

**ALAT PENENTU KEMATANGAN BUAH
BERDASARKAN PANTULAN GELOMBANG MIKRO**

Oleh

Fiona Yeoh Li Hsia

**Disertasi ini dikemukakan kepada
UNIVERSITI SAINS MALAYSIA**

**Sebagai memenuhi sebahagian daripada syarat keperluan
untuk ijazah dengan kepujian**

SARJANA MUDA KEJURUTERAAN (KEJURUTERAAN ELEKTRONIK)

**Pusat Pengajian Kejuruteraan
Elektrik dan Elektronik
Universiti Sains Malaysia**

Mei 2006

**FRUIT RIPENESS TESTING DEVICE
BASED ON MICROWAVE SIGNAL REFLECTION**

By

Fiona Yeoh Li Hsia

**Dissertation submitted to
UNIVERSITY SCIENCE MALAYSIA**

**As fulfilling part of the requirement
to obtain the degree with honours**

BACHELOR OF ENGINEERING (ELECTRONIC ENGINEERING)

**School of Electrical and
Electronic Engineering
University Science Malaysia**

May 2006

ABSTRAK

Terdapat pelbagai cara untuk menentukan tahap kematangan sesuatu buah, tetapi kebanyakan cara ini akan merosakkan buah tersebut, misalnya seperti memicit buah itu atau mengambil jus buah untuk membuat ujian kimia. Tujuan projek ini ialah untuk merekabentuk satu alat yang dapat menentukan tahap kematangan buah tanpa merosakkan buah itu. Projek ini adalah sebahagian daripada kajian yang berterusan di USM. Dalam projek tahun ini, gelombang mikro akan digunakan untuk menentukan tahap kematangan buah. Dua antena heliks ragam paksi akan digunakan, satu sebagai pemancar, dan yang satu lagi sebagai penerima. Antena pemancar akan memancarkan gelombang mikro ke arah buah yang diuji, dan antena penerima akan menerima gelombang mikro yang dipantul oleh buah tersebut. Kekuatan gelombang mikro yang terpantul akan memberi gambaran tentang tahap kematangan buah itu. Ini adalah kerana buah dengan tahap kematangan yang berbeza mempunyai komposisi kimia (komposisi dalaman) yang berbeza, dan pantulan gelombang mikro akan bergantung kepada komposisi kimia buah. Oleh itu, adalah dijangka bahawa buah dengan tahap kematangan yang berbeza akan memantulkan gelombang mikro dengan kekuatan yang berbeza. Kekuatan gelombang mikro terpantul itu turut disampel pada ketika-ketika yang berbeza dengan menggunakan penukar analog-ke-digital (ADC). Penyampelan perlu dilakukan untuk memperolehi sambutan transien gelombang mikro yang terpantul. Corak sambutan transien gelombang mikro yang terpantul juga dapat memberi maklumat tentang tahap kematangan buah kerana, buah dengan tahap kematangan yang berbeza akan memantulkan gelombang mikro dengan corak sambutan transien yang berbeza. Buah pisang digunakan dalam projek ini. Dua tahap kematangan buah pisang akan diuji, iaitu tahap masak dan belum masak. Keputusan yang diperolehi daripada kajian dianalisis untuk menentukan tahap kematangan buah pisang. Terdapat perbezaan diantara keputusan yang diperolehi daripada pisang masak dan belum masak, oleh itu, konsep menentukan tahap kematangan buah dengan menggunakan pantulan gelombang mikro adalah munasabah.

ABSTRACT

There exists many ways to detect the ripeness of a fruit, but most of the time these methods are destructive, like for example, pressing the fruit or extracting the juice for chemical tests. The aim of this project is to develop a method to detect the degree of ripeness of a fruit without destroying it. This project is part of an ongoing effort carried out in USM. In this year's project, microwave signal will be used to detect the degree of ripeness of the fruit. Two axial mode helical antennas are used, one as the transmitter, and the other as the receiver. The transmitter will radiate the microwave signal towards the fruit, and the receiver will pick up the microwave signal that is reflected from the fruit. The strength of the reflected microwave signal will show how ripe the fruit is. This is because fruits with different degree of ripeness have different chemical (internal) composition and the reflection of microwave signal will depend on the chemical composition. So, it is expected that fruits with different degree of ripeness will reflect microwaves with different strength. The strength of the reflected microwave signal is also sampled at different instances using analogue-to-digital converters. Sampling is needed to obtain the transient response of the reflected microwave signal. The transient response pattern could also give information about the degree of fruit ripeness because, fruits with different degree of ripeness will reflect microwave signal with different transient response pattern. Bananas are used in this project. Two levels of banana ripeness is tested, ripe and unripe. The results obtained are analysed to determine the degree of ripeness of the bananas. The results do show some difference between ripe and unripe bananas, therefore the concept of using microwave reflection to detect the degree of fruit ripeness is feasible.

ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisor Professor Syed Idris Syed Hassan, for his help and guidance in doing my final year project.

I am also very grateful to the staff of the School of Electrical and Electronics Engineering for all their technical assistance.

I would also like to thank my parents for all their support towards me during my course of study.

Finally, to my coursemates who has been helpful to me in sharing their knowledge, thank you.

TABLE OF CONTENTS

Abstrak	ii
Abstract	iii
Acknowledgement	iv
Table of Contents	v

CHAPTER	PAGE
1.0 Introduction	1
1.1 Project Objective	2
1.2 Project Scope	2
1.3 Report Guide	3
2.0 Literature Review	5
2.1 The Axial Mode Helical Antenna	5
2.2 Silicon PIN Diode	8
2.3 Schottky Diode	8
2.4 555 Integrated Circuit Timer	10
2.4.1 555 Timer in the Monostable Mode	12
2.4.2 555 Timer in the Astable Mode	13
2.5 Analogue-to-Digital Converter	14
2.6 Demultiplexer	17
2.7 J-K Flip-flop	19
3.0 Project Hardware and Procedure	20
3.1 Project Overview	20
3.2 Microwave Switching Circuit	21
3.3 Microwave Detector Circuit	25
3.4 Sampling Circuit	26
3.5 The Axial Mode Helical Antenna Design	34
3.6 Procedure For Testing The Fruit Ripeness	38
3.6.1 Lab Equipments That Are Used	38

4.0	Results and Discussion	40
4.1	Hardware Test Results	40
4.1.1	Accuracy of Analogue-To-Digital Converters	40
4.1.2	Performance of Helical Antennas	42
4.1.3	Performance of Microwave Switching Circuit	45
4.2	Data Collection of the Degree of Fruit Ripeness	45
5.0	Conclusion	51
5.1	Problems and Setbacks Encountered	52
5.2	Considerations for Future Improvement	53
5.2.1	Using Mathematical Analysis, Computer and Software To Analyse The Collected Data	55

REFERENCES

APPENDIX A : Schematic and Layout of Sampling Circuit

APPENDIX B : Circuit and Hardware Photographs

APPENDIX C : Data Sheet of BA885 Silicon PIN Diode

APPENDIX D : Data Sheet of AD7822 Analogue-To-Digital Converters

APPENDIX E : Data Sheet of MC14051B Analogue Multiplexers/Demultiplexers

APPENDIX F : Data Sheet of MC14027B Dual J-K Flip-Flop

APPENDIX G : Data Sheet of NE555 Precision Timers

APPENDIX H : Data Sheet of HSMS-2850 Schottky Detector Diodes

APPENDIX I : Designing Detectors for RF/ID Tags, Application Notes 1089 by
Agilent Technologies

APPENDIX J : Data Sheet of MJF32C Power Transistor

APPENDIX K : Data Sheet of LM 258 Low Power Dual Operational Amplifiers

LIST OF FIGURES

	PAGE
Figure 2.1 : The normal mode helical antenna	5
Figure 2.2 : The axial mode helical antenna	6
Figure 2.3 : The design parameters of the axial mode helical antenna	7
Figure 2.4 : Silicon PIN diode structure and symbol	8
Figure 2.5 : Symbol and structure of a Schottky diode	9
Figure 2.6 : +25°C Output Voltage vs. Input Power, HSMS-2850 at Zero Bias	10
Figure 2.7 : The internal diagram of the 555 timer intergrated circuit	11
Figure 2.8 : 555 timer configured to operate in the monostable mode	12
Figure 2.9 : 555 timer configured to operate in the astable mode	13
Figure 2.10 : The block diagram of an ADC	14
Figure 2.11 : Internal diagram of a flash ADC	16
Figure 2.12 : AD7822 chip and the pins	17
Figure 2.13 : The functional block diagram for a digital demultiplexer	17
Figure 2.14 : The pins of the MC14051B	18
Figure 2.15 : Clocked J-K flip-flop	19
Figure 3.1 : System to detect the degree of ripeness of fruit	20
Figure 3.2 : Schematic diagram of the microwave switching circuit	24
Figure 3.3 : Schematic of the microwave detector circuit	25
Figure 3.4 : Simplified block diagram of the sampling circuit	27
Figure 3.5 : Output waveforms of the monostable and astable 555 timers	28
Figure 3.6 : Arrangements of the J-K flip-flops as a three-bit binary down counter	30
Figure 3.7 : Input and output signals of the J-K flip-flops and demultiplexer U10	31
Figure 3.8 : Simulation schematic of the matching microstrip	36
Figure 3.9 : Simulation result of the matching microstrip	37
Figure 3.10 : Setup of hardware and lab equipments to test the fruit	39

Figure 4.1 : Setup to test transmission and reception of helical antennas (reflection)	43
Figure 4.2 : Setup to test transmission and reception of helical antennas	44
Figure 4.3 : Setup to test performance of microwave switching circuit	45
Figure 4.4 : Graph of sampled output voltage versus time	47
Figure 4.5 : Graph of the output voltage versus transmitted signal level	49
Figure 5.1 : Setup to test ripeness of fruit	55

LIST OF TABLES

	PAGE
Table 2.1 : Truth table for J-K flip-flop	19
Table 3.1 : Summary of sampling operation	32
Table 3.2 : Summary of reading operation	33
Table 4.1 : Output of ADCs when analogue input voltage is 2.5 V	41
Table 4.2 : Output of ADCs when analogue input voltage is 1.03 V	41
Table 4.3 : Output of ADCs when analogue input voltage is 0.3 V	42
Table 4.4 : Transmitted signal level, received signal level, received signal DC voltage	43
Table 4.5 : Output of ADCs for all four bananas (transient)	46
Table 4.6 : Output voltage for the ripe and unripe bananas in different orientations and tested at different transmitted signal levels	48

CHAPTER 1 : INTRODUCTION

Generally, the ripeness of a fruit is determined by looking at its colour or by pressing it with our fingers. The colour and the softness or hardness of the fruit will tell the user whether the fruit is ripe or not, and the degree of the ripeness – how ripe or unripe it is. However, sometimes the method mentioned above will not give an accurate answer of the degree of the ripeness of the fruit. Moreover, by pressing the fruit, the user might damage it. Also, for fruits that have a hard covering, for example durians, the user has got to pry open the fruit to find out whether it is ripe. If it is not ripe enough, then the fruit is spoiled because it is opened before it is ripe enough to be eaten.

There are also scientific methods to determine the degree of ripeness of a fruit. Many of these methods use chemical tests, compression tests and hardness tests. These methods provide an accurate answer of the degree of ripeness of the fruit but the fruit will be spoiled because its juice needs to be extracted, the fruit needs to be compressed or hit at when conducting the tests.

Therefore, due to the destructive nature of these tests, the need arose for a non-destructive yet accurate scientific method to determine the degree of ripeness of a fruit.

The purpose of this project is to create a system which will be able to detect whether the fruit under test is ripe or not, and also the degree of the ripeness, without destroying the fruit. Projects with this same purpose had already been done during previous years by USM students using horn antenna, normal mode helical antenna, and capacitance together with neural networks. However, my project this year is different because it will utilize the axial mode helical antenna together with a circuit comprising of eight ADCs (analog to digital converter). One axial mode helical antenna will be the transmitting antenna, while the second one will be the receiving antenna. Therefore, this project will make use of the microwave signal that is reflected from the fruit, unlike the projects of previous years that utilize microwave signal that penetrates through the fruit, to find out about the fruit ripeness. The strength of the received microwave signal that is received by the receiving antenna will be sampled by the ADCs at eight different instances. The sampled data will provide the information about the degree of ripeness of

the tested fruit. Fruits with different degree of ripeness have different chemical (internal) composition, so it is expected that fruits with different degree of ripeness will reflect microwave signal with different intensity and strength, and also produce different transient response patterns.

Therefore, this project will provide users with a way to determine the degree of ripeness of a fruit without destroying the fruit. This undestructive method of testing would be useful to the farmers to help them determine the degree of ripeness of the fruit so that they will know when to pluck and sell the fruits.

1.1 PROJECT OBJECTIVE

The objective of this project is to:

- 1) Create a system which will be able to detect whether the fruit under test is ripe or not, and also the degree of the ripeness, without destroying the fruit.
- 2) Apply microwave propagation concept in detecting the degree of ripeness of a fruit.
- 3) Obtain the transient response of the microwave signal received by the receiving antenna by sampling. ADCs are used to do the sampling.

1.2 PROJECT SCOPE

This project involves the use of two axial mode helical antennas. The first antenna functions as the transmitting antenna to radiate the microwave signal towards the fruit. The second antenna functions as the receiving antenna which will pick up the microwave signal that is reflected back from the fruit. The receiving antenna is the data collecting device. A circuit consisting of eight ADCs is designed and implemented to sample the amplitude of the microwave signal that is reflected back from the fruit at eight different instances. The reason for sampling at eight different instances is to obtain the transient response of the strength of the reflected microwave received by the receiving antenna. This is based on the concept that fruits with different degree of ripeness would reflect microwave signal with different transient responses as well as

strength. The sampled data is obtained from the output of the ADCs. The output is eight bits and displayed by eight LEDs (light emitting diodes). The transient response pattern as well as strength of the microwave signal received by the receiving antenna will give a picture of how ripe or unripe the fruit is.

1.3 REPORT GUIDE

This project began by collecting all the related information to design and implement the hardware system that is needed to test the fruit to determine the degree of its ripeness. After obtaining the relevant information, the design of the hardware is begun.

Firstly, a circuit which could act as a microwave switch is designed. This circuit will be referred to in this text as the microwave switching circuit. This microwave switch is needed because the ADCs must start sampling at the same instance when the transmitting antenna starts to radiate the microwave signal towards the fruit. So, this microwave switch will cause the microwave signal to start radiating towards the fruit and at the same time trigger the ADCs to do sampling.

Next, a microwave detector circuit is designed. This circuit is needed to convert the received microwave signal power that is reflected back from the fruit into a DC (direct current) voltage. The received microwave signal power needs to be converted into a DC voltage so that it could be input to the ADCs to be sampled.

Then, a circuit comprising of eight ADCs is designed. This circuit will be referred to in this text as the sampling circuit. The ADCs will each sample the amplitude of the received microwave signal at eight different instances to get the transient response. The sampled data will give the result of the degree of ripeness of the fruit under test.

The schematics and layouts of all the circuits are created using the OrCad software.

Two axial mode helical antennas are also designed. One antenna will be the transmitting antenna to transmit the microwave signal towards the fruit, while the other antenna will be the receiving antenna to receive the microwave signal that is reflected from the fruit. The antennas are designed to operate at 1 GHz. 1 GHz is chosen to be the frequency to test the fruit.

After all the necessary hardware is designed, build and able to work properly, the fruit is tested. Bananas are chosen as the test subject. The data that are collected in this project are :

- 1) The strength of the microwave signal that is reflected from the banana and received by the receiving antenna
- 2) The transient response of the reflected microwave signal.

Two groups of bananas are tested, that is ripe (yellow) and unripe (green). After gathering the data from the ripe and unripe bananas, the data are analysed to see whether there is a difference between the data obtained from the ripe bananas and the unripe bananas.

CHAPTER 2 : LITERATURE REVIEW

This chapter contains the theory behind all the hardware design in this project. It contains the specification of the axial mode helical antenna design, the function and operation of the components used, as well as the circuitry that is needed to make the entire fruit testing system function.

2.1 THE AXIAL MODE HELICAL ANTENNA

There are two modes of operation for the helical antenna, that is, normal mode and axial mode.

In the normal mode of operation, the maximum field radiated by the antenna is in the plane that is normal to the helix axis, as shown in Figure 2.1.

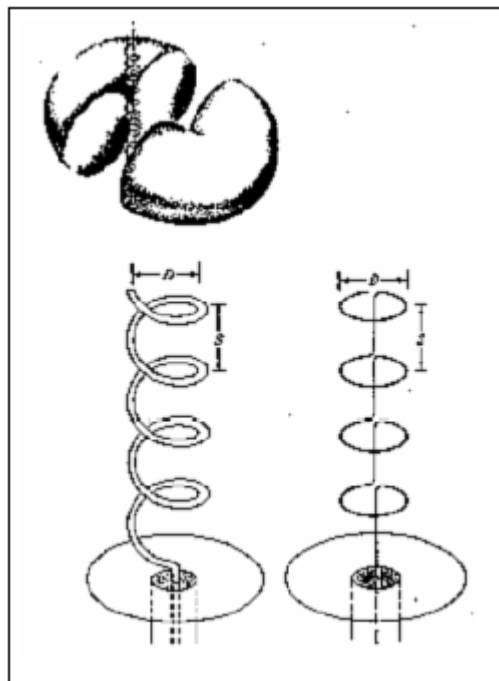


Figure2.1 : The normal mode helical antenna
(www.ece.tufts.edu/en/61/Lab1_antenna.pdf)

In the axial mode of operation, there is only one major lobe and the maximum radiation intensity is along the axis of the helix, as shown in Figure 2.2. The minor lobes are at oblique angles to the axis.

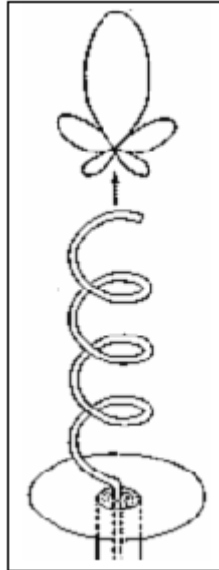


Figure2.2 : The axial mode helical antenna
(www.ece.tufts.edu/en/61/Lab1_antenna.pdf)

The design specification for the axial mode helical antenna is as follows:

$$0.75\lambda < C < 1.3333\lambda \quad (2.1)$$

$$S = \lambda / 4 \quad (2.2)$$

$$N \geq 3 \quad (2.3)$$

$$\alpha = \tan^{-1} (S/C) \quad (2.4)$$

where C : circumference of the helix

λ : operating wavelength of the helical antenna

S : spacing between the turns of the helix

N : number of turns

α : pitch angle

$$\text{Total length of wire for the entire helix} = N \times L_0 \quad (2.5)$$

$$\text{where } L_0 = \sqrt{(S^2 + C^2)} \quad (2.6)$$

= length of wire between each turn

The impedance at the terminal of the axial mode helical antenna is :

$$Z = 140 (C / \lambda) \quad (2.7)$$

(www.ece.tufts.edu/en/61/Lab1_antenna.pdf)

Figure 2.3 shows the design parameters of the axial mode helical antenna.

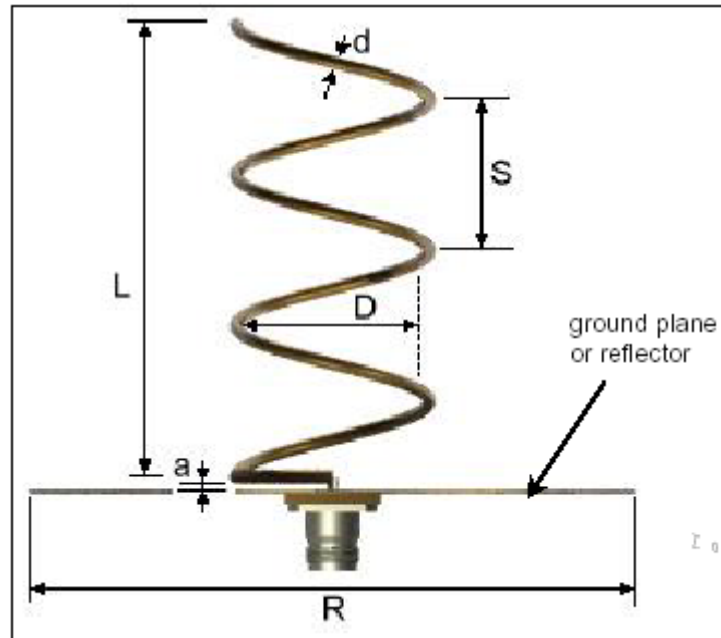


Figure 2.3 : The design parameters of the axial mode helical antenna

(www.ece.tufts.edu/en/61/Lab1_antenna.pdf)

The pitch angle, α , is the angle formed by a line tangent to the helix wire and a plane perpendicular to the helix axis. α must be between 12° and 14° (www.ece.tufts.edu/en/61/Lab1_antenna.pdf).

When $\alpha = 0^\circ$, then the winding is flattened and the helix is reduced to a loop antenna of N turns. When $\alpha = 90^\circ$, the the helix reduces to a linear wire. Varying the dimensions listed above can control the output of the antenna. The input impedance of the antenna is generally dependent upon the pitch angle and the size of the conducting wire near the feed point to the transmission line (www.ece.tufts.edu/en/61/Lab1_antenna.pdf).

2.2 SILICON PIN DIODE

The pin diode consists of heavily doped p and n regions separated by an intrinsic, i region, as shown in Figure 2.4 . When reversed biased, the PIN diode acts like a nearly constant capacitance. When forward biased, it acts like a current-controlled variable resistance. The low forward resistance of the intrinsic region decreases with increasing current.

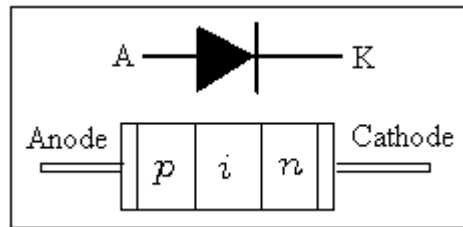


Figure 2.4 : Silicon PIN diode structure and symbol

The PIN diode is used as a dc-controlled microwave switch operated by rapid changes in bias or as a modulating device that takes advantage of the variable forward resistance characteristic. Since no rectification occurs at the pn junction, a high frequency signal can be modulated (varied) by a lower frequency bias variation (Thomas L. Floyd, 2002).

The silicon PIN diode used in this project is the BA 885 surface mount device (SMD). This silicon PIN diode can work in the frequency range of 1 MHz to 2 GHz.

2.3 SCHOTTKY DIODE

Schottky diodes are used in high frequency and fast switching applications. Another name for Schottky diode is *hot-carrier diode*. Figure 2.5 shows the symbol and structure for a Schottky diode. A Schottky diode is formed by joining a doped semiconductor region (usually the n -type) with a metal such as gold, silver or platinum. So, instead of a pn junction, there is a metal-to-semiconductor junction.

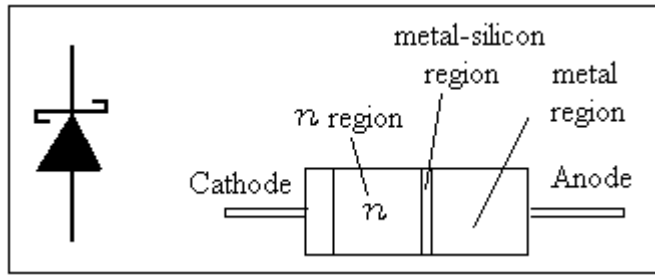


Figure 2.5 : Symbol and structure of a Schottky diode.

The Schottky diode operates only with majority carriers. There are no minority carriers and thus no reverse leakage current as in other types of diodes. The metal region is heavily occupied with conduction-band electrons, and the n -type semiconductor region is lightly doped. When forward biased, the higher-energy electrons in the n region are injected into the metal region where they give up their excess energy very rapidly. Since there are no minority carriers, there is a very rapid response to change in bias. The Schottky diode is a very fast-switching diode, and most of its applications make use of this property. It can be used in high-frequency applications and in many digital circuits to decrease switching times (Thomas L. Floyd, 2002).

The Schottky diode is also used as a microwave detector. A microwave detector will convert a microwave signal into a DC voltage.

The Schottky diode used in this project is the HSMS-2850 manufactured by Agilent Technologies. It could be used optimally at frequencies below 1.5 GHz with input power level lower than -20 dBm. Figure 2.6 shows the output voltage versus input power graph of the HSMS-2850 Schottky diode.

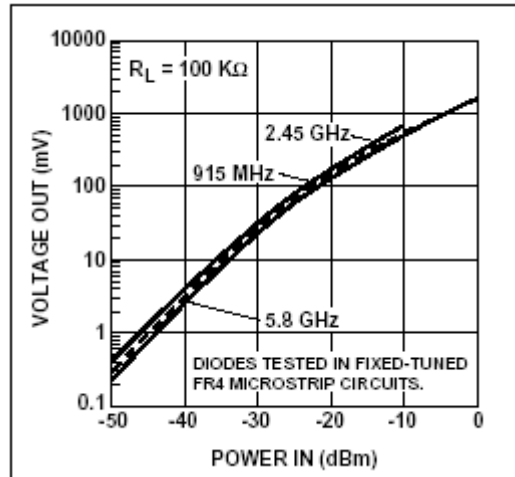


Figure 2.6 : +25°C Output Voltage vs. Input Power, HSMS-2850 at Zero Bias (Agilent Technologies Surface Mount Microwave Schottky Detector Diodes Data Sheet)

According to the graph, at 915 MHz, if the microwave signal input power to the Schottky diode is -30 dBm, the output DC voltage will be about 30 mV.

2.4 555 INTEGRATED CIRCUIT TIMER

The 555 timer is an integrated circuit used in many applications. It basically consists of two comparators, flip-flop, a discharge transistor and a resistive voltage divider, as shown in Figure 2.7. The flip-flop is a two-state device whose output can be either at a high level, (set, S) or a low level, (reset, R). The state of the output can be changed with proper input signals.

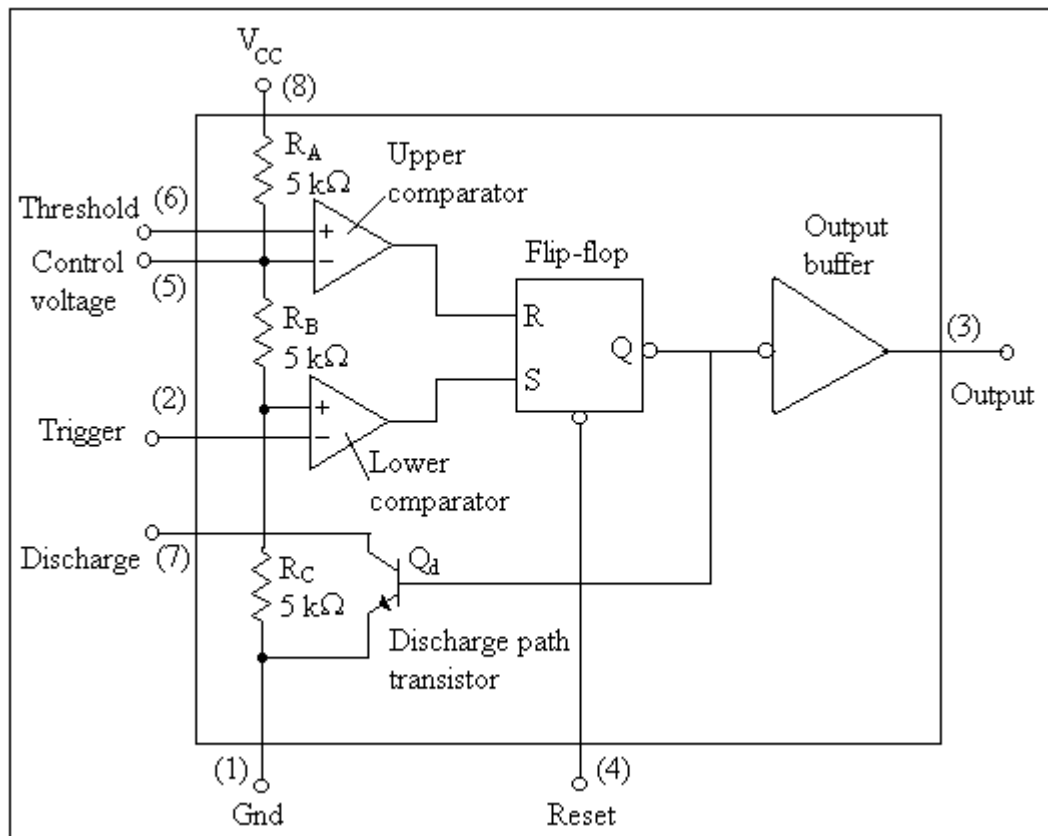


Figure 2.7 : The internal diagram of the 555 timer integrated circuit

The resistive voltage divider is used to set the voltage comparator levels. All three resistors are of equal value, therefore, the upper comparator has a reference of $\frac{2}{3} V_{CC}$ and the lower comparator has a reference of $\frac{1}{3} V_{CC}$. The comparators' outputs control the state of the flip-flop. When the trigger voltage goes below $\frac{1}{3} V_{CC}$, the flip-flops sets and the output jumps to its high level. The threshold input is normally connected to an external RC timing circuit. When the external capacitor voltage exceeds $\frac{2}{3} V_{CC}$, the upper comparator resets the flip-flop, which in turn switches the output back to its low level. When the device output is low, the discharge transistor (Q_d) is turned on and provides a path for rapid discharge of the external timing capacitor. This basic operation allows the timer to be configured with external components to operate as a monostable (one-shot), an astable (oscillatory), or a time-delay element (Thomas L. Floyd, 2002).

The 555 integrated circuit chip used in this project is the Texas Instruments NE555. Two 555 timer integrated circuits are used in this project, one as a monostable and the other as an astable.

2.4.1 555 TIMER IN THE MONOSTABLE MODE

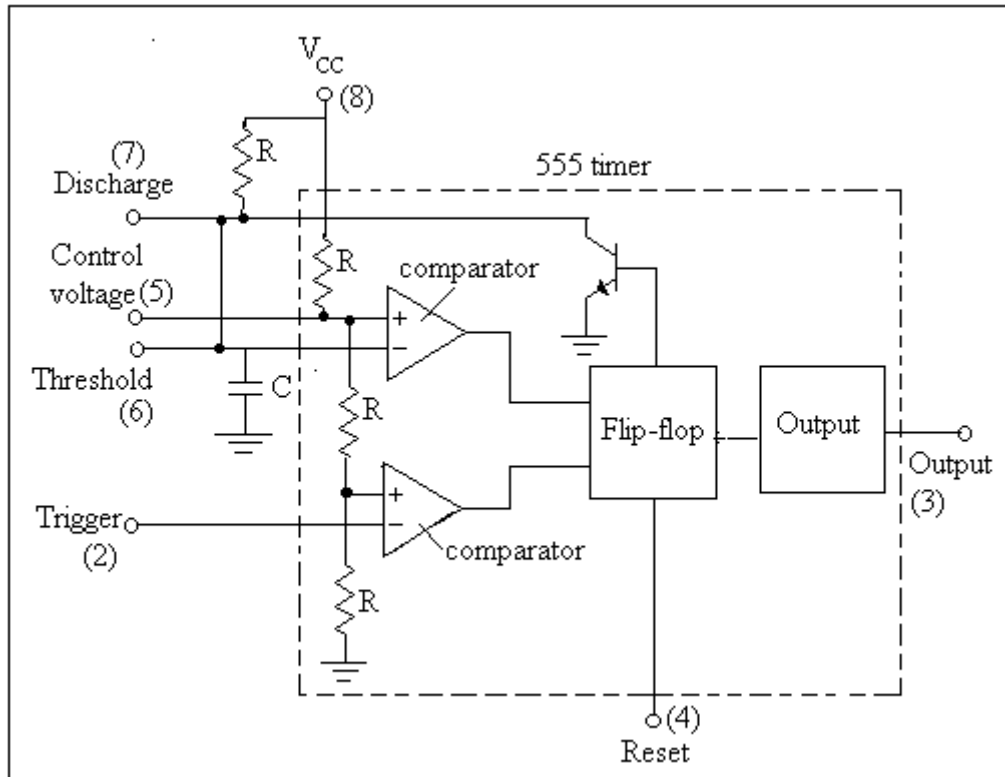


Figure 2.8 : 555 timer configured to operate in the monostable mode (NE555 and NE556 applications, Philips Semiconductors application note, 1988)

Figure 2.8 shows the 555 timer configured to operate in the monostable mode. It requires an external resistor and capacitor.

The operation as a monostable starts when a voltage below $1/3 V_{CC}$ is sensed by the trigger comparator. The trigger is usually applied in the form of a short negative-going pulse. On the negative-going edge of the pulse, the device triggers, the output goes high and the discharge transistor turns off. Prior to the input pulse, the discharge transistor is on, shorting the timing capacitor to ground. At this point, the timing capacitor, C, starts charging through the timing resistor, R. The voltage on the capacitor

increases exponentially with a time constant $T = RC$. The capacitor will reach $2/3 V_{CC}$ in 1.1 time constant or

$$T = 1.1 RC \quad (2.8)$$

where T is in seconds, R in ohms and C in Farads.

This voltage level trips the threshold comparator, which will drive the output low and turn on the discharge transistor. The transistor discharges the capacitor rapidly. The timer has now completed its cycle and will await another trigger pulse (NE555 and NE556 applications, Philips Semiconductors application note, 1988).

2.4.2 555 TIMER IN THE ASTABLE MODE

Figure 2.9 shows the 555 timer configured to operate in the astable mode. It requires two external resistors and one external capacitor.

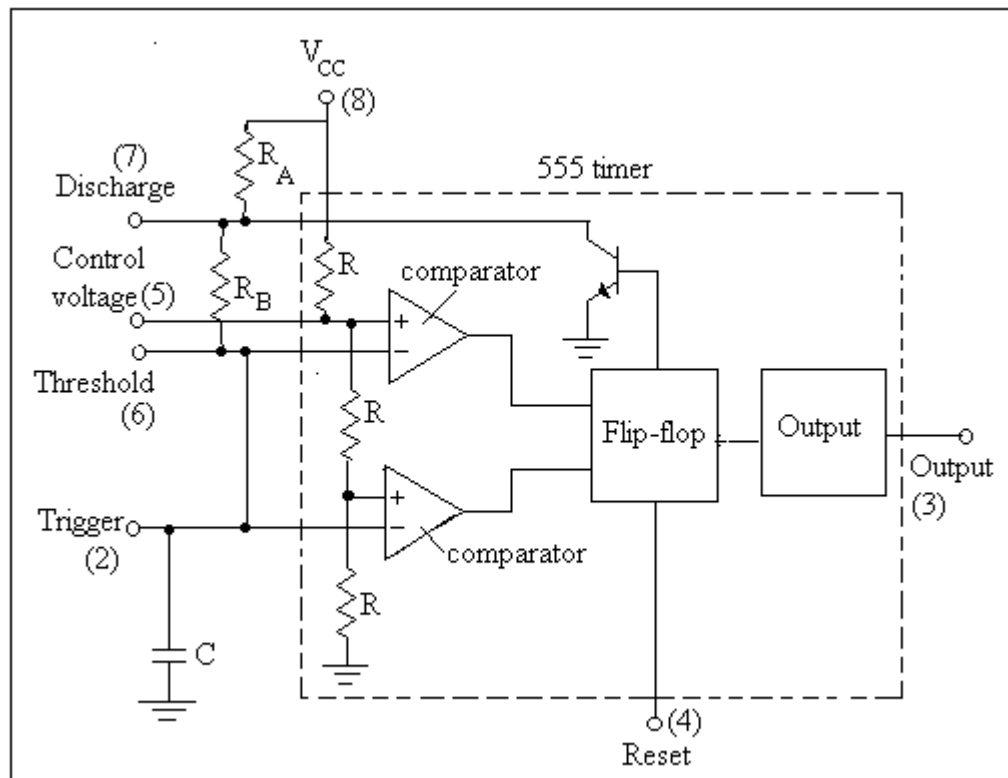


Figure 2.9 : The 555 timer configured to operate in the astable mode (NE555 and NE556 applications, Philips Semiconductors application note, 1988)

For the astable mode, the trigger is tied to the threshold pin. At power-up, the capacitor is discharged, holding the trigger low. This triggers the 555 timer, which establishes the capacitor charge path through R_A and R_B . When the capacitor reaches the threshold level of $2/3 V_{CC}$, the output drops low and the discharge transistor turns on.

The timing capacitor now discharges through R_B . When the capacitor voltage drops to $1/3 V_{CC}$, the trigger comparator trips, automatically retriggering the 555 timer, creating an oscillator whose frequency is given by :

$$f = \frac{1.49}{(R_A + 2R_B)C} \quad (2.9)$$

Selecting the ratios of R_A and R_B varies the duty cycle accordingly (NE555 and NE556 applications, Philips Semiconductors application note, 1988).

2.5 ANALOGUE-TO-DIGITAL CONVERTER (ADC)

The function of an analogue-to-digital converter (ADC) is to measure an analogue input signal and provide a quantized representation of the signal in the form of a digital output code. The ADC is considered as an encoding device that translates between the analogue signal and the digital word. Figure 2.10 shows the block diagram of an ADC.

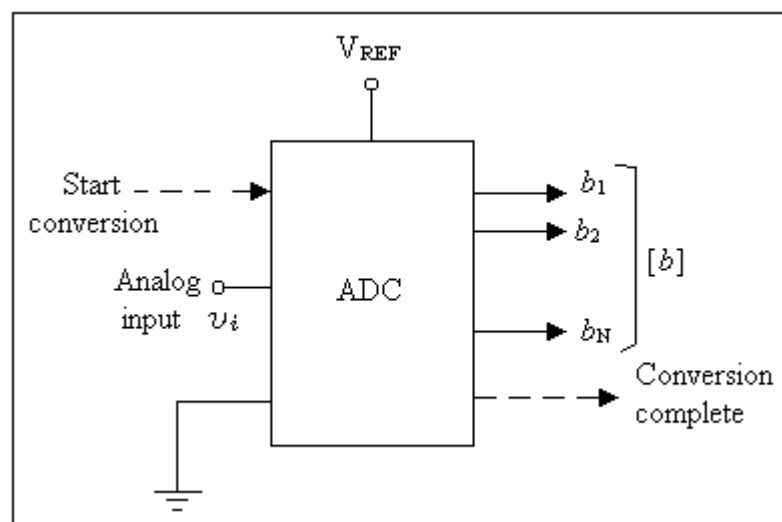


Figure 2.10 : The block diagram of an ADC.

The analogue-to-digital converter (ADC) accepts an analogue input signal and produces a digital output code that corresponds to some characteristics of the input signal. Often, this characteristic is the magnitude of the input signal at the time of conversion. The range of the input signal is typically divided into some number of equal quantum intervals. These levels are numbered consecutively. The output of the ADC is a coded equivalent of this level number. Among the several types of ADC are the parallel or flash converter, the successive approximation converter, and the ramp converter (David J. Comer and Donald T. Comer, 2003).

The flash ADC is used in this project. The flash ADC has the fastest conversion speed compared to conventional ADCs.

The flash method of analogue-to-digital conversion uses parallel comparators to compare the linear input signal with various reference voltages developed by a voltage divider. When the input voltage exceeds the reference voltage for a given comparator, a high level is produced on that comparator's output. To illustrate this, consider a flash ADC as in Figure 2.11 that produces three-digit binary numbers on its output, which represent the values of the analogue input voltage as it changes. This comparator requires seven comparators. In general, $2^n - 1$ comparators are required for conversion to an n -digit binary number. The large number of comparators necessary for a reasonably sized binary number is one of the drawbacks of the flash ADC. Its chief advantage is that it has a high conversion speed.

The reference voltage for each comparator is set by the resistive voltage-divider circuit and V_{REF} . The output of each comparator is connected to an input of the priority encoder. The priority encoder is a digital device that produces a binary number on its output representing the highest value input.

The encoder samples its input when a pulse occurs on the enable line (sampling pulse), and a three-digit binary number proportional to the value of the analogue input signal appears on the encoder's outputs.

The sampling rate determines the accuracy with which the sequence of binary numbers represents the changing input signal. The more samples taken in a given unit of time, the more accurately the analogue signal is represented in digital form (Thomas L. Floyd, 2002).

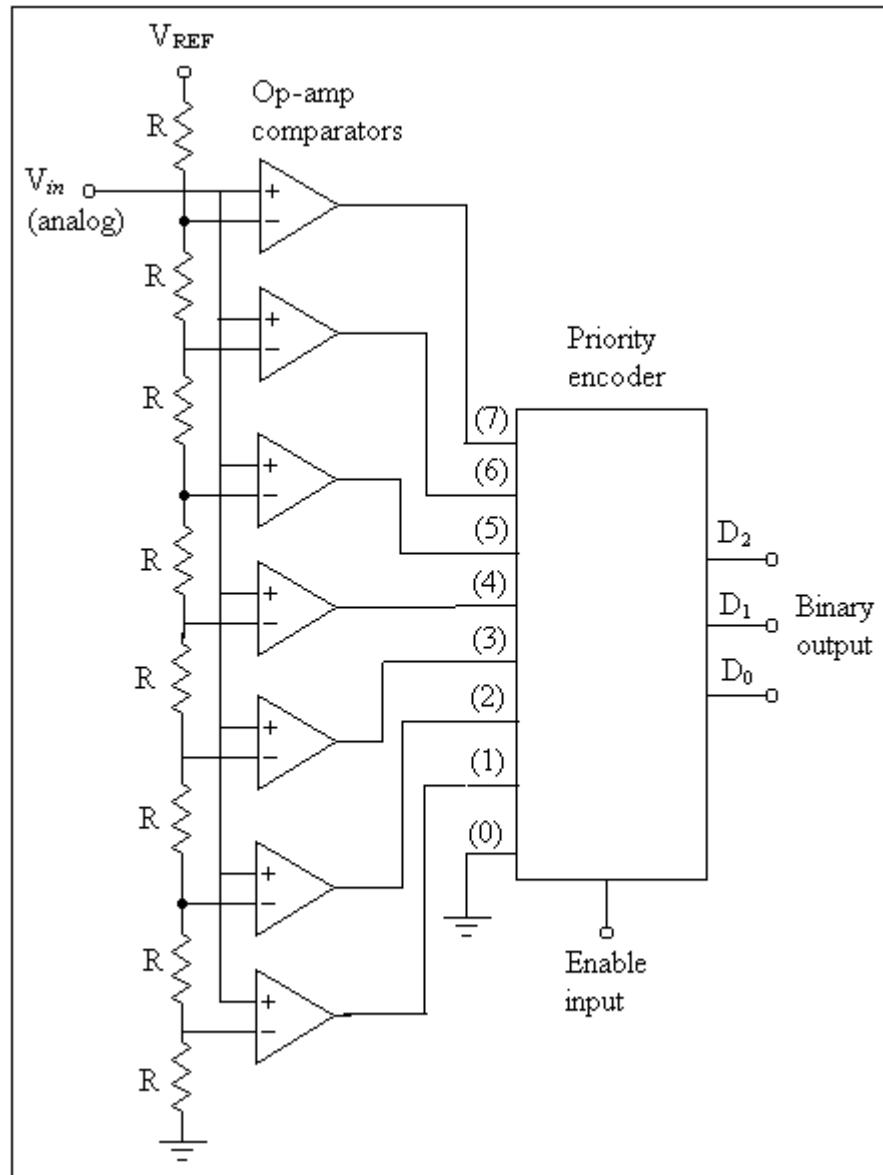


Figure 2.11 : Internal diagram of a flash ADC.

The ADC used in this project is the AD7822 manufactured by Analog Devices. The AD7822 is an 8-bit half-flash ADC with 420 ns conversion time. The on-chip reference is 2.5 V. Figure 2.12 shows the AD7822 chip and the pins. DB_0 to DB_7 are the data output lines which will give the sampled data as an eight-bit binary number. To

enable the ADC to start analogue-to-digital conversion (sampling), the CONVST must have a logic 0 (LOW) input. Both the RD and the CS must be given a logic 0 (LOW) input when the user wants to read the eight-bit output data.

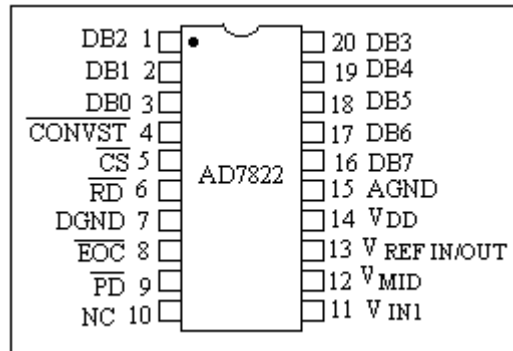


Figure 2.12 : AD7822 chip and the pins

2.6 DEMULTIPLEXER

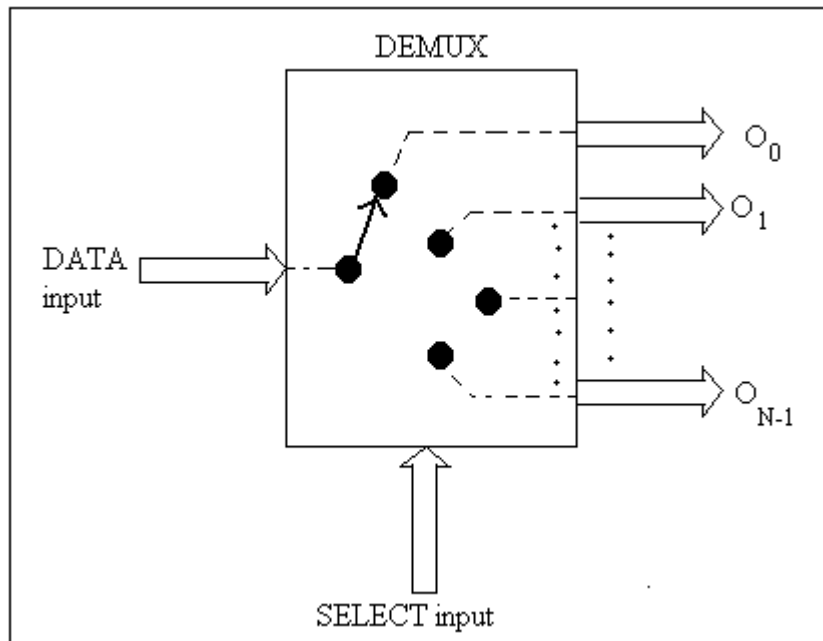


Figure 2.13 : The functional diagram for a digital demultiplexer

A demultiplexer (demux) takes a single input and distributes it over several outputs. Figure 2.13 shows the functional diagram for a digital demultiplexer. The select input code will determine to which output the DATA input will be transmitted. The demultiplexer takes one input data source and selectively distributes it to 1 of N output channels just like a multiposition switch (R. J. Tocci and N. S. Widmer, 2001).

The demultiplexers used in this project is the MC14051B manufactured by Motorola. Figure 2.14 shows the pins of the MC14051B. Pins C, B and A are the select input code pins. The C, B, and A input code will determine to which output (X0 until X7) the data input at pin X will be transmitted. For example, if the C, B, and A input code is C = 1, B = 1 and A = 0, (which is 110, that is 6 in decimal), the data input at pin X will be transmitted to the output pin X6. In this project, the data input at pin X is always zero (LOW) because pin X is connected to ground. Therefore, any output (X0 until X7) that is selected by the C, B, and A input code will be LOW. The output (X0 until X7) must be LOW because the output are connected to the CONVST , RD and CS pins of the analog-to-digital converters (ADCs) which need to be logic LOW to do conversion and read.

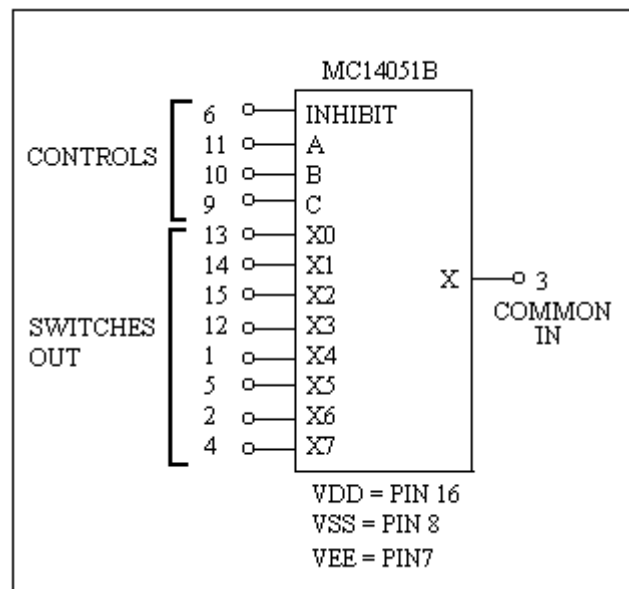


Figure 2.14 : The pins of the MC14051B

2.7 J-K FLIP-FLOP

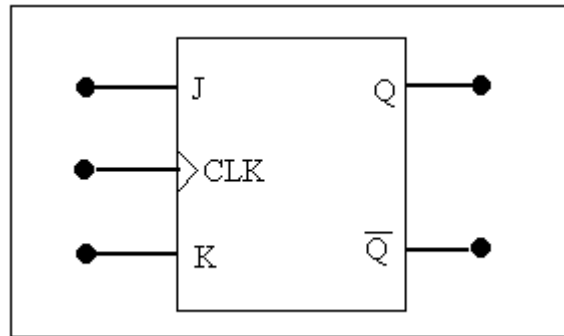


Figure 2.15 : Clocked J-K flip-flop

The J-K FF is the most widely used FF because of its versatility. Figure 2.15 shows a clocked J-K flip-flop that is triggered by the positive-going edge of the clock signal. The J and K inputs control the state of the FF. The truth table in Table 2.1 summarizes how the J-K flip-flop responds to the the positive-going edge of the clock for each combination of J and K (R. J. Tocci and N. S. Widmer, 2001).

Table 2.1 : Truth table for J-K flip-flop

J	K	CLK	Q
0	0	↑	Q ₀ (no change)
1	0	↑	1
0	1	↑	0
1	1	↑	Q ₀ (toggles)

The J-K flip-flop used in this project is the MC14027B manufactured by Motorola.

CHAPTER 3 : PROJECT HARDWARE AND PROCEDURE

This chapter explains about the hardware design and implementation and how the project is being carried out.

3.1 PROJECT OVERVIEW

This section gives a brief summary of the whole system which is designed and created in this project.

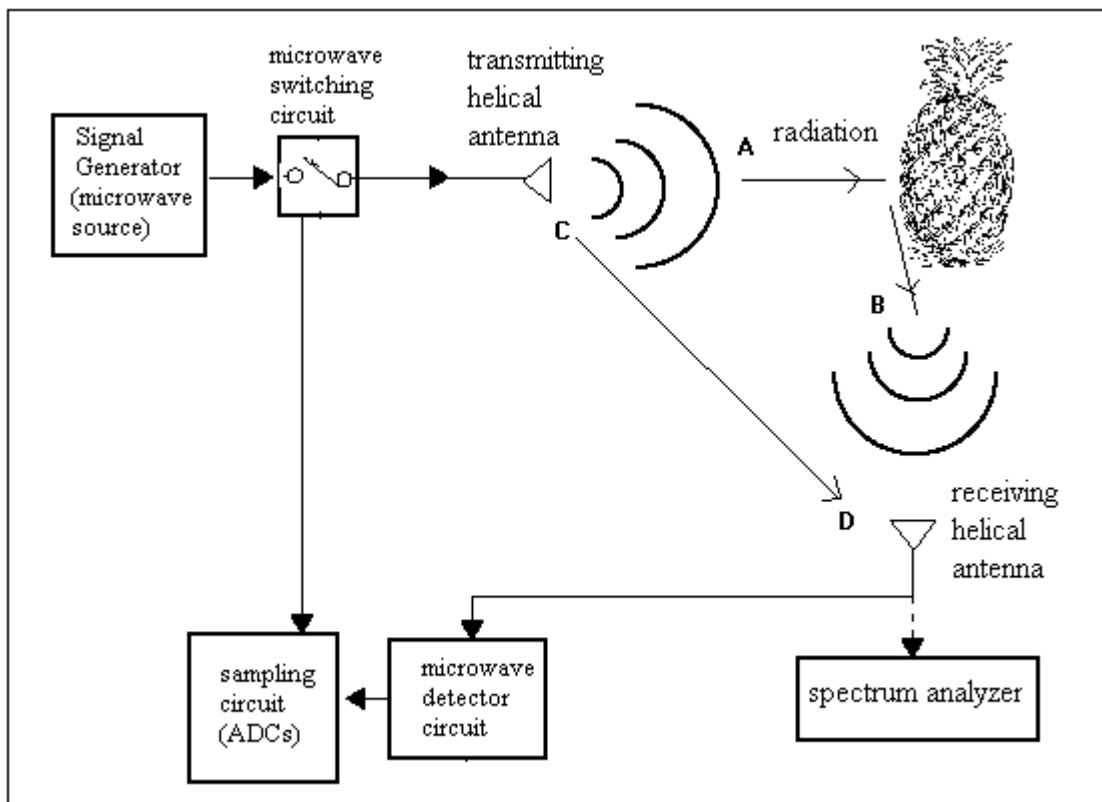


Figure 3.1 : System to detect the degree of ripeness of fruit

Figure 3.1 shows the system which is created in this project. Except for the signal generator and spectrum analyser which are provided in the lab, the other devices and circuits shown in Figure 3.1 are designed and build as part of this project.

The signal generator is the microwave signal source. The microwave signal will be able to pass through from the signal generator to the transmitting helical antenna when the microwave switching circuit is ON because the PIN diode is conducting.

Microwave signal will radiate to the fruit. When the microwave switching circuit is OFF, microwave signal will not radiate because the PIN diode is not conducting. The ADCs will also start sampling when the microwave switching circuit is ON.

The transmitting helical antenna will radiate microwave signal towards the fruit when the microwave switching circuit is ON. Microwave signal that hits the fruit will be reflected from the fruit. The receiving helical antenna will pick up the microwave signal that is reflected from the fruit.

The reflected microwave signal will be input to the microwave detector circuit. The Schottky diode in this circuit will rectify the reflected microwave signal and convert it to DC voltage. The DC voltage is then input to the ADCs in the sampling circuit. The 8 ADCs, one at a time, will sample the input DC voltage. This is to get the transient response. The sampled input DC voltage will be output from the ADCs as an eight bit binary number (digital form).

3.2 MICROWAVE SWITCHING CIRCUIT

A circuit which could act as a microwave switch is designed. This microwave switch is needed because the ADCs must start sampling at exactly the same instance when the transmitting antenna starts to radiate the microwave signal towards the fruit. So, this microwave switch will cause the microwave signal to start radiating towards the fruit and at the same time trigger the ADCs to do sampling.

The ADCs must start sampling at the same instance when the transmitting antenna starts to radiate the microwave signal towards the fruit so that, the transient response of the microwave signal that is reflected from the fruit and picked up by the receiving antenna could be obtained. The transient response needs to be obtained because it is assumed that the microwave signal will penetrate deeper into the fruit as time goes by, and so the strength of the reflected microwave signal may be different at different instances. For example, during the first microsecond that the microwave signal hits the fruit, the microwave may only penetrate the skin before it gets reflected back to the receiving antenna. But at the second or third microsecond, the microwave signal

may penetrate into the flesh of the fruit before getting reflected back. Finally, at the fifth or sixth microsecond, the microwave signal may have reached into the core of the fruit before it is reflected back to the receiving antenna. So, the strength of the microwave signal that is picked up by the receiving antenna may vary as the transmitted microwave signal penetrates deeper into the fruit before it is reflected back. However, the strength of the reflected microwave signal may reach a steady state as well when the strength stays constant as time goes by. The aim of this project is to obtain the transient response of the reflected microwave signal.

The reader might wonder why the sampling must start at the same instance when the transmitting antenna starts to radiate the microwave signal instead of at the instance when the reflected microwave signal first hits the receiving antenna. Logically thinking, the reflected microwave signal will only reach the receiving antenna after a short time after the transmitting antenna start radiating the microwave signal. But in practical, the microwave signal propagates at a very high speed, 3×10^8 meters per second. Therefore, the receiving antenna will be able to pick up the microwave signal that is reflected from the fruit at almost the identical instance at which the transmitting antenna starts to radiate the microwave signal towards the fruit.

Figure 3.2 shows the schematic of the microwave switching circuit. When the "ON MICROWAVE" switch is closed, current will flow into the base of transistor Q11 and transistor Q11 will turn on. Current will flow from the 5V supply into transistor Q10 and Q11. Current will also flow through the two back-to-back PIN diodes, D2 and D4. Current will flow as shown by the arrows. The ON LED will light up to indicate that the microwave switching circuit is ON.

The PIN diodes, D2 and D4, are used as microwave switches. The PIN diodes used are the BA 885 silicon PIN diode with a frequency range of 1 MHz to 2 GHz. When current flows through them, D2 and D4 will become almost short-circuit to microwave. So, microwave will flow from the signal generator, through capacitor C2, PIN diodes D2 and D4, and capacitor C4, and to the transmitting antenna. Microwave signal can flow through PIN diode D2 eventhough the forward bias direction of the diode is opposite to the direction of microwave signal flow. The reason for using two

PIN diodes instead of only one is to create more resistance towards microwave signal when the microwave switching circuit is OFF (microwave signal not supposed to flow through from signal generator to the transmitting antenna). When the "ON MICROWAVE" switch is closed, the eight ADCs will also start sampling.

When the "ON MICROWAVE" switch is open, microwave will not flow through from signal generator to the transmitting antenna.

The resistors R2, R3 and R4 and inductors L2, L3 and L4 are radio frequency (RF) chokes. The RF chokes are needed so that the microwave signal will flow from C2 to D2, D4 and C4 and out to the antenna, instead of flowing away to other parts of the circuit. Capacitor C10 is needed to stabilize the supply voltage, which means that if the supply voltage were to dip down at any time, the capacitor which has stored-up charge, will supply the voltage that is needed.

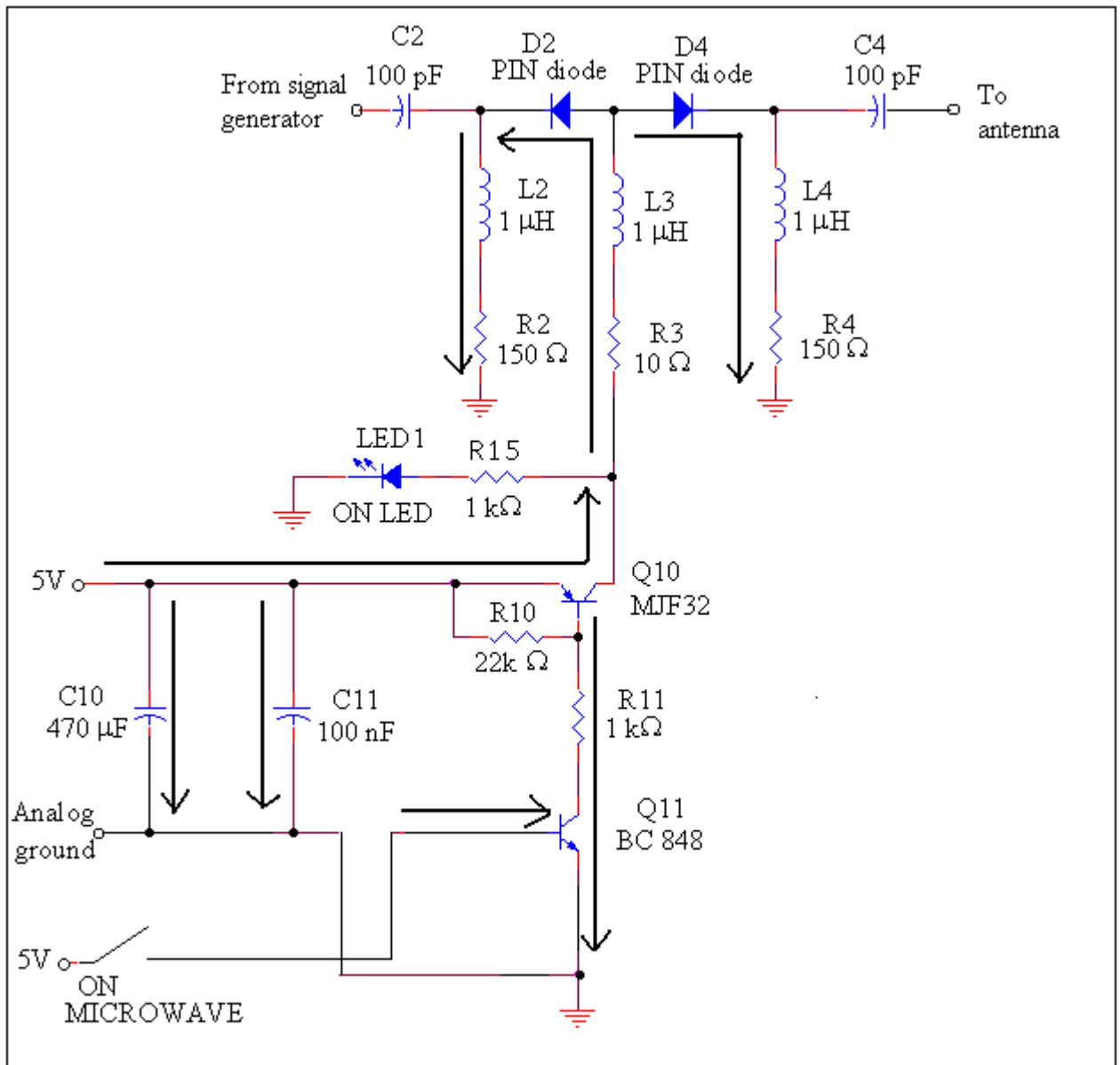


Figure 3.2 : Schematic diagram of the microwave switching circuit