} \int_{-\pi}^{\pi} 0 \sin nx \, dx \\
 &= \frac{1}{\pi} \left[-\frac{\cos nx}{n} \right]_{-\pi}^{\pi} \\
 &= \frac{-1}{n\pi} [(\cos nx)]_{-\pi}^{\pi} \\
 &= -\frac{1}{n\pi} (1 - \cos(-n\pi)) \\
 b_n &= \frac{1}{n\pi} (1 - (-1)^n)
 \end{aligned}$$

$$f(x) = a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$$

$$a_0 = 1$$

$$a_n = 0$$

$$b_n = \frac{1}{n\pi} (1 - (-1)^n)$$

The correct representation for this is:

$$f(x) = \left(\frac{1}{2}\right) - \frac{2}{\pi} \left(\sin x + \frac{1}{3} \sin 3x + \frac{1}{5} \sin 5x \right)$$

Verification of spectral analysis

First I will need to calculate the first seven harmonics using fast Fourier transform.

When calculating the amplitude for the first harmonic I used the equation

$$\frac{2}{\pi}$$

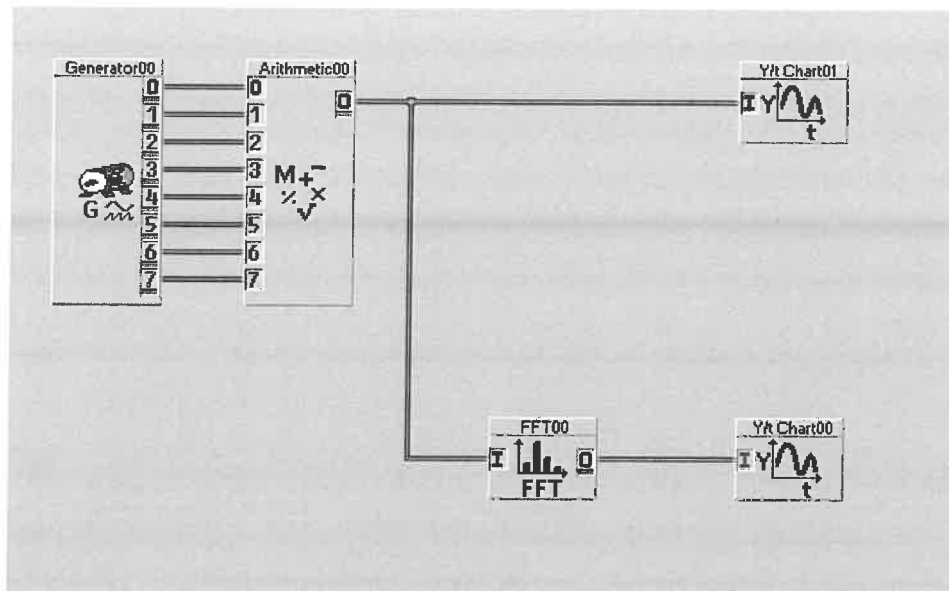
When calculating the second harmonic I used the equation

$$\frac{2}{2\pi}$$

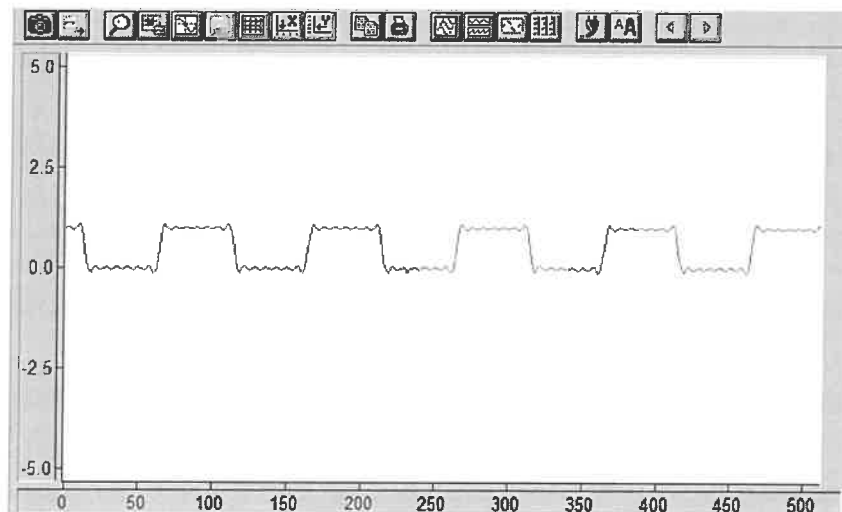
I continued to increase the value of x by two every harmonic $\frac{2}{x\pi}$

<u>Wave</u>	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
<u>Offset</u>	0.5	0	0	0	0	0	0	0
<u>Frequency</u>	/	10	30	50	70	90	110	130
<u>Amplitude</u>	/	0.636	0.212	0.127	0.091	0.071	0.057	0.049

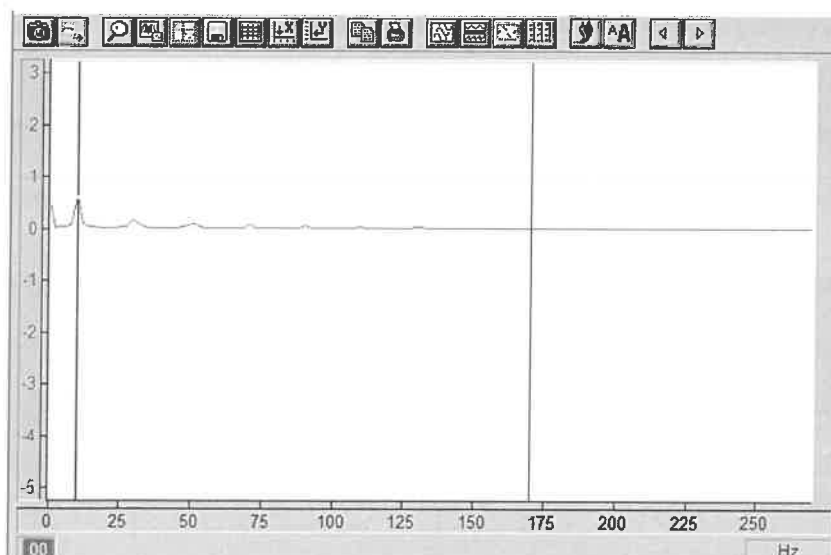
I will now attempt to recreate my results by designing a circuit in daisy lab, a simulation software. I will then compare the amplitudes of the harmonics with the previously calculated values. I used five components in order to do this. A signal generator, the arithmetic module, the FFT module and two charts. I connected my components up and added 0-7 harmonics using my calculated values for amplitude. The frequency was increased by 20 using only odd vales on every harmonic starting on 10. Below is the configuration I used.



Here is the square wave produced.



I used the cursor tool to measure out the amplitudes recorded on my chart, after passing through the FFT module.



I recorded each value in the same table as previously used. The values produced via daisy lab are very close to my calculated values. In most cases my values are almost identical. There are measures that I could have taken to make my results more accurate. I will discuss this in my analysis.

<u>Wave</u>	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
<u>Offset</u>	0.5	0	0	0	0	0	0	0
<u>Frequency</u>	/	10	30	50	70	90	110	130
<u>Amplitude</u>	/	0.62	0.17	0.09	0.07	0.07	0.05	0.03

Analysis

I believe my results were accurate enough to be reliable however a higher standard could be achieved if I was going to do a second test. To make my results more accurate no values should be simplified. I would use as many decimal places as possible.

References

- Cheever, E. (2014). *The Fourier series*. Retrieved from <http://lpsa.swarthmore.edu/Fourier/Series/ExFS.html#Symmetries>
- cv.nrao.edu. (n.d.). *The Fourier series*. Retrieved from <https://www.cv.nrao.edu/course/ast534/FourierTransforms.html>
- Kumar, A. (2016). *What are the engineering applications of Fourier series?* Retrieved from https://www.researchgate.net/post/What_are_the_engineering_applications_of_Fourier_series

