SMALL SIGNAL MODEL OF THE COCKCROFT-WALTON VOLTAGE MULTIPLIER

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This report is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electronic Engineering (Industrial Electronics) With Honours

Faculty of Electronic Engineering and Computer Engineering
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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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Especially dedicate to my lovely father, mother, my whole family members, my friends and my supervisor

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ABSTRACT

In this Cockcroft-Walton project, the theory of this method is to build power supply that can generate voltage with low current. Designing the circuit based on the basic of Cockcroft-Walton circuit that consist of capacitors and diodes. Both components with their characteristics will act to produce the desired output voltage. This method also has its disadvantage as stated in chapter before. The problem statement is hard to maintain or reduce ripples, and the voltage drop under load, which accounts for the popularity of driving a multiplier stack with a switching power supply. Some objectives are to learn in designing power supply, to understand the theory of Cockcroft-Walton and to comprehend well about software will be used. The methodology for this project is firstly preparing Gantt chart, doing literature review and software simulation and demonstration of the completed project. The result hopefully can fulfill the theory of the Cockcroft-Walton which main point is to generate voltages from AC to DC voltage.

ABSTRAK

Dalam projek Cockcroft-Walton, teori untuk kaedah ini adalah untuk membina bekalan kuasa yang boleh menghasilkan voltan dengan arus yang kecil. Litar direka berdasarkan litar asas Cockcroft-Walton yang terdiri daripada beberapa biji kapasitor dan diod. Kedua-dua komponen mempunyai ciri-ciri yang akan bertindak untuk manghasilkan keluaran voltan yang dikehendaki. Kaedah ini juga mempunyai kekurangan seperti yang dinyatakan dalam bab sebelum ini. Masalah dinyatakan adalah sukar untuk menetap atau mengurangkan riak, dan muatan bawah susutan voltan, yang merupakan popularitи ke arah satu susunan pengganda dengan satu pertukaran bekalan kuasa. Beberapa objektif adalah untuk belajar dalam mereka bekalan kuasa, untuk memahami teori Cockcroft-Walton dan memahami mengenai perisian akan digunakan. Metodologi untuk untuk projek ini pertama adalah menyediakan carta Gantt, melakukan ulasan karya dan perisian simulasi serta demonstrasi untuk projek yang disiapkan. Semoga hasil yang diperoleh diharap boleh memenuhi teori Cockcroft-Walton dimana tujuan utama adalah untuk menghasilkan voltan daripada AC kepada voltan DC.

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CW	-	Cockcroft-Walton
AC	-	Alternating Current
DC	-	Direct Current
HV	-	High Voltage

BAB I

INTRODUCTION

1.1 Introduction to Project

The description of the small-signal dynamics of the Cockcroft-Walton (CW) voltage multiplier is obtained through state-space modeling in the discrete time. Its small-signal equivalent circuit is a two-port linear network whose four transfer functions are given in the Z-transform.

Main characteristics and general formulae of the multiplier with an arbitrary number of cells are derived. The expressions of cut-off frequency, gain and output impedance are given, and module and phase frequency responses are plotted.

The CW is basically a voltage multiplier that converts Alternating Current (AC) or pulsing Direct Current (DC) electrical power from a low voltage level to a higher DC voltage level. It is made up of a voltage multiplier ladder network of capacitors and diodes to generate high voltages. The Cockcroft-Walton or Greinacher design is based on the Half-Wave Series Multiplier, or voltage doubler. Unlike transformers, this

method eliminates the requirement for the heavy core and the bulk of insulation/potting required.

Using only capacitors and diodes, these voltage multipliers can step up relatively low voltages to extremely high values, while at the same time being far lighter and cheaper than transformers. The biggest advantage of such circuits is that the voltage across each stage of the cascade is equal to only twice the peak input voltage, so it has the advantage of requiring relatively low cost components and being easy to insulate. One can also tap the output from any stage, like a multitapped transformer.

1.2 Project Objectives

For the first objective, at the end of the project I can learn how to designing power supply. This mean that the project use the Cockcroft-Walton instead of using transformer; learn from the start process by understanding its theory, how to choose suitable components, to using software programming and for the hardware analysis to the last step to design the power supply casing.

Second is to understand about the heat dissipation may become a problem with small diodes. This is important to know how this problem can be some of point or reason which can affect the process of gain output voltage.

Next is to understand the theory of Cockcroft-Walton. Usually, this method is compared to the using of transformer which has their differences in advantages and disadvantages. This include the components involves to design the circuit as we know

that from the basic circuit, we can design a new circuit depends on the stages of the circuit which means the modification of additional capacitors and diodes as long as its depends on the theory.

Fourth is to know how to calculate the output using different formula. As we know, to calculate or find the values such as Eripple, Eout, and more are depends on the values of inputs. This inputs are include the values of capacitor and diodes, how many stages are involves, the input voltage (AC) and more.

Lastly is to learn well about software that will be used. In this project, I will use either PSPICE or MULTISIM. This last objective means hopefully I can learn on how to designing circuit, the advantage and disadvantage or limited of the software that related to the project, to know how to check the result and learn to read the result based on the input/output (I/O) graph.

1.3 Problem Statement

For the already situation, some issues are still be discussed as it has some problem that are in researching. The problems are like to design of High Voltage (HV) regulators, in many cases as increasing number of applications require extended bandwidth performances and imply the designer to know the multiplier dynamics and to own the skill for optimizing the feedback. Then, it is hard to maintain or reduce ripples, and the voltage drop under load, which accounts for the popularity of driving a multiplier stack with a switching power supply. Capacitors tend to be more efficient, and

their only concern is their voltage rating. The value of the output voltage will decreases, although the measured output voltage of a voltage multiplier may be several times greater than the input voltage once a load is connected.

1.4 Scope of Work

The Small-Signal Model of the Cockcroft-Walton Voltage Multiplier project scopes are to study about the project that consist of about the Cockcroft-Walton voltage multiplier project works includes the calculation consist to make sure to get the exact output values and achieved the objectives, learn each components usage or characteristic and its benefits, and lastly understand and compare the result or output. Then, the second is to design the circuit which has to identifying and choose suitable components first, and simulate the circuit either using MULTISIM, MATLAB, PSPICE, or other programming software. About the hardware analysis, the circuit must be must constructed to configure better and complex circuit design on the breadboard before test whether the circuit works properly or not. Lastly is to build models and prototype of product including solder and desolder process, check the circuit's continuity using multimeter and study the suitable apparatus for its casing and safety before can be fully used.

1.5 Methodology

Firstly, to show the progress of project a Gantt chart for guidelines and work planning are prepared and also Log book for guidelines for PSM II.

Next, for literature review, study and understand about the theory, components characteristic will be used in the circuit and the output result. After that, doing researching for the information by referring through journal, references book and also from the supervisor's point of view.

Thirdly is about software simulation, a complete circuit in software programming will be design and run the simulation to check the continuity and result. Lastly is making a demonstration to the supervisor and panels.

BAB II

BACKGROUND STUDIES

There are many kind of modification to the basic Cockcroft-Walton multiplier created by Cockcroft and Walton in the 1950's which it is one of the easiest and most inexpensive means for creating very high voltages at low currents. In some applications, an additional capacitor stack is connected to the output capacitor stack in the basic design. This is particularly popular in electrostatic accelerator applications and high voltage x-ray systems, where low ripple desired.

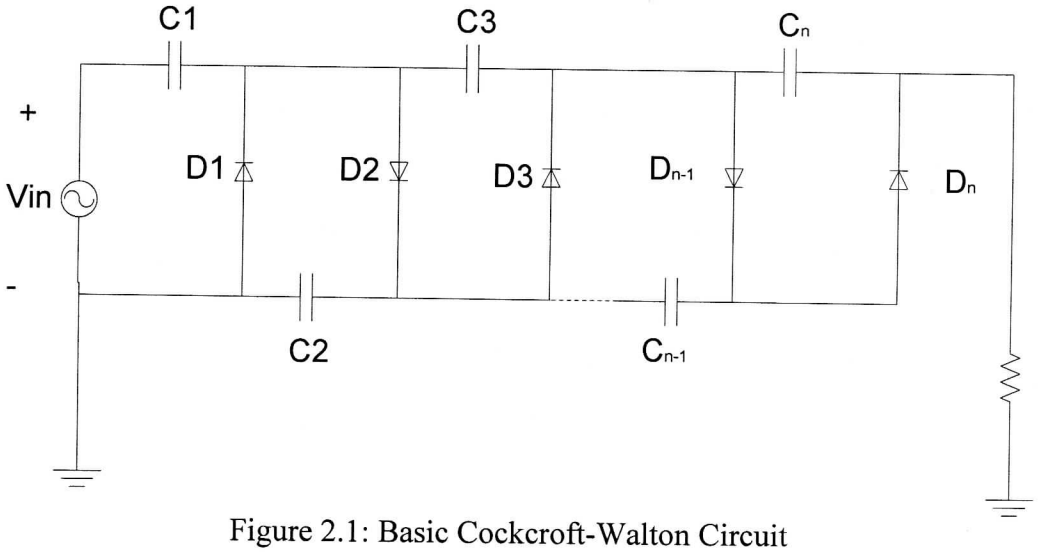

Figure 2.1: Basic Cockcroft-Walton Circuit

2.1. Components Involve

2.1.1 Capacitor

The capacitor's capacitance (C) is a measure of the amount of charge (Q) stored on each plate for a given potential difference or voltage (V) which appears between the plates:

$$C = \frac{Q}{V} \qquad (2.1)$$

In Standard International (SI) units, a capacitor has a capacitance of one farad when one coulomb of charge is stored due to one volt applied potential difference across the plates. Since the farad is a very large unit, values of capacitors are usually expressed in microfarads (μF), nanofarads (nF), or picofarads (pF).

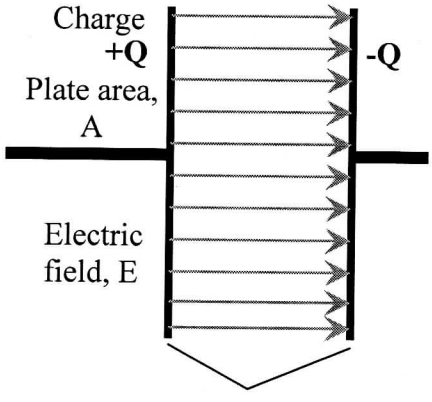

Figure 2.2: Capacitor

When there is a difference in electric charge between the plates, an electric field is created in the region between the plates that is proportional to the amount of charge that has been moved from one plate to the other. This electric field creates a potential difference $V = E \cdot d$ between the plates of this simple parallel-plate capacitor.

The capacitance is proportional to the surface area of the conducting plate and inversely proportional to the distance between the plates. It is also proportional to the permittivity of the dielectric (that is, non-conducting) substance that separates the plates.

The capacitance of a parallel-plate capacitor is given by:

$$C = \frac{\varepsilon A}{d}; A >> d^2 \tag{2.2}$$

Where;

ε = permittivity of the dielectric,

A = area of the plates,

d = spacing between them.

In the diagram, the rotated molecules create an opposing electric field that partially cancels the field created by the plates, a process called dielectric polarization.

2.1.1.1 Stored energy

As opposite charges accumulate on the plates of a capacitor due to the separation of charge, a voltage develops across the capacitor due to the electric field of these