HEART FAILURE DETECTOR

By

CHAN SENG KOON

FINAL YEAR PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Chan Seng Koon

ABSTRACT

This report describes the application of the biomedical theory and communication theory. The project is proposed to help the problem that occurs to elderly person especially to the person with heart problems. When heart attack occurs during the absence of their children, the consequences might be death. Thus, a Heart Failure Detector device will be very useful to the children who always leave their old parents alone especially to heart problem parents. When the attack occurs, it will automatically send an alarm signal to their children or neighbours via wireless communication. The scope of study for this project is narrowed down to the people with the abnormal heartbeats (arrhythmia). Abnormal heartbeats occur when the heart has an irregular heart rhythm, beats too fast (*tachycardia*), or beats too slow (*bradycardia*). This may result in feeling light headed, tired or faint.

The circuit is design and simulate using the PSpice and Multisim simulation software. The circuit is made small and compact enough in order to make it easy to be taken anywhere. An infrared light emitter with the wavelength of approximately 940nm is use to measure the pulsatile blood volume changes. The pulsatile signal that is received by a phototransistor is then amplified by an Op-amp and the counter will be the analyzer to differentiate between the normal heartbeat and abnormal heartbeat. The last part is the transmitter and the receiver circuit. These two circuits are able to send and receive the alarm signal using radio frequency (RF) modulation. The alarm receiver part is the part where all the alert routines are done such as dialling the emergency number and activating the siren.

ACKNOWLEDGEMENT

Firstly I would like to express sincere gratitude to my supervisor, Miss Salina Mohmad for her constant supervision, support and guidance besides sharing her knowledge and experience throughout the project.

I also would like to appreciate the contribution of Mr Patrick Sebastian, Miss Siti Hawa and Mr Isnani, lab technician and staff from RS Components, Miss Ivy, as well as all colleagues who had been kind and helpful in assisting me to carry out the work.

Throughout the project, I had been exposed to different obstruction and had leaned to overcome challenges. Thanks again for the patience and encouragement from those who directly or indirectly involved.

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LIST OF ABBREVIATION

A_{CL}	Closed-loop Gain
BJT	Bipolar Junction Transistor
c	concentration of the substance absorbing the light
CMOS	Complementary metal–oxide–semiconductor
d	optical path length
DC	Direct Current
DTMF	Dual Tone Multi Frequency
EAGLE	Easily Applicable Graphical Layout Editor
ECG	Electrocardiograph
IR	Infra Red
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MSB	Most Significant Bit
Op-Amp	Operational Amplifier
PCB	Printed Circuit Board
t_d	Delay time
t_f	Fall time
t_r	Rise time
t_s	Storage time
$\varepsilon(\lambda)$	extinction coefficient of absorptivity
λ	wavelength

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Heart is one of the most important organs in human body. The heart serves as a pump to move blood through vessels called *arteries* and *veins*. Blood is carried away from the heart in arteries and is brought back to the heart in veins.

Heart failure or heart attack happens when the heart failed to pump the blood. This problem can be harmful to that particular person. This is due to the artery bringing blood to the heart becomes partially or totally occlude (i.e. blocked off). When this happen, the heart beat will become slower and the person most probably will faint[1].

There are few devices which are used to detect heart problem. Those devices are:-

- Electrocardiographs (ECG)
- Pulse Oximeter
- Stethoscope
- Wristwatch

1.2 Problem Statement

Heart attack can happen to any people especially to old people. Sometimes these groups of people were left alone in their house while their children go to work. If the heart attack happens during the absence of their children , the consequences might be death. This is because no device that can alert their children, neighbours or hospital when the attack happens.

1.3 Objective and Scope of Study

1.3.1 Objective

The objective of this project is to design a gadget that can detect the normal heart beat and mild heart beat. When the attack happens, this gadget would be able to transmit an alarm signal to the person who should responding to the signal (i.e their children, neighbours or hospital) automatically. The gadget must be small, attachable and not dangerous to human body.

1.3.2 Scope of Study

The scope of the study will be narrowed down to the people with the abnormal heart beat (arrhythmia). Abnormal heartbeats occur when the heart has an irregular heart rhythm, beats too fast (tachycardia), or beats too slow (bradycardia).

- ***Tachycardia*** - It is an abnormal rapidity of heart action that usually is defined as a heart rate more than 100 beats per minute (bpm) in adults. The heart may not pump enough blood for the body's needs[1]. This may result in feeling light headed, tired or faint.
- ***Bradycardia*** - It can be defined as a sinus rhythm with a resting heart rate of 60 beats/minute or less. However, few patients actually become symptomatic until their heart rate drops to less than 50 beats/minutes[1]. A person with a tachycardia may feel that their heart is racing. If the heart beats too fast it can also fail to pump enough blood.

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

2.1 Infra Red Sensor

There are several sensors that can detect the heart beat. The sensor that applicable to this project is infra red sensor.

The most commonly used method to measure pulsatile blood volume changes is by the photoelectric method. Two methods are common: Reflectance method and transmittance method.

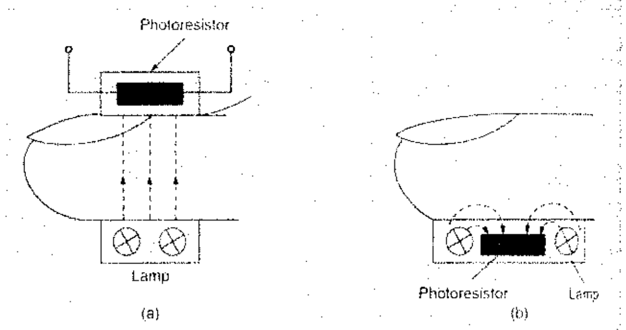


Figure 1: Arrangement of photoresistor and lamp(infrared) in a finger probe for pulse pick up: (a) Transmission method (b) Reflectance method [1].

In the *transmittance method,* a light-emitting diode (LED) and photoresistor are mounted in an enclosure that fits over the tip of the patient's finger. Light is transmitted through the finger tip of the subject's finger and the resistance of the photoresistor is determined by the light reaching it. With each contraction of the heart, blood is forced to the extremities and the amount of blood in the finger increases. It alters the optical density with the result that the light transmission through the finger reduces and the resistance of the photoresistor increases accordingly. The photoresistor is connected as part of a voltage divider circuit and produces a voltage that varies with the amount of blood in the finger

The arrangement used in the *reflectance method* of photoelectric plethysmography is shown in **Figure 1 (b).** The photoresistor, in this case, is placed adjacent to the exciter lamp. Part of the light rays emitted by the LED is reflected and scattered from the skin and the tissues and falls on the photoresistor. The quantity of light reflected is determined by the blood saturation of the capillaries, Therefore, the voltage drop across the photoresistor, connected as a voltage divider, will vary in proportion to the volume changes of the blood vessels.

2.2 Principle of Heart Beat Detection using Infra-Red

The theory of using infra-red as a sensor to detect heart beat is based on principle that the signal is propagated through the tissue where it is submitted to modifications due to reflection, refraction, scattering and absorption. The resulting signal, after propagation through the tissue is grasped by one or multiples optical sensors, which are located at distance of about 10 mm around the optical source. Since variations of optical tissue characteristics are related to variations in the subcutaneous blood flow, the received signal can be used for the estimation of the heart rate [4].

When Infra Red light is transmitted through biological tissue, reflection and refraction occur at the interfaces between the probe and the subject. Scattering is due to the microscopic variations of the dielectric properties of the tissue. These variations are due to the cell membranes and the subcellular components (*e.g.* mitochondria and nuclei).

The absorption is mainly due to chromophores such as hemoglobin, myoglobin, cytochrome, melanin, lipid, bilirubin and water [4]. The relative importance depends on the wavelength considered and their distribution in the tissue. Under ideal steady-state condition, the received IR light signal contains both a constant and a time varying component. The constant component is generally ascribed to baseline absorption of blood and soft tissue, non expansive tissue such as bone, as well reflectance loss.

The varying component reflects the modification of the effective path length due to the expansion of the tissues subject to the varying blood pressure.

For the near IR wavelength, the light propagation into the tissue is governed by scattering and absorption. The *Beer-Lambert* equation is generally used to describe the phenomenon of light absorbtion in biological tissue [3]:

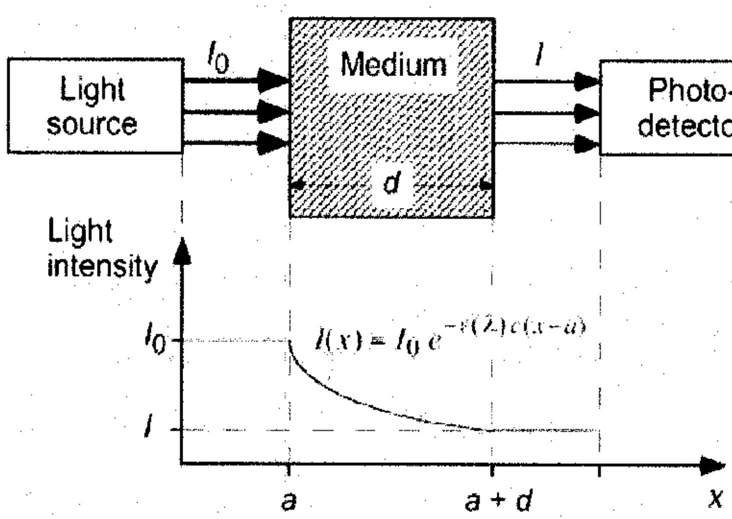


Figure 2: Graphical Representation of Beer-Lambert Law[3]

where ε(λ) is the extinction coefficient of absorptivity at a specific wavelength λ, c is concentration of the substance absorbing the light and d is the optical path length.

The intensity of light transmitted across the fingertip is varies as shown in **Figure 3**. A pulsatile signal, which varies in time with the heart beat, is superimposed on a DC level. The amplitude of this cardiac–synchronous pulsatile signal is approximately 1% of the d.c. level [5].

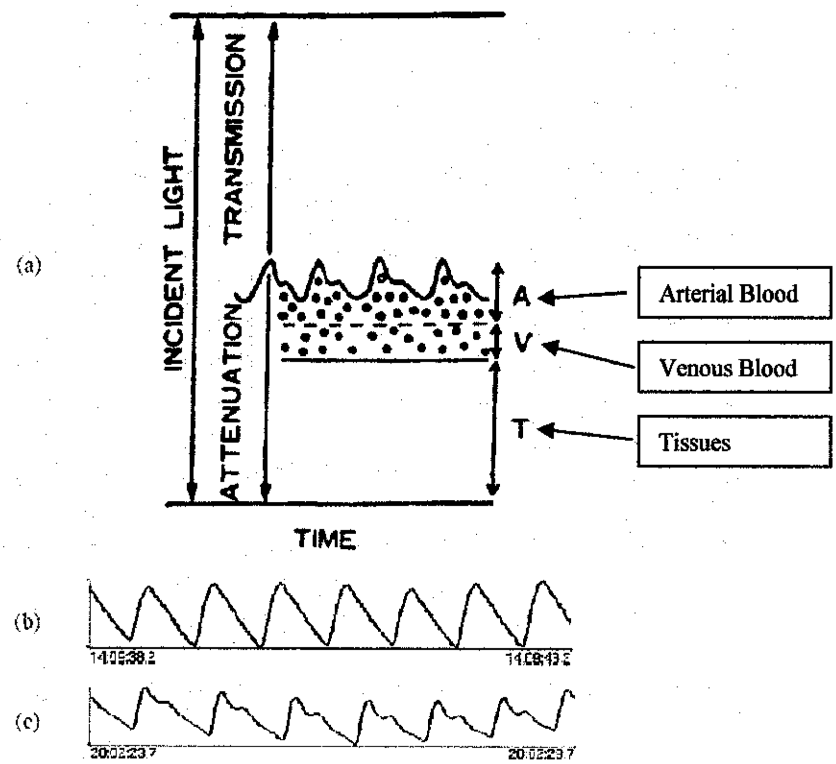


Figure 3: (a) Transmission of light through the finger when the attenuation of light is caused by arterial blood (A), venous blood (V) and tissues (T). (b) and (c) show typical pulsatile signals detected in the intensity of detected light when light is shone through a finger[5].

Figures 3(b) and **3(c)** show typical cardiac synchronous pulsatile signals detected when IR light is shone through a finger. It is clear from these graphs that there is quite a wide variation in the shape of the signals between people.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Conceptual of Heart Failure Detector

There are four important parts in this project that should be designed in order for it successfully achieves the project objective. Those four parts are:

1) Sensor Circuit
2) Trigger Circuit
3) Alarm Transmitter Circuit
4) Alarm Receiver Circuit

The block diagram in **Figure 4** shows the four important parts:

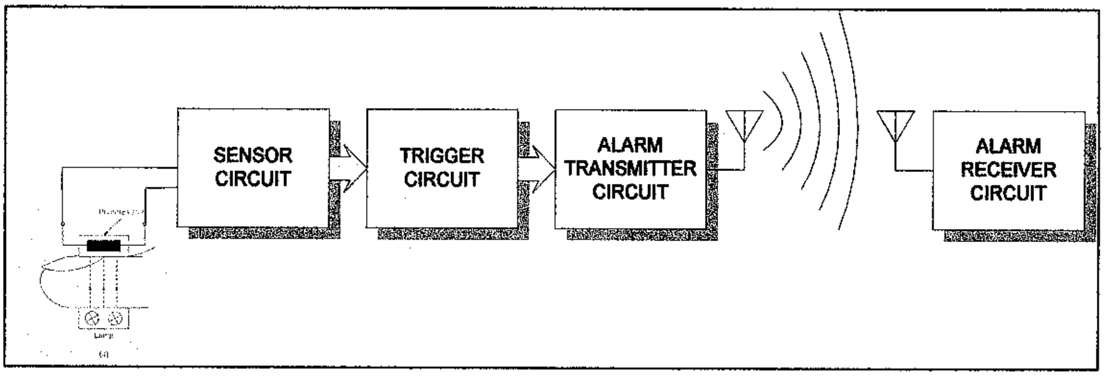


Figure 4: Project block diagram

The Infra Red light that is shone through the finger will be received by the phototransistor. The phototransistor will receive a pulsatile Infra Red light from finger due to pulsating arterial blood. The sensor circuit will amplified the pulse signals so that it can be send to the trigger circuit.

The function of the trigger circuit is to set a warning level when a mild heart attack happens. For example, when the heartbeat is abnormal (<60bpm) the circuit will start to trigger. The triggering signal will be send to the alarm transmitter circuit whereby it will send out an alarm signal to the alarm receiver via wireless communication.

3.2 Planning

The methodology of the project can be divided to three main parts, which including research, circuit design and hardware implementation. Below is the flow chart showing the project flow for the project:

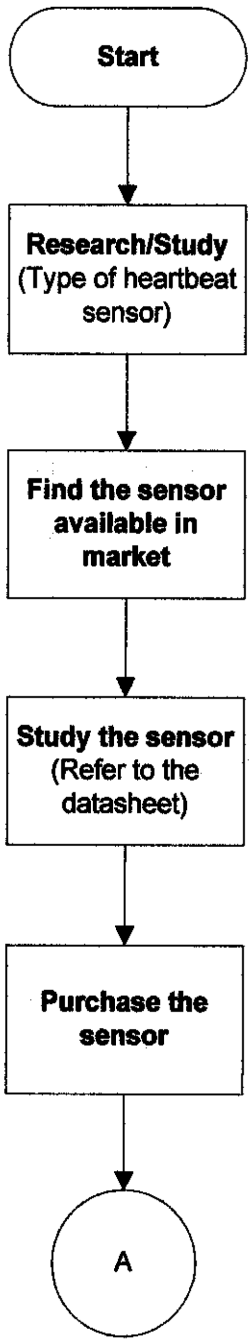


Figure 5(a): Project flow diagram

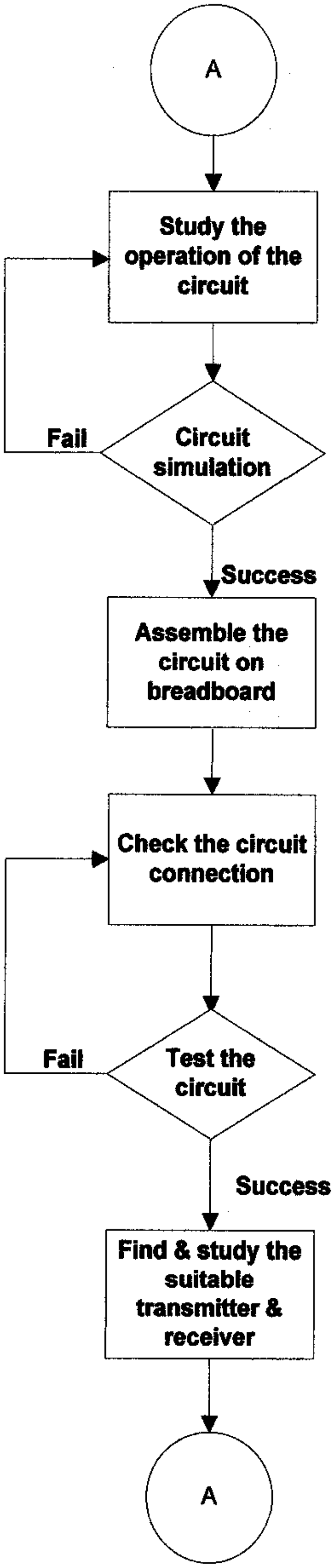


Figure 5(b): Project flow diagram

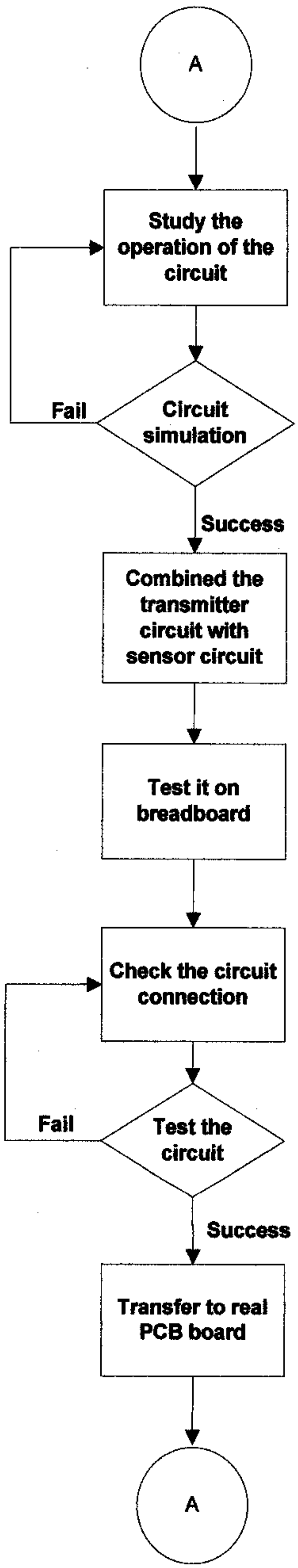


Figure 5(c): Project flow diagram

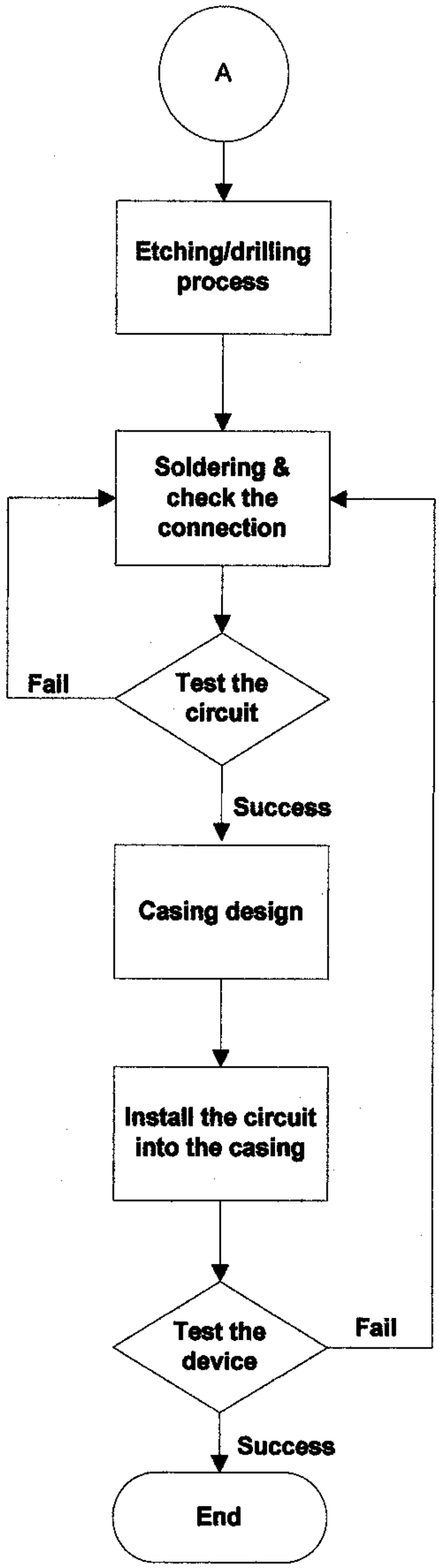


Figure 5(d): Project flow diagram

3.3 Research

During the first semester, sufficient research and relevant background study were gathered. The project started with research on several heartbeats detection sensors that were used by hospitals or medical centres. The research cover the Infra Red Sensor and ECG electrodes. The main concern is that the sensor must be easy to get in the market.

Finally, the study had been narrowed down to the type of Infra Red sensor and its operation since infra red sensors are easy to get and cheap. The research continued with theories and principles of heartbeat detection using Infra Red. Then, the operation and configuration of Operational Amplifier (Op-amp) were reviewed.

The research also covers the method of transmitting the alarm signal to the responding person, as far as possible. The full project Gantt chart is shown in **Appendix I**

3.4 Circuit Design

A circuit needs to be design in order to amplify the produced signal and interface it with the sensor. The suitable circuit for signal communication also needs to be package well with the circuit sensor. The softwares that is used to draw and simulate the circuit is PSpice and EAGLE.

3.4.1 Phototransistor Interface Circuit

The basic circuit for interfacing the phototransistor is constructed using 2 op-amp as pre-amplifier and comparator. The circuit is shown below:

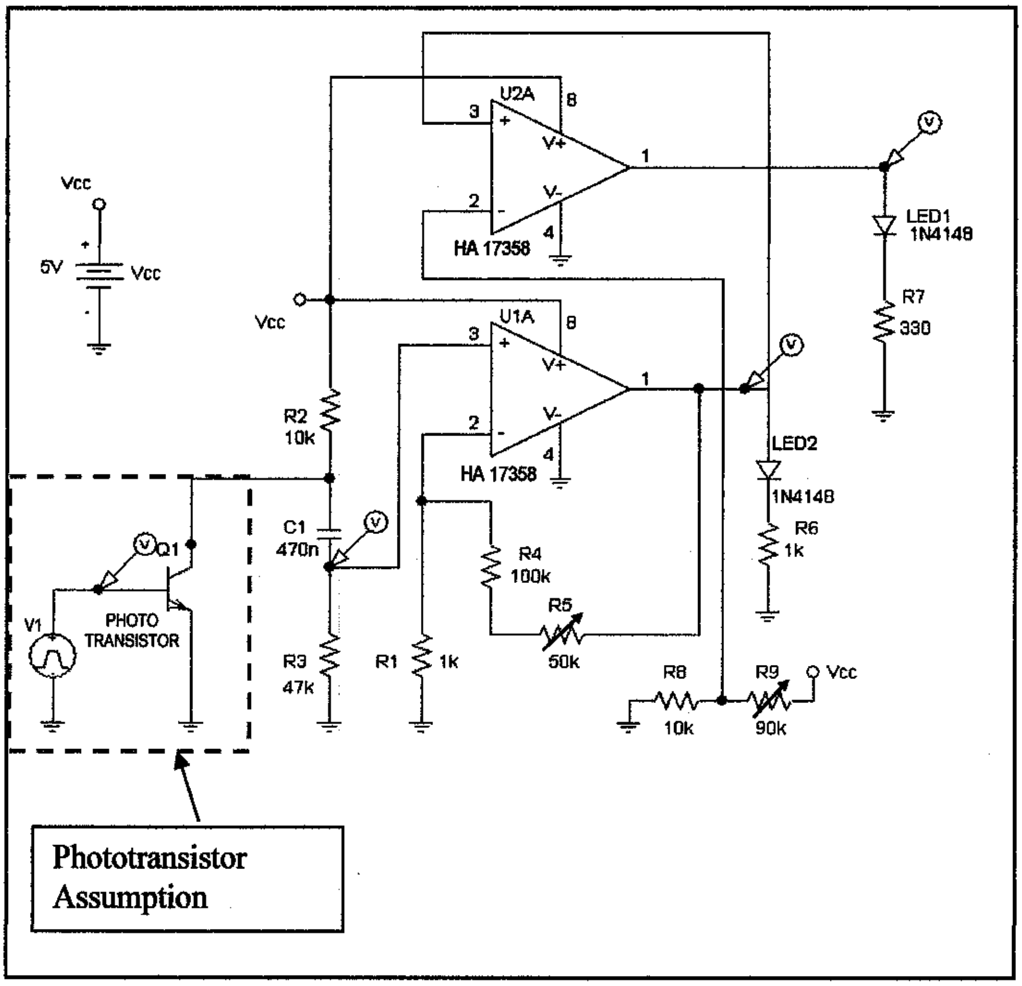


Figure 6: Infra-red Sensor Interface Circuit

This circuit is supplied by 5 VDC voltage. The signal generator V1 is assumed to be the heart pulse whereby it will generates a sequence of pulse every 1 second. The Q1 (NPN transistor) is assumed to be the phototransistor as the Pspice software did not have this part.

During the initial state, the output from op-amp U1A and U2A is 0V due to the transistor Q1 being in "ON" (short circuit) condition and the current flows from Vcc, through R2 and Q1 and straight to ground.

When the base of the Q1 transistor senses a pulse, it will change from "ON" condition to "OFF" condition. At this time, the current will flow from Vcc through R2, C1, R3 and to ground.

The capacitor will generate a spike so that the noninverting input of the op-amp U1A will be triggered from its steady state condition *(the details for this operation will be discuss in 3.4.1.1).*

The output signal from the op-amp U1A is indicated by the LED2 and simultaneously the signal is send to the op-amp U2A comparator to be compared with the noninverting input as the reference input. When the noninverting input is higher than the reference voltage, the op-amp U2A will produce a DC High and Low output indicated by LED1.

3.4.1.1 The importance of a capacitor, C1, operation

The schematic diagram of an op-amp HA17358 had to be studied first in order to understand the capacitor C1 operation. As shown in **Figure 7**, the op-amp consists of many complicated connection of transistor. However the main concern is at the noninverting input's bipolar junction transistor (Q4) whereby it is connected to the C1 capacitor.

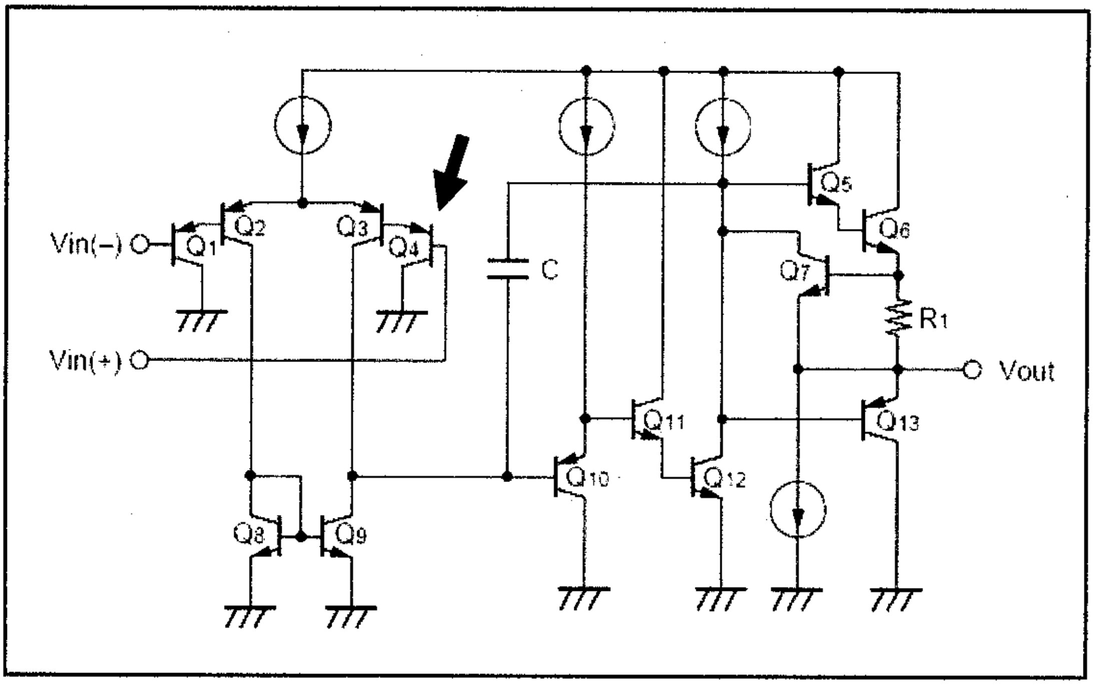


Figure 7: Schematic diagram of op-amp HA17358

In the normal operation of the BJT transistor, the square wave and pulse input will not cause the output to change instantly. This is due to a delay between each input transition and the start of the output transition. The output transition is not vertical, implying that they require some measurable amount of time to occur. The delay is due to the base-emitter depletion layer is at its maximum width, and I_C is essentially at zero. When the input of the BJT goes positive, the depletion layer starts to “dissolve”, allowing Ic to increase. Delay time is required for the depletion layer to dissolve to the point where 10% of the maximum value of Ic is allowed to pass through the component.

The example of the square wave delay between the BJT input and output is shown in **Figure 8**. The overall delay between the input and output transition (as measured at the 50% points on the two waveform) is referred to as propagation delay[6].

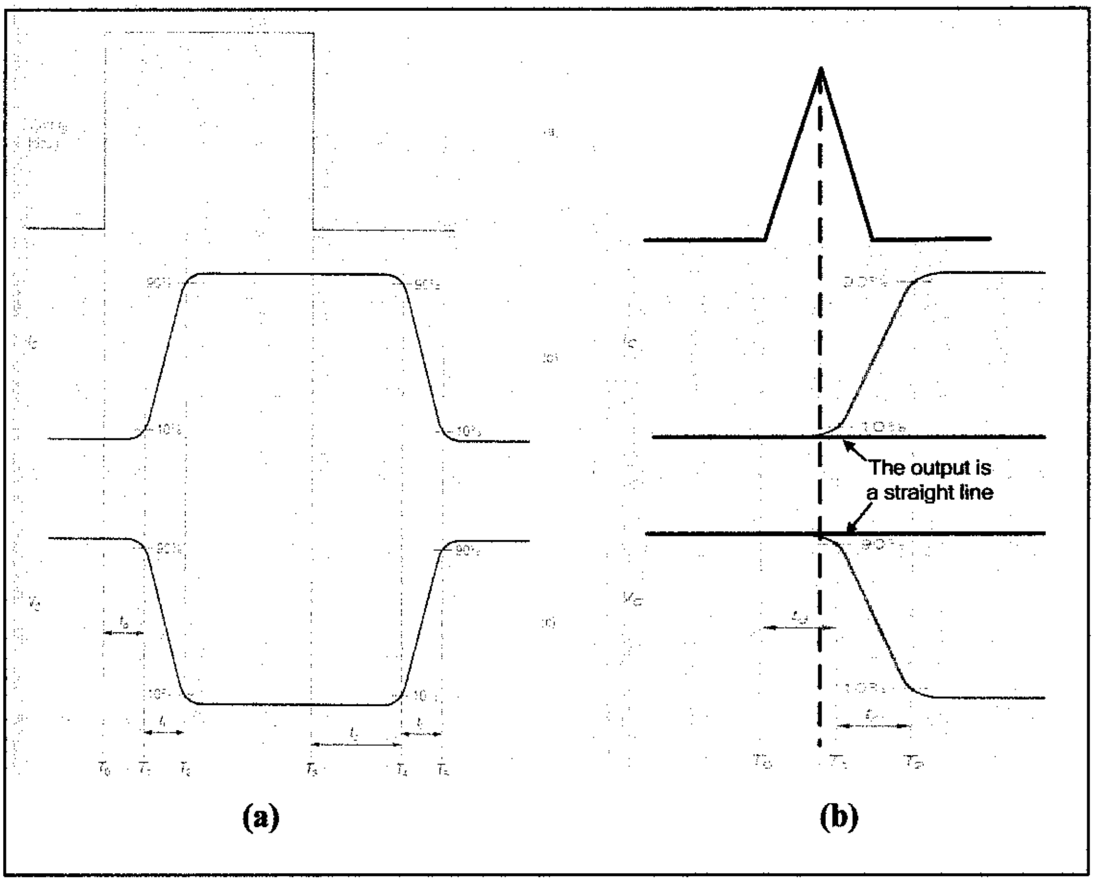


Figure 8(a) and (b): The effect of propagation delay to the square wave and pulse input

There are actually four sources of BJT propagation delay, each measured during one time period as shown in **Figure 8(a)**. Those delay are:

- Delay time (t_d) = Time required for the transistor to come out of cutoff.
- Rise time (t_r) = Time required for the BJT to make the transition from cutoff to saturation.
- Storage time (t_s) = Time required for the BJT come out from saturation.
- Fall time (t_f) = Time required for the BJT to make transition saturation to cutoff.

However if the input is a pulse, then there will be no output from the BJT. This is because the pulse duration time is too short. It cannot come out from the BJT cut off condition and still in the delay time (t_d) zone as shown in **Figure 8(b)**.

In order to solve this propagation delay problem, a series capacitor had been added to the input of the inverting op-amp U1A. This capacitor is called speed-up capacitor[8]. The purpose of the capacitor is:

1) Applying a high initial value of I_B
2) Using the minimum value of reverse bias required to hold the BJT in cutoff.
3) By limiting I_B to a value lower than that required to completely saturate the BJT
4) Applying an initial reverse bias that is very large.

As indicated in **Figure 9(a)**, a positive spike is coupled to the base of the transistor when V_{in} makes its transition from 0 V to +5V. This spike generates a high initial value of I_B. Then, as the capacitor charges, the spike returns to 0V level and I_B decreases to some value slightly less than that required to fully saturates the transistor. As a result, delay time is reduced while ensuring that I_B returns to a value that is low enough to prevent saturation.

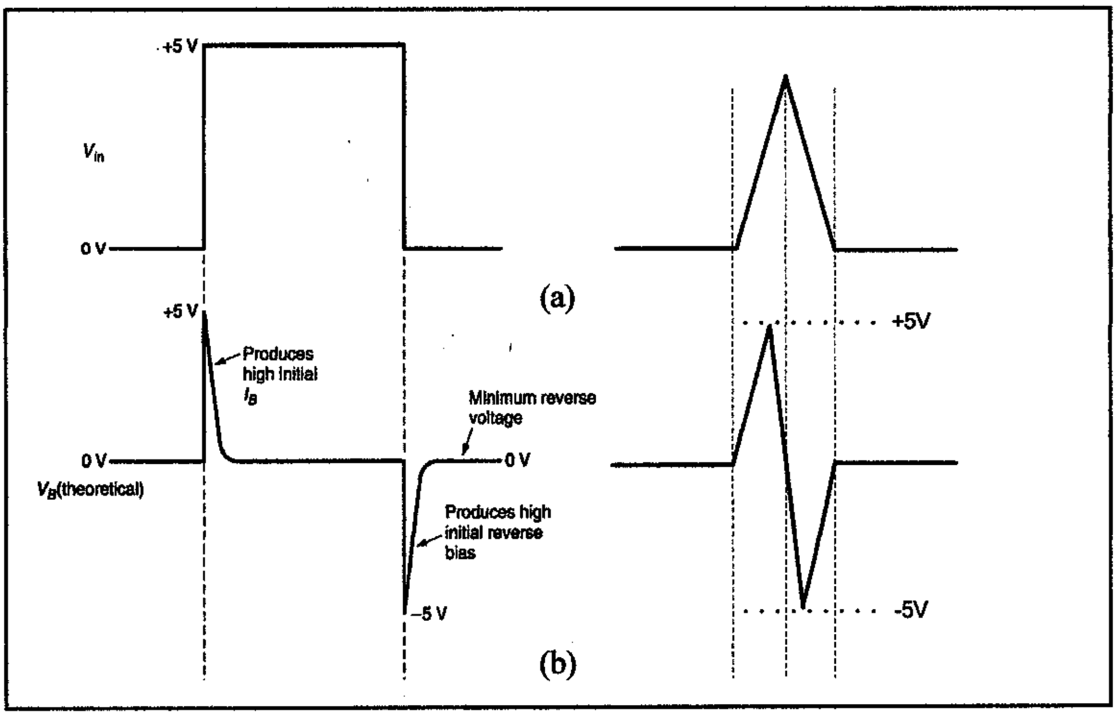


Figure 9 : Waveform caused by a speed up capacitor

When the input signal returns to 0 V, the charge on C1 drives the output of the RC circuit to -5 V. This is the high initial reverse bias needed to reduce storage time. Since the transistor was prevented from saturating by I_B, the capacitor has done all that can be done to reduce storage time. Also, since V_B returns to 0 V at the end of the negative spike, the final value of reverse bias is at a minimum. This, coupled with the high initial I_B spike, ensures that delay time is held to a minimum. The operation can be simplified in **Figure 9**.

3.4.1.2 Op-amp U1A operation

This op-amp U1A act as the amplifier, where it amplified the signal from the output of capacitor C1.

This is a noninverting amplifier because the input signal is applied to the noninverting terminal as shown in **Figure 10**. The amplifier characteristics are:

1) Higher input impedance
2) Does not produce an 180^{o} voltage phase shift from input to output. Thus, the input and output signals are in phase.

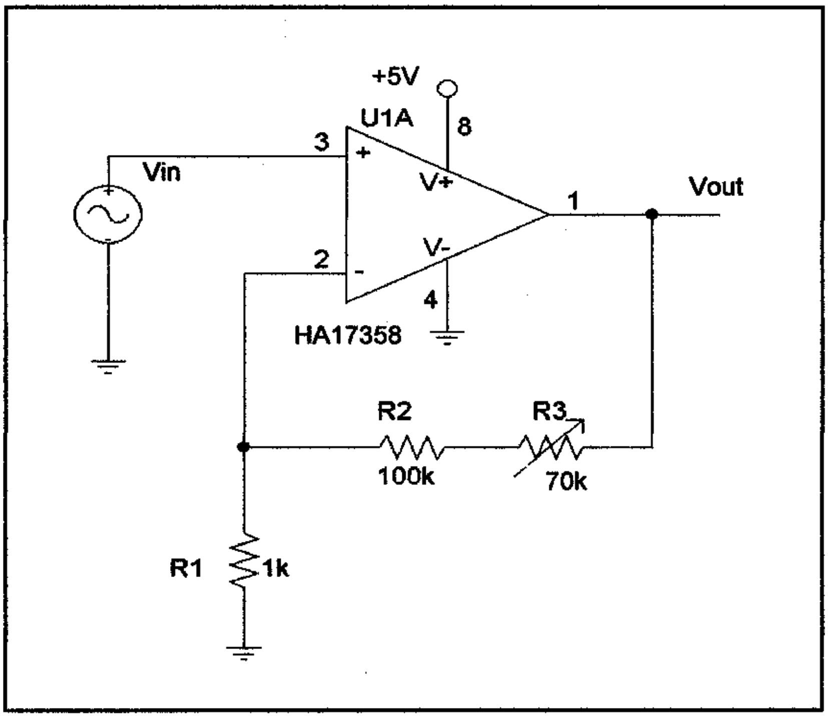


Figure 10: Noninverting amplifier[8]

The complete analysis of the noninverting amplifier as shown in **Figure 10** is shown as following:

The closed-loop voltage gain (A_{CL}) of the circuit is found as

$$\begin{aligned} A_{CL} &= \frac{R_f}{R_{in}} + 1 \\ &= \frac{(R_2 + R_3)}{R_1} + 1 \end{aligned} \qquad \textbf{(3.1)}$$

The peak to peak output voltage is

$$\begin{aligned} A_{CL} &= \frac{V_{out}}{V_{in}} \\ V_{out} &= A_{CL} V_{in} \end{aligned} \qquad \textbf{(3.2)}$$

The resistor R3 is a variable resistor. It is use to adjust the gain (A_{CL}) of the amplifier in the equation (3.1) and simultaneously it also will effect the output voltage in equation (3.2).

3.4.1.3 Op-amp U2A operation

This op-amp is a comparator configuration. It is relatively a simple circuit used to compare two voltages and provide an output indicating the relationship between those two voltages [8].

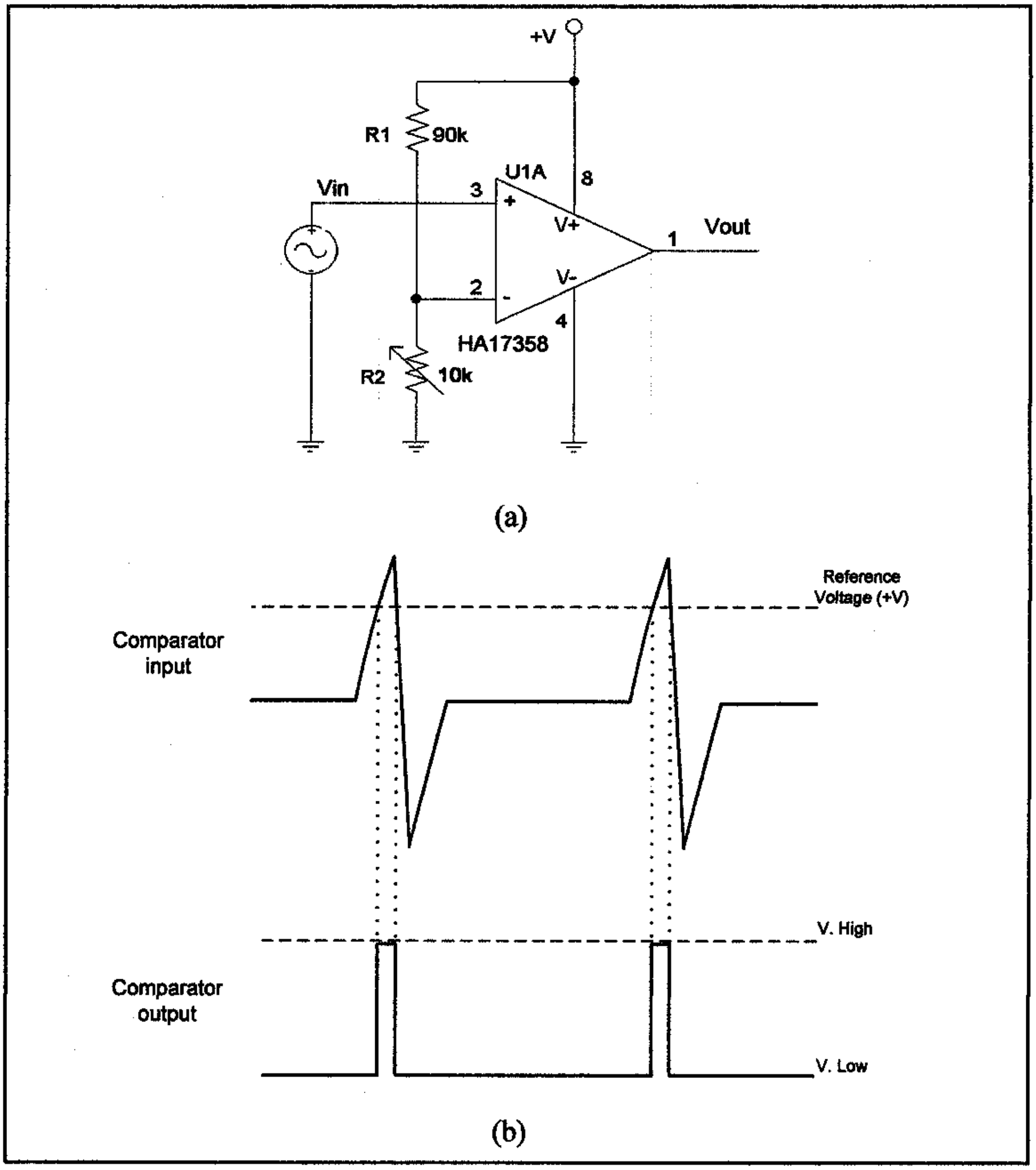


Figure 11: Op-amp Comparator

In the heartbeat sensor circuit, it is use to detect the peak of the pulse. Here's how the circuit work:

- The inverting input of the comparator is connected to a voltage – divider circuit R1 and R3 whereby the R3 is a variable resistor that controlled the level of the reference voltage. Such circuit is shown in **Figure 11(a)**. The reference voltage would be found using the standard voltage-divider formula as follows:

$$V_{ref} = +V\frac{R_3}{R_1 + R_3} \qquad \textbf{(3.3)}$$

- When the pulse output from op-amp U1A is less than voltage reference, the output from the comparator is *low*. The output from the comparator remains *low* until the pulse exceeds the value of the reference voltage.
- When the pulse output from op-amp U1A is exceeds the voltage reference, the output from the comparator is *high*.

The circuit operation is illustrated by the voltage waveform shown in **Figure 11(b)**. The analysis for the comparator circuit as shown in **Figure 11(a)** is: When the noninverting input is at +V, the input of the op-amp is found as

$$V_{diff} = V_{in} - V_{ref} \qquad \textbf{(3.4)}$$

and the op-amp output voltage is found as

$$V_{out} = A_{OL}V_{diff} \qquad \textbf{(3.5)}$$

Since this output voltage is beyond the limit of the output, so the real V_{out} is:

$$V_{out} \cong +V - 1V \qquad \textbf{(3.6)}$$

3.5 Heartbeat Counter

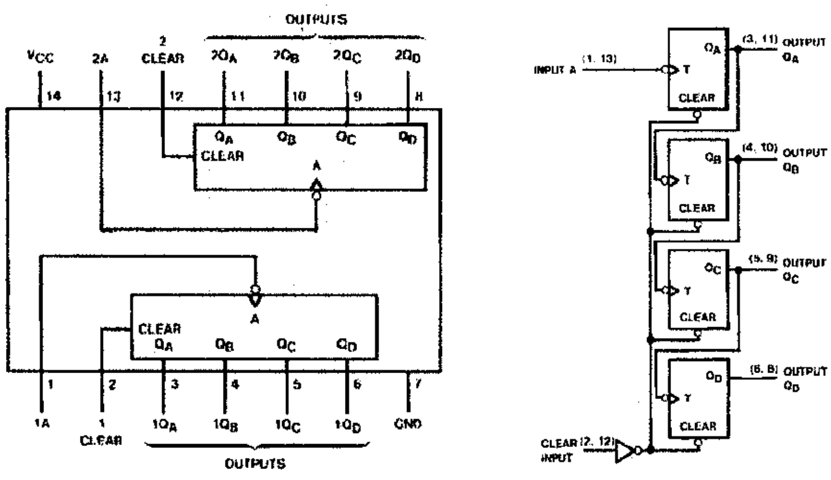
The function of the heartbeat counter is to count the heartbeat from the output of the Op-Amp. This part consists of 3 parts and those parts are:

- 4-bit binary counter
- Magnitude comparator
- Timer

3.5.1 4-bit Binary Counter

The 4-bit Binary Counter (74LS393) is CMOS type of Integrated Circuit (IC) that contains of dual master-slave flip-flop and also additional gates to perform the 4-bit binary counter. The details of the 74LS393 binary counter can be referred to the **Appendix II**. The clock input of the 74LS393 counter will be connected directly to the HA17358 Op-amp output which produced the square wave with the width of 100ms. This pulse is able to trigger the master-slave flip-flop.

The full structure of the 4-bit binary counter is shown in **Figure 12(a)** and the connection of the flip-flop is shown in **Figure 12(b).**



(a) (b)

Figure12 (a) & (b) shows the structure of the 4-bit binary counter (Taken from 74LS393, Fairchild Semiconductor Datasheet)

When the 74LS393 counter clock input sense a pulse transition from HIGH to LOW, then the flip-flop A will be toggled (change to its opposite state). Note that all the flip-flop J and K is equal to 1.

The output of the flip-flop A is now acting as the clock input for flip-flop B, so flip-flop B will toggle each time the output A goes from 1 to 0. Similarly, flip-flop C will toggle when B goes from 1 to 0, and flip-flop D will toggle when C goes from 1 to 0.

The flip-flop outputs D,C,B and A are representing the 4-bit binary number with D as the most significant bit (MSB). The waveform in **Figure 13** shows a binary counting from 0000 to 1111, which is 0 to 15 in decimal [10].

Once the sixteenth clock pulse has occurred, all the flip-flop will goes from 1 to 0 which reset back the output to zero. However there are one more pins to reset the counter which is Master Reset Pin that will reset all the flip-flop to zero once the pins is put to 0 or Ground.

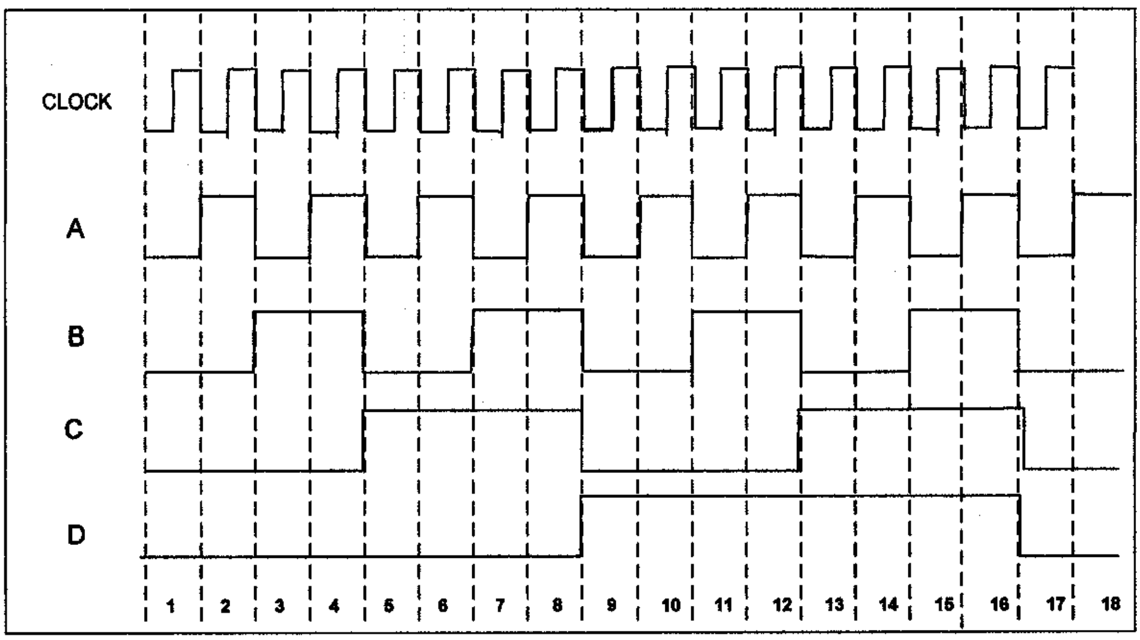
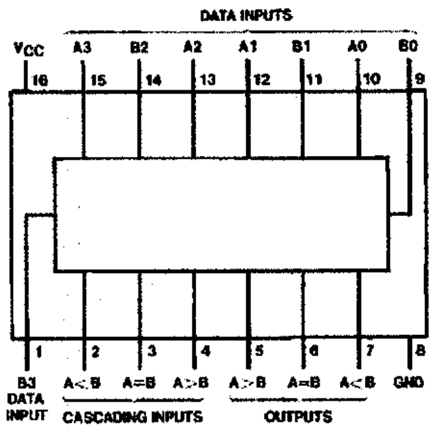


Figure 13: The ABCD output of the 4-bit Binary Counter [10]

3.5.2 Magnitude Comparator

The 4-bit Magnitude Comparator (74LS85) is a combinational logic circuit that compares two input binary quantities and generates output to indicate which one has the greater or less magnitude. The **Figure 14(a) & (b)** show the connection diagram and function table of the magnitude comparator. The details of the 74LS85 magnitude comparator can be referred to the **Appendix III.**



(a)

Comparing Inputs				Cascading Inputs			Outputs		
A3, B3	A2, B2	A1, B1	A0, B0	A > B	A < B	A = B	A > B	A < B	A = B
A3 > B3	X	X	X	X	X	X	H	L	L
A3 < B3	X	X	X	X	X	X	L	H	L
A3 = B3	A2 > B2	X	X	X	X	X	H	L	L
A3 = B3	A2 < B2	X	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 > B1	X	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 < B1	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 > B0	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 < B0	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	L	L	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	H	L	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	H	L	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	X	X	H	L	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	H	L	L	L	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	L	H	H	L

H = HIGH Level, L = LOW Level, X = Don't Care

(b)

Figure 14(a) & (b) The connection diagram and function table of the magnitude comparator (Taken from DM74LS85, Fairchild Semiconductor Datasheet).

This magnitude comparator compares the two 4-bit binary numbers. One of them is A3 A2 A1 and A0 which is called word A; and the other is B3 B2 B1 and B0 which is called word B. The term word is used to described the group of bits that used to specific type of information. It also has three active-HIGH outputs which is output A>B, A=B and A<B [10].

Output A>B will be HIGH when the magnitude of word A is greater than the magnitude of word B. Output A=B will be HIGH when the word A and B are equal. Output A<B will be HIGH when the magnitude of word A is less than word B [10].

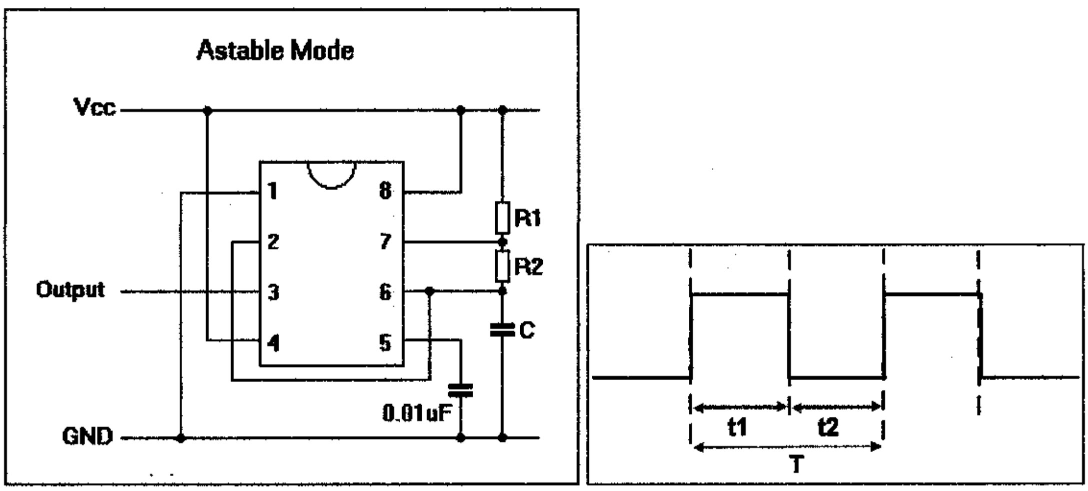
3.5.3 Timer

There are two types of timer used in this counter circuit to control the binary counter and magnitude comparator. These two timer are:

- Astable Multivibrator
- Delay-On Timer

3.5.3.1 Astable Multivibrator

This astable multivibrator configuration is shown in **Figure 15(a),** which produces a square wave type of waveform shown in **Figure 15(b).**



(a) **(b)**

Figure 15: Astable Timer and the square wave generated by the timer [12]

t_1 is the HIGH time while t_2 is LOW time. The total period of the signal is the summation of HIGH time and LOW time [9].

Where,

$$t_1 = 0.693(R1 + R2)C1 \quad (3.7)$$

And,

$$t_2 = 0.693R2C1 \quad (3.8)$$

Therefore period is,

$$T = 0.693(R1 + 2R2)C1 \quad (3.9)$$

3.5.3.2 Delay-On Timer

Initially the delay-on timer will not be ON when the power is supplied. It will only goes HIGH when it reach t_a The output will goes HIGH and remains HIGH. The **Figure 16** shows the connection of the Delay-On timer.

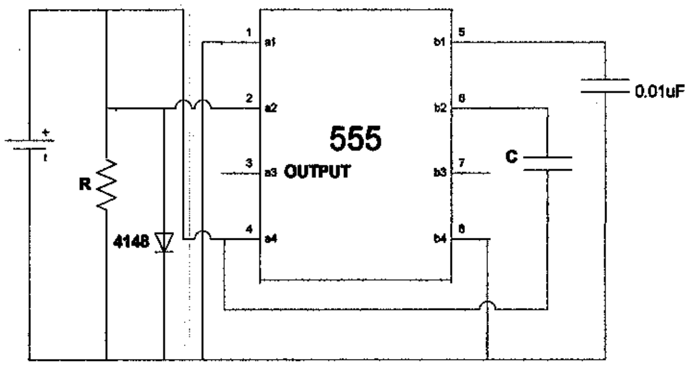


Figure 16: Delay-On Timer [12]

In order to find out the desired value of t_a, the value of capacitor C must be selected first. Then the calculation to find the value of R is shown in formula below [12];

$$t_a = 1.1(R)\left(\frac{C}{1000}\right) \quad (3.3)$$

3.6 The Heartbeat Counter Operation

The pulse from Op-amp HA17358 output is connected directly to the 74LS393 4-bit Binary Counter clock input as shown in **Figure 17**.

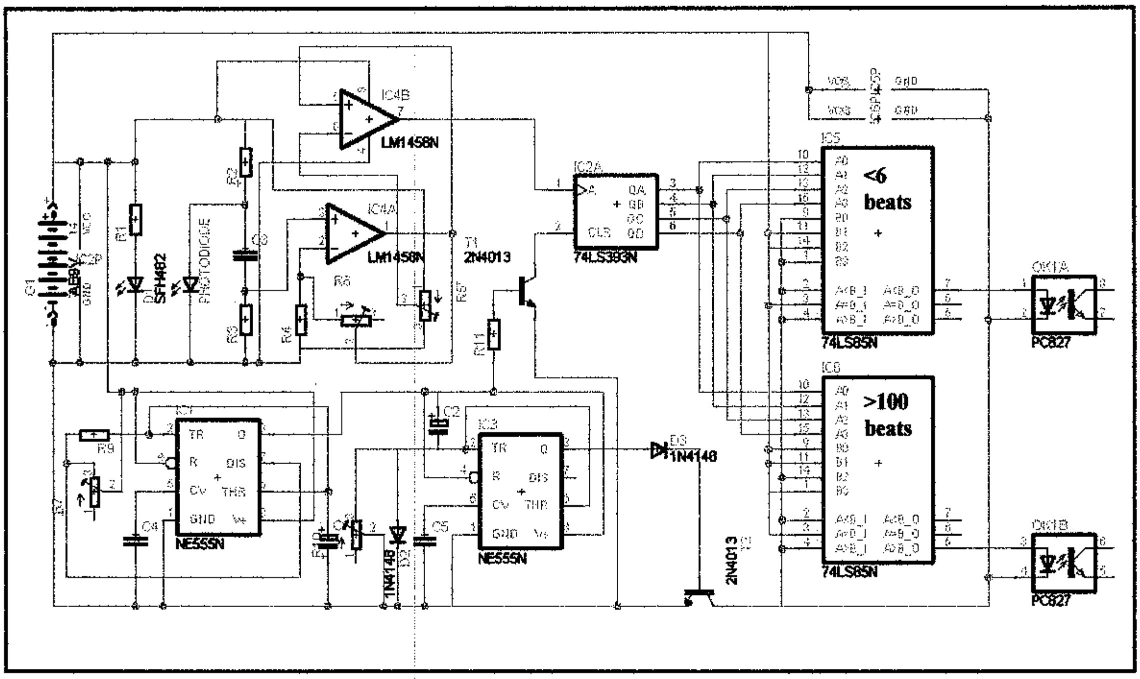


Figure 17: The complete counter circuit

The normal way to count the heartbeat is 60 second or 1 minute. For normal heartbeat is 60bpm, *Tachycardia* symptom is more than 100bpm and *Bradycardia* symptom is 60bpm.

However, due to the limitation of the Binary Counter that's can only count up to maximum 15 beats. So the counting time must be reduced to 6 second only and the normal heart beat will be in the range of 7 to 9 beats, *Tachycardia* symptom is more than 10 beats while *Bradycardia* is less than 6 beats as shows in the **Table1.**

Table 1: Shows the counting time for heartbeat in 60 and 6 second.

	Tachycardia	Normal Heartbeat	Bradycardia
Normal time to count heartbeat (60 second)	More than 100	90 to70	Less than 60
Count the heartbeat in 6 second	More than 10	9 to 7	Less than 6

The two Magnitude Comparator (74LS85) is connected parallel to the output of 4-bit Binary Counter (74LS393). The first magnitude comparator is used to compare the lowest word (<6) while the second magnitude comparator is used to compare the highest word (>10).

These two magnitude comparator will be switch ON at the sixth second to compare whatever value of the pulse during that particular time which is counted by binary counter.

After 6 seconds, the binary counter and the magnitude comparator will be switch OFF for 1 second to reset the binary counter back to 0000 conditions. This is needed for the binary counter to be counting for the next cycle.

When the input of the magnitude comparator detect a higher or lower word than the reference word, the output will goes HIGH in order to activate the Opto-Isolator (PC 827) which act as a switch. The function of this opto-isolator is to isolate the wireless transmitter circuit so that it will not cause the two magnitude comparator to sink so much current into the transmitter circuit.

The two timers (NE555) are used to control the binary counter and also the magnitude comparator. The first 555 timer is "Astable Multivibrator" that controls the second timer and also the binary counter. The first timer will provide the square wave of 7 second ON and 1 second OFF.

The second 555 timer is Delay-On Timer that controls the two magnitude comparator. The source of this timer is connected to the output of first 555 (Astable Multivibrator) timer. This timer will be ON at sixth second for 1 second to activate the magnitude comparator. After that, it will goes OFF again due to the first 555 Astable Multivibrator timer output is OFF as shown in **Figure 18**.

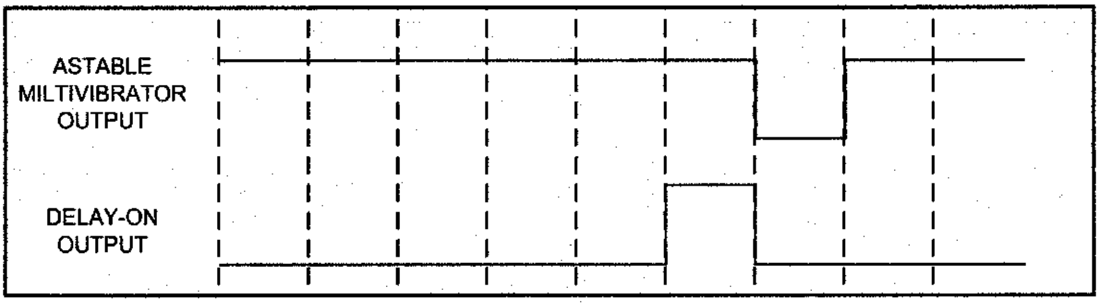
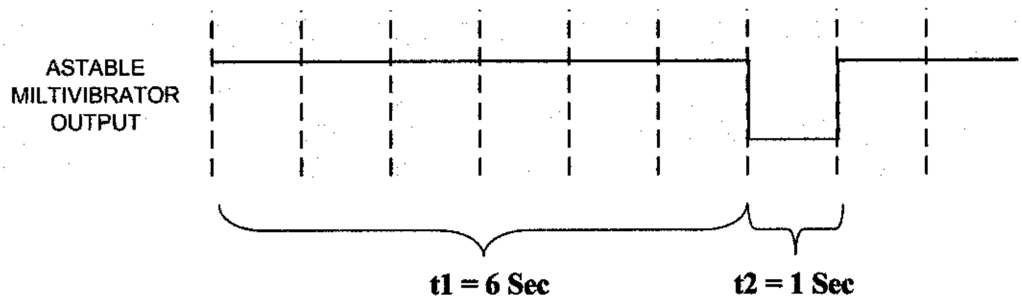
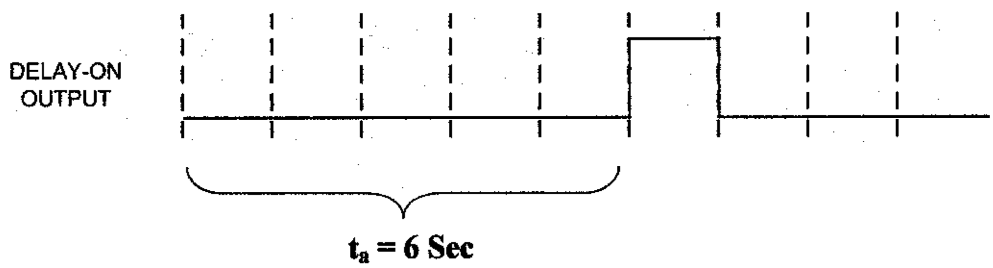


Figure 18: The Astable Multivibrator Timer output and Delay-On Timer Output

In order to make the Astable Multivibrator and Delay-On timer have the proper time to operate, a few calculation had been carried out according to the formula of those two timers to find out the value of resistor and capacitor. The calculation was summarized in the **Table 2** below.

Table 2: Shows the calculation for Astable Multivibrator and Delay-On Timer

Astable Multivibrator Timer
<u>Desired Output:</u>  Assumed the capacitor is 100uF $t_1 = 0.693(R_1 + R_2)C$ $t_2 = 0.693R_2C_1$ $6 = 0.693(R_1 + 14.43k\Omega)(100uF)$ $1 = 0.693R_2(100uF)$ $R_1 = 72.15k\Omega$ $R_2 = 14.43k\Omega$
Delay-On Timer
<u>Desired Output:</u>  Assumed the capacitor is 100uF $t_a = 1.1(R_a)\left(\frac{C}{1000}\right)$ $6 = 1.1(R_a)\left(\frac{100uF}{1000}\right)$ $R_a = 54.55k\Omega$

3.7 The PIC16F877A microcontroller operation

The receiver of the system is controlled by the PIC 16F877 microcontroller[13]. This microcontroller can be programme in C language to do various type of task. In this project, this particular microcontroller will be use to connect to the output of the wireless transmitter for the purpose of triggering. Then it will be programmed to activate the alarm/display, phone line and dial the emergency number via the normal DTMF telephone that is connected to the TELEKOM phone line. The conceptual of the receiver part is shown in **Figure 19.**

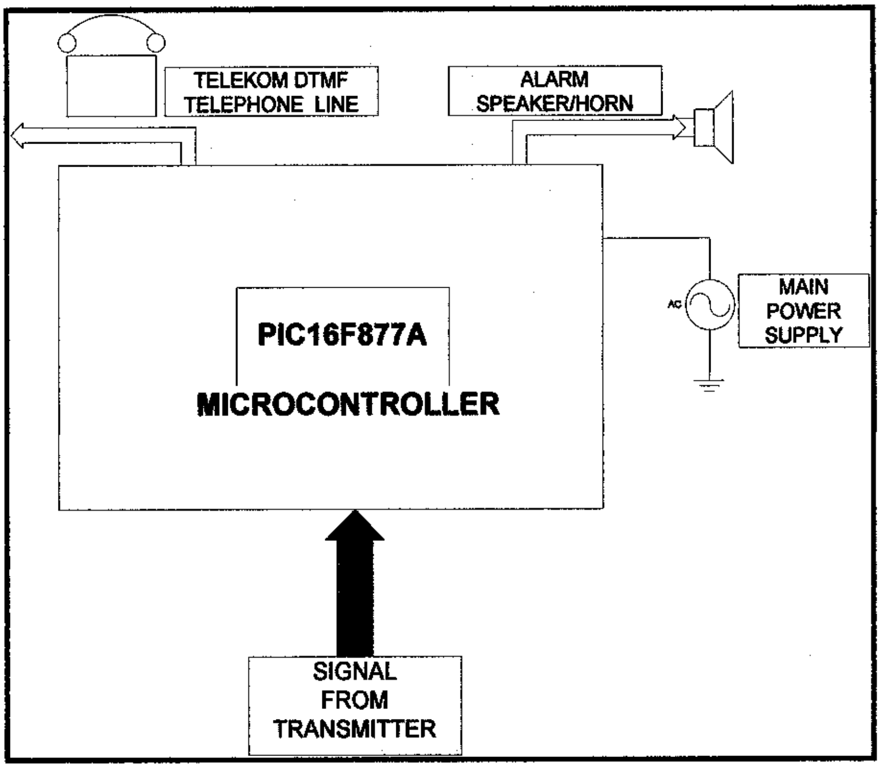


Figure 19: The conceptual of the receiver part.

All of these components will be embedded into one single casing in order to make it more tidy and good looking.

The working principles of this PIC microcontroller is that the PortA, RA0 (Pin2) input will be connected to the output of the wireless transmitter (the details of the PIC microcontroller pin diagram can be refer to **Appendix IV**) while the output RA2 will be connected to siren, PortB will be connected to LCD display, RA1 will be connected to telephone for line activation/deactivation, while RA3 is connected to the voice player/recorder and finally the PortC and PortD will be connected to each number of the telephone for dialling routines, the connection of the phone number and output of the microcontroller is shows in **Table 3** below

Table 3: Shows the connection between the number on the phone to the output of microcontroller.

No. on the phone	1	2	3
PIC output	RD4	RC7	RC6
No. on the phone	4	5	6
PIC output	RC5	RC4	RD3
No. on the phone	7	8	9
PIC output	RD2	RD1	RD0
No. on the phone	*	0	#
PIC output	RC3	RC2	RC1

This microcontroller will remains in stand by mode until the input has been triggered by the transmitter. Once the input is trigger, the output PortB of the microcontroller will be goes from Low to High which will activate the alarm, display and also the phone line. After that, the emergency number was dialed according to the programmed output bit.

The voice recorder will activate to tell the person on the phone about the alarm had been activated. Finally, when the recipient received the phone and acknowledge about the alarm, the phone line will be deactivated. The sequences of how the microcontroller work can be summarize in **Figure 20.**

The complete C programming code that used to run the sequences in **Figure 20** are shown in **Appendix V**.

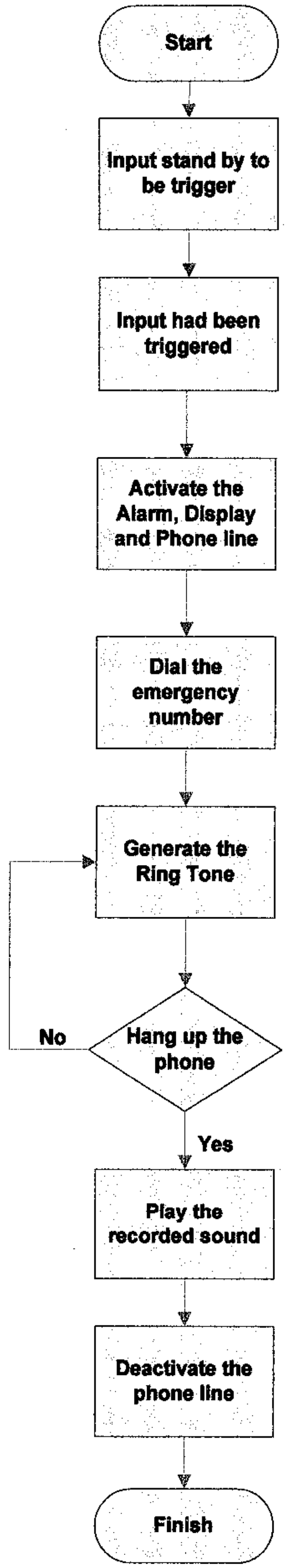


Figure 20: Shows the flow chart of PIC working sequence

3.8 Wireless Transmitter & Receiver

The transmitter and the receiver part for this project will be using the FM Transmitter & Receiver Hybrid Module (FM-RTFQ series & FM-RRFQ series). The block diagram for the transmitter and receiver is shown in **Figure 21(a) & (b)** below. The details of the transmitter and receiver can be refer to **Appendix VI**.

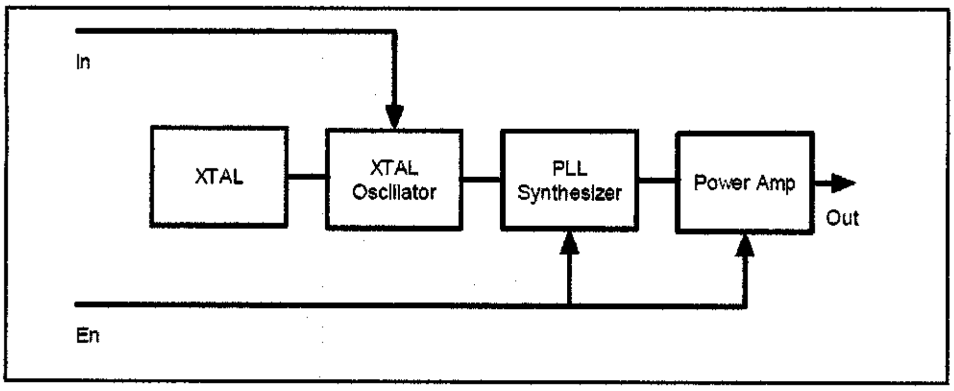


Figure 21(a): FM-RTFQ 868 Transmitter

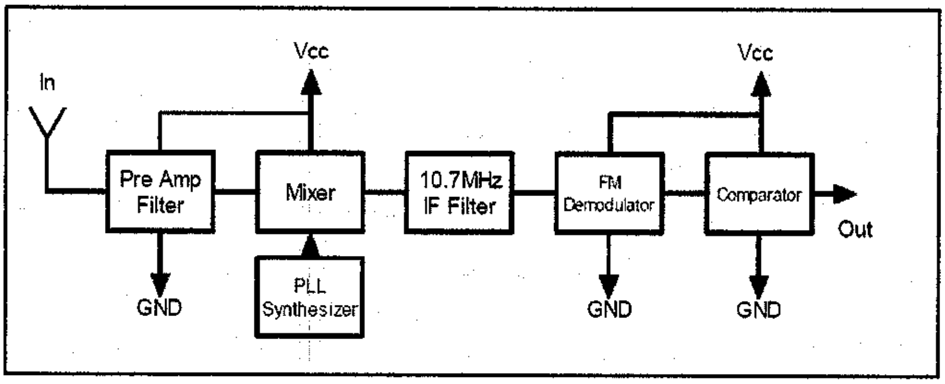


Figure 21(b): FM-RRFQ 868 Receiver

This two transmitter and receiver provide a cost effective high performance Radio data link and operates at 868Mhz. The trimmed Thick Film ceramic Hybrid Technology makes the modules very stable to operate over a temperature range.

The transmitter in able to send a signal at a distance up to 75 meters in building and 250 metres open ground. This distance will be suitable for the patient to walk around in the building without loosing the transmitting signal.

The wiring depends on the application of this transmitter and receiver. For this project, the connection was shown in **Figure 22(a) & (b)** the output of the heartbeat counter is connected directly to the data-in pin for the transmitter part and data-out to the input of the microcontroller.

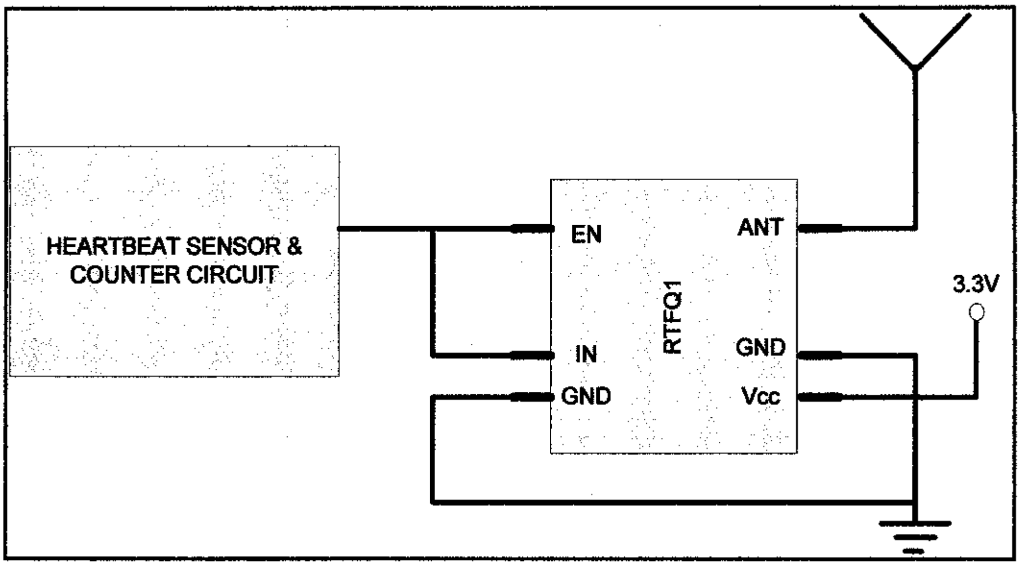


Figure 22(a): The connection of the transmitter part

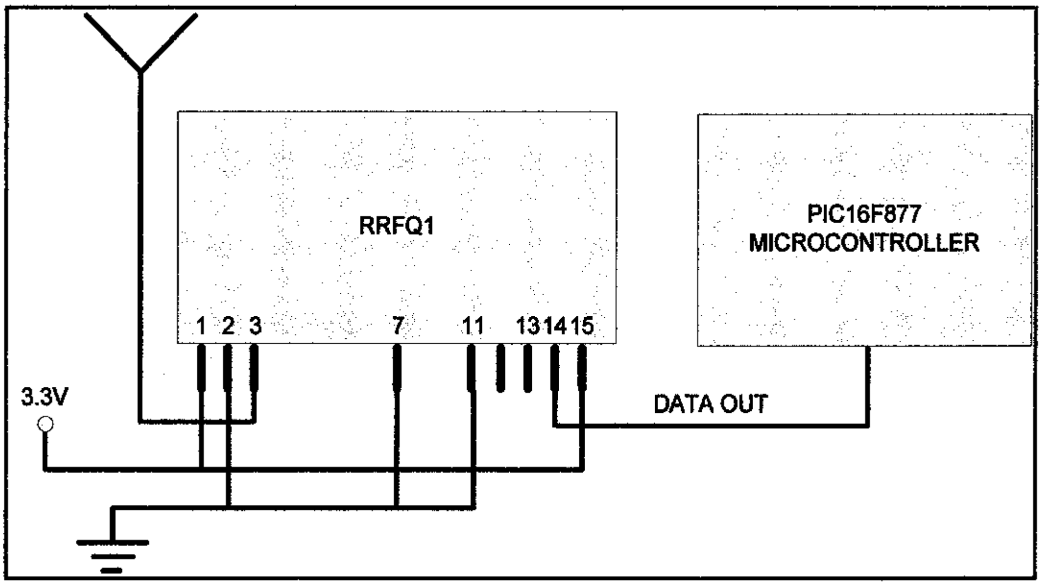


Figure 22 (b): The connection of the receiver part

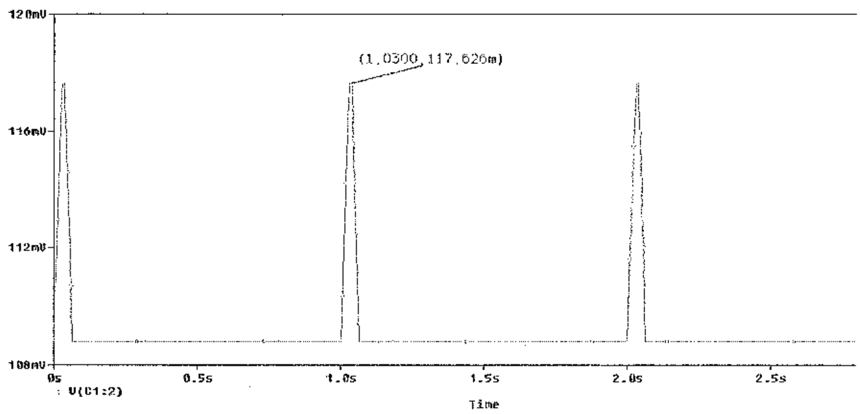
CHAPTER 4
RESULTS AND DISCUSSION

4.1 Phototransistor Interface Circuit Analysis

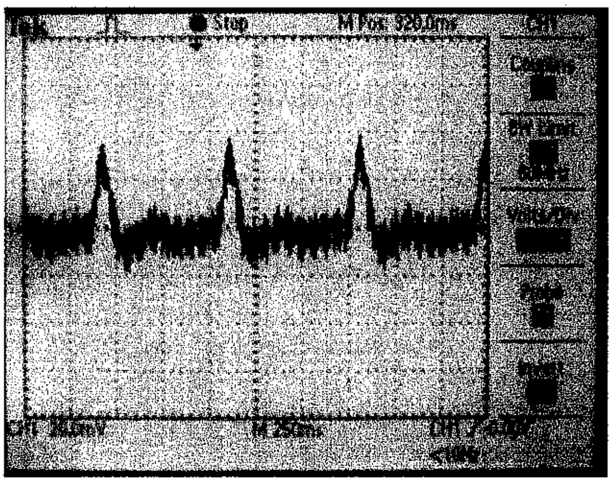
The Pspice circuit simulation had been used to simulate the phototransistor circuit. A few points on the circuit such as the phototransistor output, C1 output, op-amp U1A output and op-amp U2A output had been taps in order to see the waveform as shown in **Figure 6**(Chapter 2). Those same points also will be taps on the real circuit to check the differences.

4.1.2 Phototransistor output analysis

The phototransistor will detect the pulsating infra red which is shone through the finger and the output waveform will be first can be seen here as shown in the **Figure 23(a)** and **(b).**



(a)

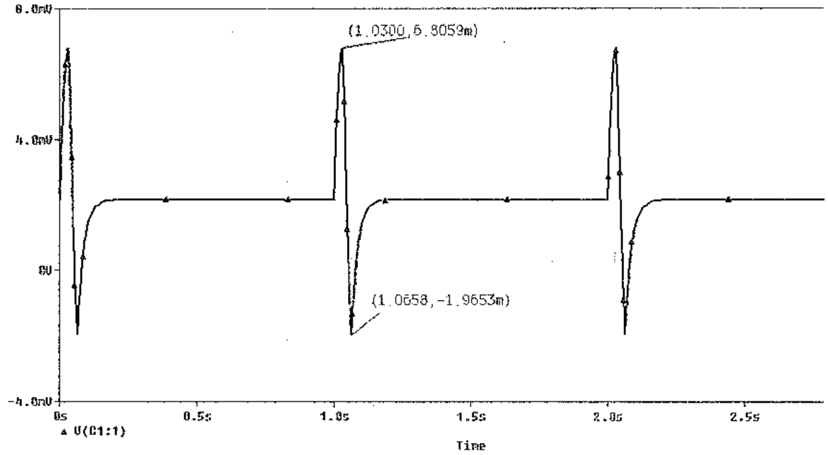


(b)

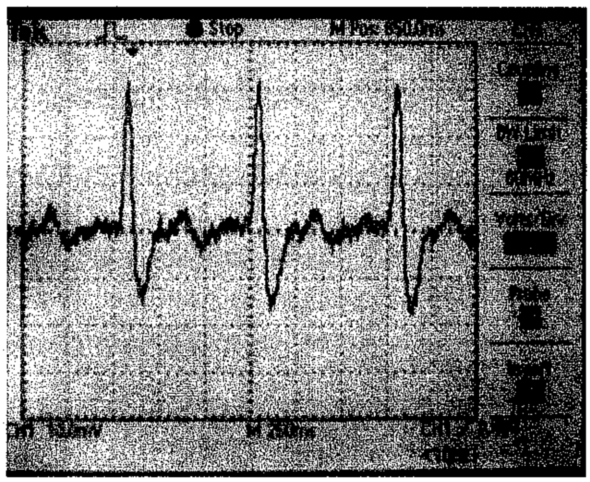
Figure 23: The comparison between the simulation result and practical result of the phototransistor output

4.1.3 Capacitor C1 output analysis

The C1 output is the op-amp U1A input. This signal will be amplified so that it can be compared at the U2A comparator op-amp. The simulation and also the real result are shown is **Figure 24.**



(a)



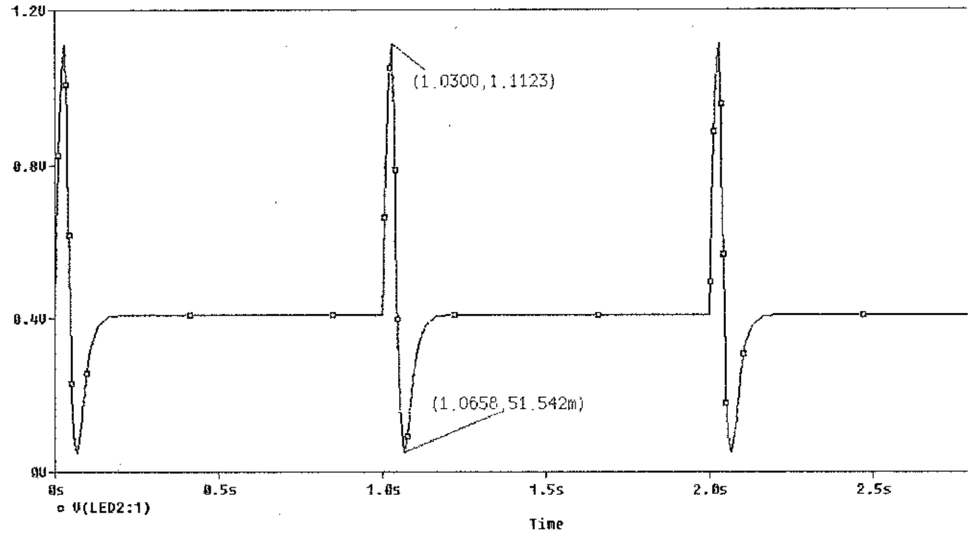
(b)

Figure 24: The comparison between the simulation and practical result of the capacitor C1 output

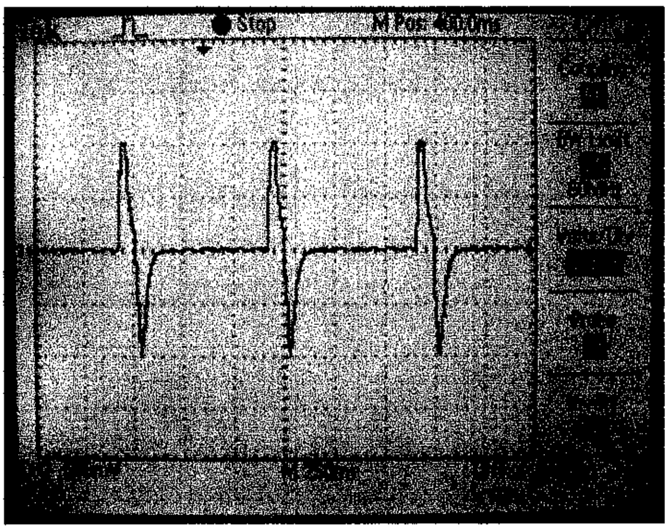
The **Figure 24(a)** and **Figure 24(b)** shows the comparable waveform between the simulation and oscilloscope output. However the output voltage is difference from each other.

The input pulses are changing from a single positive peak as shown in **Figure 23** to the positive and negative peak as shown in **Figure 24**. This is due to the charging and discharging of the speed up capacitor. The capacitor is use to eliminate the delay time of the BJT in the op-amp during the transition from 0V to +ve peak because of the base-emitter depletion layer is at its maximum width.

4.1.4 The Op-amp U1A output analysis



(a)



(b)

Figure 25: The comparison between the simulation and practical result of the op-amp U1A output

It can be seen that the output of the op-amp U1A shows the comparable waveform. However the peak-to-peak output voltage shows a different value.

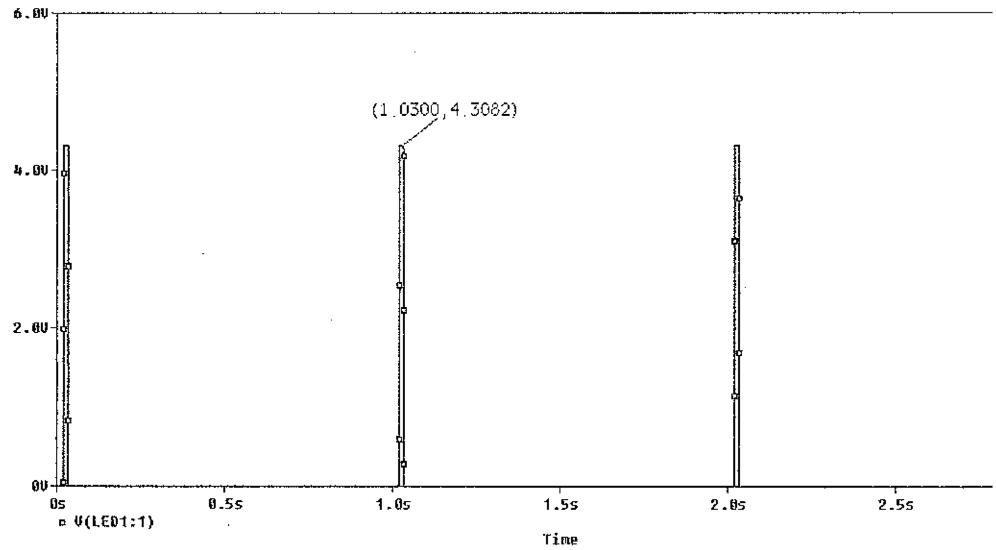
The equation 3.1 and equation 3.2 had been used to calculate the output of the op-amp U1A.

The calculation between the simulation result and the practical result is as shown in **Table 3**:

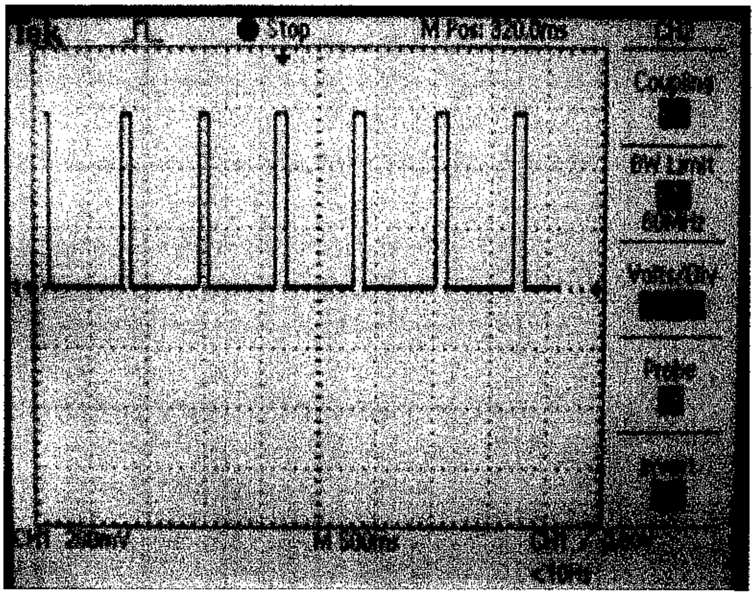
Table 3: The comparison between the simulation result and the practical result.

Simulation Result	Practical Result
Given, $Vin = 8.7712mV_{pp}$ [From Figure 14(a)]	Given, $Vin = 0.045V_{pp}$ [From Figure 14(b)]
$R_1 = 1k\Omega$ $R_2 = 100k\Omega$ $R_3 = 70k\Omega$ $\mathrm{A_{CL}} = \frac{R_f}{R_{in}} + 1$ $= \frac{(R_2 + R_3)}{R_1} + 1$ $= \frac{(100k + 70k)}{1k} + 1$ $= 171$	$R_1 = 1k\Omega$ $R_2 = 100k\Omega$ $R_3 = 70k\Omega$ $\mathrm{A_{CL}} = \frac{R_f}{R_{in}} + 1$ $= \frac{(R_2 + R_3)}{R_1} + 1$ $= \frac{(100k + 70k)}{1k} + 1$ $= 171$
$A_{CL} = \frac{V_{out}}{V_{in}}$ $V_{out} = 171(8.7712mV)$ $= 1.5V_{PP}$	$A_{CL} = \frac{V_{out}}{V_{in}}$ $V_{out} = 171(0.045)$ $= 7.69V_{PP}$
	Since the output voltage is beyond the limit of the output, the equation 3.6 is applied. $V_{out} \cong +V - 1V$ $\cong 5 - 1$ $\cong 4V_{PP}$
From the graph in Figure 15(a) the Vout is 1.06V_{pp}. The difference between the calculation result and simulation result is 0.44V_{pp}	From the graph in Figure 15(b) the Vout is 2V_{pp}. The difference between the calculation result and practical result is 2V_{pp}

4.1.5 The Op-amp U2A output analysis



(a)



(b)

Figure 25: The comparison between the simulation and practical result of the op-amp U2A output

The output from the op-amp U2A also shows a comparable waveform between the simulation result and the practical result. However there are different in output voltage as can be seen from the graph in **Figure 25**.

A calculation by using the equation 3.3, 3.4, 3.5 and 3.6 had been carried out to see the output voltage differences as shown in **Table 4**.

Table 4: The comparison between the simulation result and the practical result.

Simulation Result	Practical Result
Given: $+V = 5V$ $V_{in} = 1.11V_{peak}$	Given: $+V = 5V$ $V_{in} = 1V_{peak}$ [From Figure 15(b)]
$R_1 = 90k\Omega$ $R_3 = 10k\Omega$ $V_{ref} = +V\frac{R_3}{R_1 + R_3}$ $= 5\left(\frac{10k}{10k + 90k}\right)$ $= 0.5V$	$R_1 = 90k\Omega$ $R_3 = 10k\Omega$ $V_{ref} = +V\frac{R_3}{R_1 + R_3}$ $= 5\left(\frac{10k}{10k + 90k}\right)$ $= 0.5V$
$V_{diff} = V_{in} - V_{ref}$ $= 1.11 - 0.5$ $= 0.61V$	$V_{diff} = V_{in} - V_{ref}$ $= 1 - 0.5$ $= 0.5V$
$V_{out} \cong +V - 1V$ $\cong 5 - 1$ $\cong 4V_{peak}$	$V_{out} \cong +V - 1V$ $\cong 5 - 1$ $\cong 4V_{peak}$
From the graph in Figure 16(a) the Vout is $4.3V_{peak}$. The difference between the calculation result and simulation result is $0.3V_{peak}$	From the graph in Figure 16(b) the Vout is $0.6V_{peak}$. The difference between the calculation result and practical result is $3.4V_{peak}$

4.2 Summary of the result

The summary of the simulation and the practical result is shown in the **Table 5** below:

Table 5 : The summary of the simulation result and the practical result

Output	Simulation Result	Practical Result
Phototransistor	$117.62mV_{peak}$	$30mV_{peak}$
Capacitor,C1	$8.7712mV_{pp}$	$45mV_{pp}$
Op-amp U1A	$1.06V_{pp}$	$1V_{pp}$
Op-amp U2A	$4.30V_{peak}$	$600mV_{peak}$

From **Table 5**, it seems that the voltages are difference from each other and this is mainly due to the characteristic of the real components and simulation components. The noise such as light will also affect the output voltage from the phototransistor.

4.3 The Heartbeat Counter Output

The main function of the heartbeat counter is to count the heartbeat whether it is normal heartbeat or abnormal heartbeat which is *Tachycardia* and *Bradycardia.* The **Figure 26(a),(b) and (c)** show the response of the magnitude comparator when it sense a normal heartbeat and abnormal heartbeat.

When the counter count a normal heartbeat which is in the range of 7 to 9 beats, the magnitude comparator output will never goes HIGH. As shows in **Figure 26(a)** below.

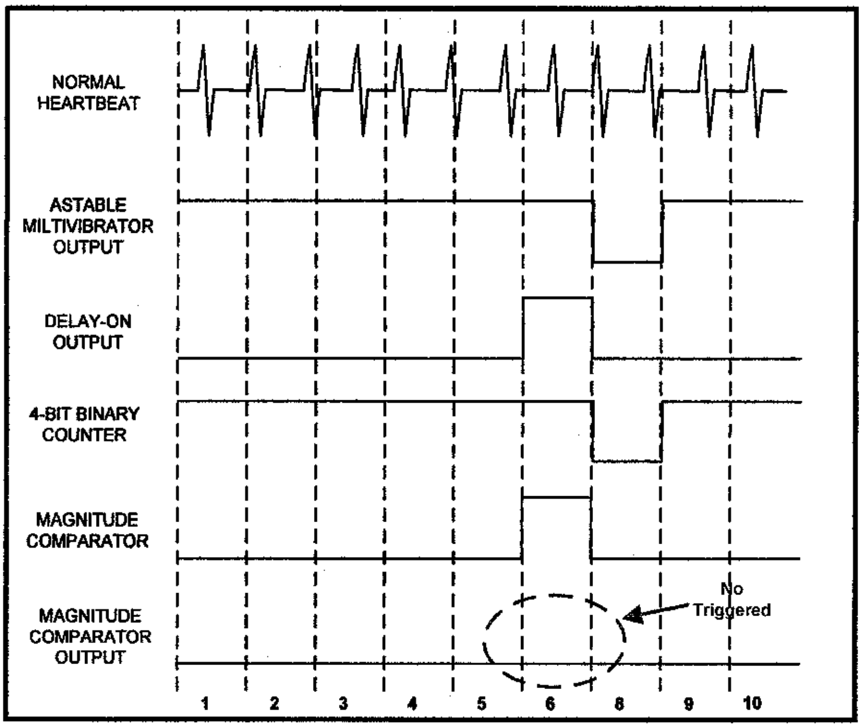


Figure 26(a): The magnitude comparator will not triggered when the heartbeat is normal

However if the Magnitude Comparator count a heartbeat which is less than 6 beats per 6 second, the output will goes HIGH to trigger the transmitter as shows in **Figure 26(b)**. This condition applied when the heartbeat sense a heartbeat which is more than 10 beats per 6 second as shows in **Figure 26(c).**

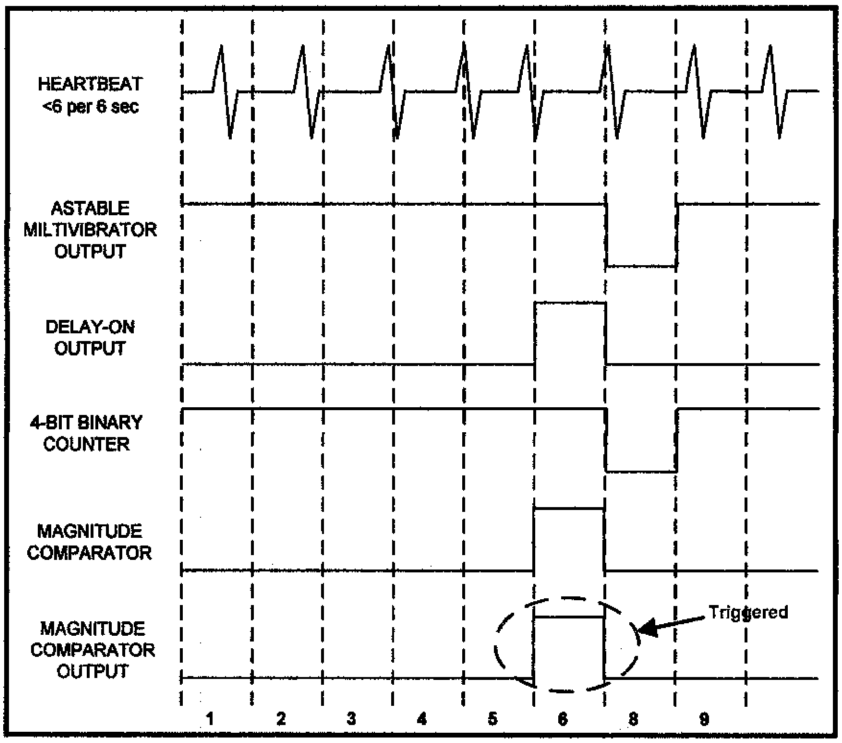


Figure 26(b): The heartbeat less than 6 beats in 6 second will trigger the magnitude comparator

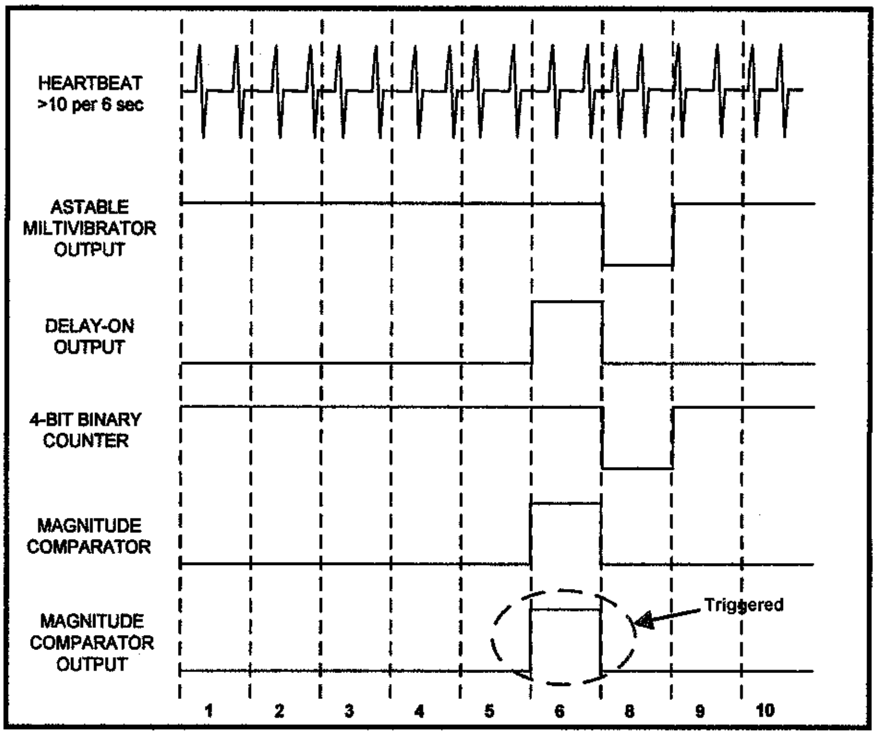


Figure 26(c): The heartbeat more than 10 in 6 second will trigger the magnitude comparator

4.4 The Testing Result of the Counter Circuit

The circuit was converted to the PCB layout and those components are puts as near as possible to make the circuit as compact as possible. The figure below shows the layout of the counter circuit.

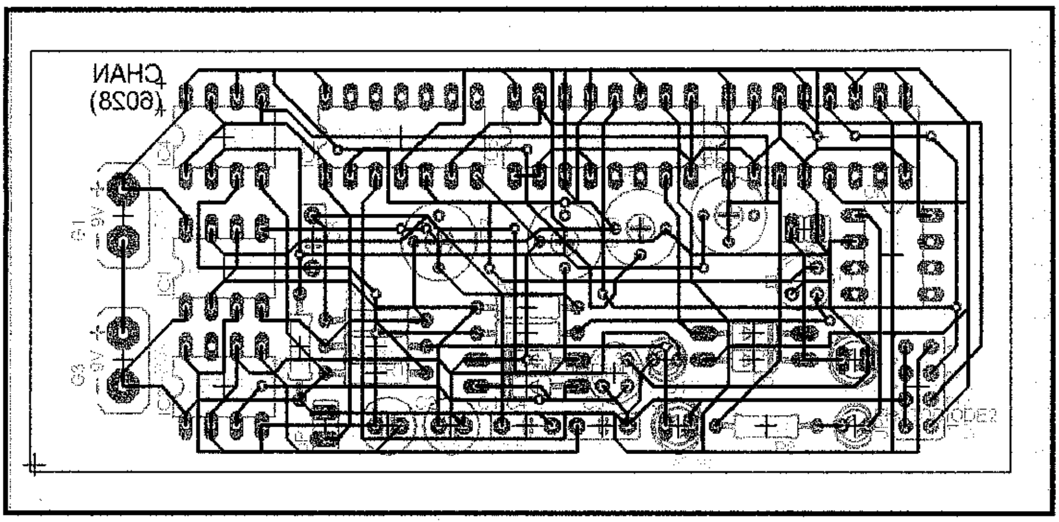


Figure 27: Shows the counter PCB layout.

Once the layout was successfully transfered into the PCB as shown in **Figure 28,** the circuit must is tested for the continuity for each track. After that, all the components will be soldered on it. Next, checking for all the components polarity is done. Finally the voltage is applied and checked to see if there any smoky or hot components.

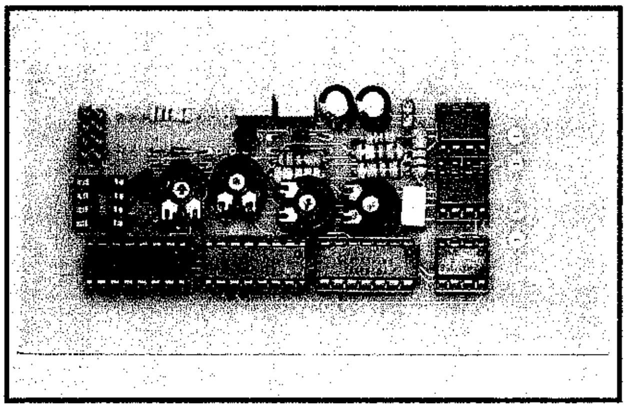


Figure 28(a): Shows the Top view of the Counter Circuit

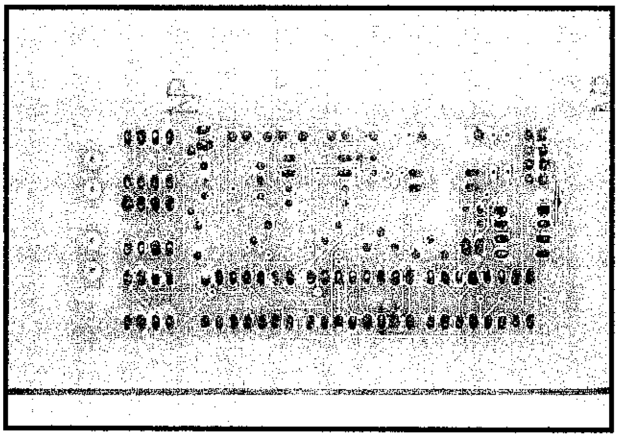


Figure 28(b): Shows the Bottom view of the Counter Circuit

This counter circuit passed all the checking criteria and it was tested successful for functionality whereby the IR sensor can sense the heartbeat and the counter can counts the heartbeat.

After that, the circuit must be put inside a casing in order to protect it and can be carrying by the patient. The picture of the casing is shown in **Appendix VII.**

CHAPTER 5

CONCLUSION AND RECOMMENDATION

A Heart Beat Failure Detector is believed can be a very useful device to help the children who has a heart problem parents. They do not need to worry some more when they leave their parents at home while they going to work.

In fulfilment of the project objective, a research on the sensor that needs to detect the heart beat have been carried out where the sensor is use the Infra Red LED to transmit the infra red light at a wavelength of approximately 940nm to measure the pulsatile blood volume changes. The pulsatile light signal that received by phototransistor is then amplified by Op-amp. The Op-amp successfully amplified the signal and showed it in the pulse waveform which is proportional to the real heartbeat.

The design on the counter circuit that need to counts the heart beat also have been carried out where the Binary Counter is used to counts the heartbeat and the Magnitude Comparator is to compare the measured heartbeat with the reference of normal heartbeat, fast heartbeat(*Bradycardia*) and slow heartbeat(*Tachycardia*). This counter circuit can successfully differentiate between the normal heartbeat and abnormal heartbeat (*Bradycardia & Tachycardia*).

The type of transmitter and receiver that had been identified to use for this project are FM-RRFQ 868 Receiver and FM-RRFQ 868 Receiver which is used the FM modulation and can send the signal up to 75 metres or 250 metres at open ground. The receiver was interface together with the microcontroller whereby this microcontroller is used to activate the siren, perform the auto dialing via DTMF phone line to inform the hospital or patient's children.

It is recommended that the heartbeat detector circuit be converted into the SMT(Surface Mount Technology) so that the circuit will be more smaller and lighter without changing its original circuit design. The sensitivity of the sensor part also need to be improve so that it can be automatically measure the pulse after put it on the finger without need to adjust the sensor position. The detector part also still can be improved by putting in an LCD display unit, so that it can display the number of heartbeat, blood pressure and also local time. The detector also should detect more type of heart failure such as *Atrial fibrillation.*

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APPENDIX I

FINAL YEAR PROJECT GANTT CHART (JAN-MAY 2006)																		
		Jan 06		Feb 06				March 06				April 06				May 06		Remark
	Status	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
(1) Title proposal/selection																		
a) Submit the proposal/selection form	Done																	
d) First discussionwith supervisor	Done																	
(2) Project Research																		
Study on method to detect heart beat	Done																	
Find the sensor available in market	Done																	
Study on the type of sensor amplifier circuit	Done																	
Study the basic signal transceiver	Done																	
Find the suitable transceiver for this project	Done																	
(3) Circuit Design																		
Draw the circuit using Pspice software	Done																	
Circuit simulation	Done																	
(4) Hardware Implementation																		
Buy the component	Done																	
Test the circuit on the Protoboard	Done																	

FINAL YEAR PROJECT GANTT CHART (JUN-DECEMBER 2006)

		Jun 06		July 06			August 06						Sept 06				October 06				November 06					December 06				Remark
	Status	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
(1) Heartbeat Counter & Alarm Trigger Circuit																														
a) Circuit Study & Design	Done																													
b) Circuit simulaion	Done																													
c) Buy the component	Done																													
d) Test on breadboard	Done																													
(2) Transmitter & Receiver Circuit																														
a) Circuit Study & Design	Done																													
b) Circuit simulaion	Done																													
c) Buy the component	Done																													
d) Test on breadboard	Done																													
(3) Transfer the circuit into PCB																														
a) Draw & design the PCB layout	Done																													
b) Transfer to the board	Done																													
c) Etching	Done																													
d) Drilling	Done																													
e) Soldering	Done																													
f) Testing	Done																													
(4) Casing Fabrication																														
a) Ring fabrication	Done																													
b) Circuit casing fabrication	Done																													
c) Final Test	Done																													

FAIRCHILD
SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS393
Dual 4-Bit Binary Counter

General Description

Each of these monolithic circuits contains eight master-slave flip-flops and additional gating to implement two individual four-bit counters in a single package. The DM74LS393 comprises two independent four-bit binary counters each having a clear and a clock input. N-bit binary counters can be implemented with each package providing the capability of divide-by-256. The DM74LS393 has parallel outputs from each counter stage so that any submultiple of the input count frequency is available for system-timing signals.

Features

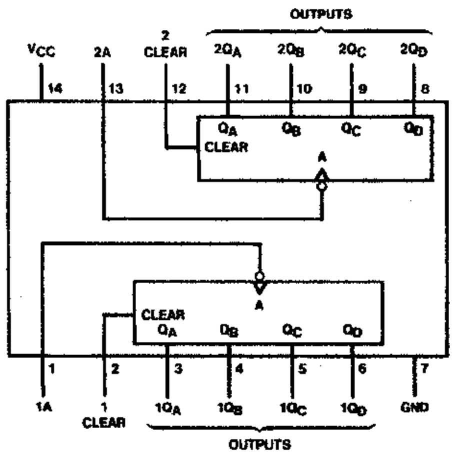
- Dual version of the popular DM74LS93
- DM74LS393 dual 4-bit binary counter with individual clocks
- Direct clear for each 4-bit counter
- Dual 4-bit versions can significantly improve system densities by reducing counter package count by 50%
- Typical maximum count frequency 35 MHz
- Buffered outputs reduce possibility of collector commutation

Ordering Code:

Order Number	Package Number	Package Description
DM74LS393M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS373N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



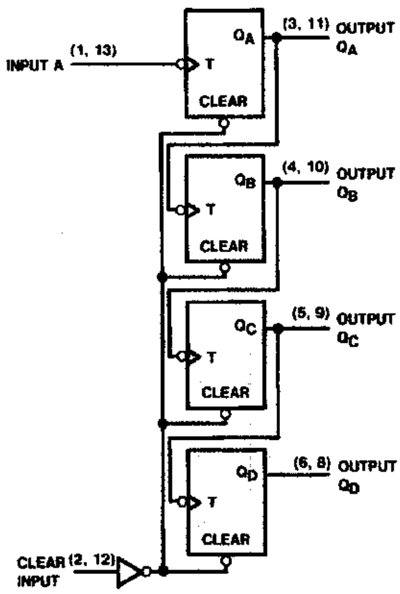
Function Table

Counter Sequence (Each Counter)

Count	Outputs			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
10	H	L	H	L
11	H	L	H	H
12	H	H	L	L
13	H	H	L	H
14	H	H	H	L
15	H	H	H	H

H = HIGH Logic Level
L = LOW Logic Level

Logic Diagram



Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	
Clear	7V
A	5.5V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter		Min	Nom	Max	Units
V_{CC}	Supply Voltage		4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage		2			V
V_{IL}	LOW Level Input Voltage				0.8	V
I_{OH}	HIGH Level Output Current				−0.4	mA
I_{OL}	LOW Level Output Current				8	mA
f_{CLK}	Clock Frequency (Note 2)		0		25	MHz
f_{CLK}	Clock Frequency (Note 3)		0		20	MHz
t_W	Pulse Width (Note 5)	A	20			ns
		Clear HIGH	20			
t_{REL}	Clear Release Time (Note 4)(Note 5)		25↓			ns
T_A	Free Air Operating Temperature		0		70	°C

Note 2: $C_L = 15$ pF, $R_L = 2$ kΩ, $T_A = 25°C$ and $V_{CC} = 5V$.

Note 3: $C_L = 50$ pF, $R_L = 2$ kΩ, $T_A = 25°C$ and $V_{CC} = 5V$.

Note 4: The symbol (↓) indicates that the falling edge of the clear pulse is used for reference.

Note 5: $T_A = 25°C$, and $V_{CC} = 5V$.

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 6)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max, V_{IH} = Min		2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IL} = Max, V_{IH} = Min			0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min			0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V	Clear			0.1	mA
		V_{CC} = Max, V_I = 5.5V	A			0.2	
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.7V	Clear			20	μA
			A			40	
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V	Clear			−0.4	mA
			A			−1.6	
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 7)		−20		−100	mA
I_{CC}	Supply Current	V_{CC} = Max (Note 8)			15	26	mA

Note 6: All typicals are at $V_{CC} = 5V$, $T_A = 25°C$.

Note 7: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Note 8: I_{CC} is measured with all outputs open, both CLEAR inputs grounded following momentary connection to 4.5V, and all other inputs grounded.

Switching Characteristics

at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	From (Input) To (Output)	R_L = 2 kΩ				Units
			C_L = 15 pF		C_L = 50 pF		
			Min	Max	Min	Max	
f_{MAX}	Maximum Clock Frequency	A to Q_A	25		20		MHz
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	A to Q_A		20		24	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	A to Q_A		20		30	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	A to Q_D		60		87	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	A to Q_D		60		87	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	Clear to Any Q		39		45	ns

FAIRCHILD
SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS85
4-Bit Magnitude Comparator

General Description

These 4-bit magnitude comparators perform comparison of straight binary or BCD codes. Three fully-decoded decisions about two, 4-bit words (A, B) are made and are externally available at three outputs. These devices are fully expandable to any number of bits without external gates. Words of greater length may be compared by connecting comparators in cascade. The A > B, A < B, and A = B outputs of a stage handling less-significant bits are connected to the corresponding inputs of the next stage handling more-significant bits. The stage handling the least-significant bits must have a high-level voltage applied to the A = B input. The cascading path is implemented with only a two-gate-level delay to reduce overall comparison times for long words.

Features

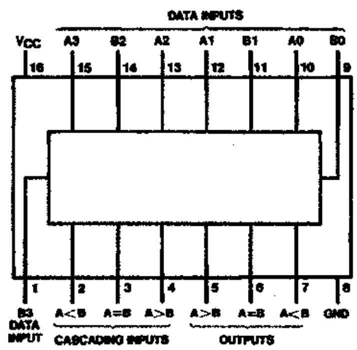
- Typical power dissipation 52 mW
- Typical delay (4-bit words) 24 ns

Ordering Code:

Order Number	Package Number	Package Description
DM74LS85M	M16A	16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow
DM74LS85N	N16E	16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



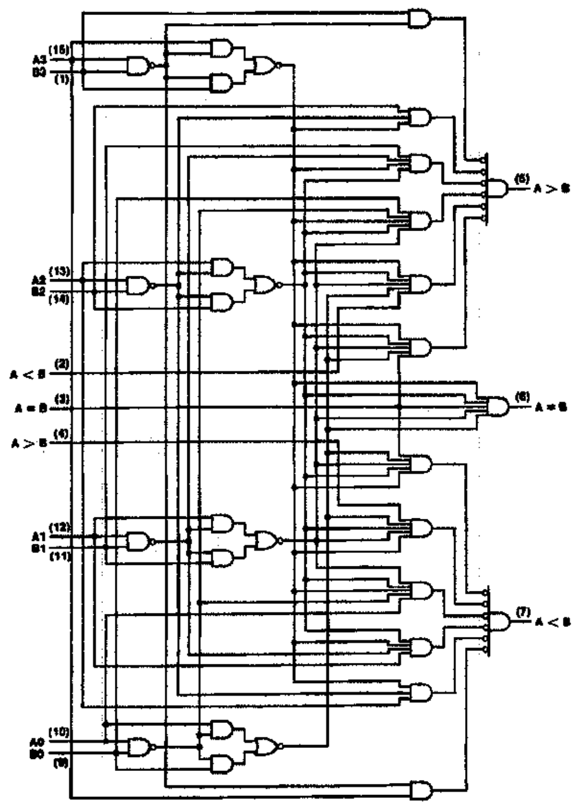
 DS006379 www.fairchildsemi.com

Function Table

Comparing Inputs				Cascading Inputs			Outputs		
A3, B3	A2, B2	A1, B1	A0, B0	A > B	A < B	A = B	A > B	A < B	A = B
A3 > B3	X	X	X	X	X	X	H	L	L
A3 < B3	X	X	X	X	X	X	L	H	L
A3 = B3	A2 > B2	X	X	X	X	X	H	L	L
A3 = B3	A2 < B2	X	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 > B1	X	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 < B1	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 > B0	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 < B0	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	L	L	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	H	L	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	H	L	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	X	X	H	L	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	H	L	L	L	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	L	H	H	L

H = HIGH Level, L = LOW Level, X = Don't Care

Logic Diagram



DM74LS85

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	°C

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max V_{IL} = Max, V_{IH} = Min		2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IL} = Max, V_{IH} = Min			0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min			0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max V_I = 7V	A < B			0.1	mA
			A > B			0.1	
			Others			0.3	
I_{IH}	HIGH Level Input Current	V_{CC} = Max V_I = 2.7V	A < B			20	μA
			A > B			20	
			Others			60	
I_{IL}	LOW Level Input Current	V_{CC} = Max V_I = 0.4V	A < B			−0.4	mA
			A > B			−0.4	
			Others			−1.2	
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)		−20		−100	mA
I_{CC}	Supply Current	V_{CC} = Max (Note 4)			10	20	mA

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Note 4: I_{CC} is measured with all outputs OPEN, A = B grounded and all other inputs at 4.5V.

Switching Characteristics

at $V_{CC} = 5V$ and $T_A = 25°C$

Symbol	Parameter	From Input	To Output	Number of Gate Levels	$R_L = 2 k\Omega$				Units
					$C_L = 15 pF$		$C_L = 50 pF$		
					Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	Any A or B Data Input	A < B, A > B	3		36		42	ns
			A = B	4		40		40	
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	Any A or B Data Input	A < B, A > B	3		30		40	ns
			A = B	4		30		40	
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	A < B or A = B	A > B	1		22		26	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	A < B or A = B	A > B	1		17		26	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	A = B	A = B	2		20		25	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	A = B	A = B	2		17		26	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	A > B or A = B	A < B	1		22		26	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	A > B or A = B	A < B	1		17		26	ns

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

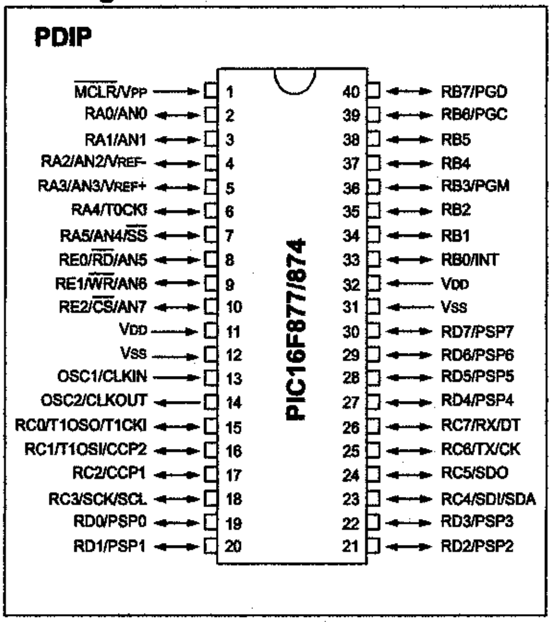
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

```
//Author:Chan Seng Koon
//**Microcontroller's C Programming code for Transmitter Part**//

#include <16f877a.h>
#USE DELAY(CLOCK=4000000) /* Using a 4 Mhz clock */
#FUSES XT,NOWDT,NOPROTECT, NOPUT, NOBROWNOUT,NOLVP
#include <stdio.h>
#include <LCD.C>
#include <string.h>

#define  PHONE_NO_1  PIN_D4    //Phone dialling number
#define  PHONE_NO_2  PIN_C7
#define  PHONE_NO_3  PIN_C6
#define  PHONE_NO_4  PIN_C5
#define  PHONE_NO_5  PIN_C4
#define  PHONE_NO_6  PIN_D3
#define  PHONE_NO_7  PIN_D2
#define  PHONE_NO_8  PIN_D1
#define  PHONE_NO_9  PIN_D0
#define  PHONE_NO_*  PIN_C3
#define  PHONE_NO_0  PIN_C2
#define  PHONE_NO_e  PIN_C1    //assign for # number

#define  PHONE_LINE  PIN_A1
#define  SIREN       PIN_A2
#define  VOICE_REC   PIN_A3

#define  TX_TRIG     PIN_A0
#define  BEEP        PIN_E2
#define  STAND_BY    PIN_C0

main()


{
   lcd_init();
   //while(1)
   //{
   //Display HEART FAILURE DETECTOR

     lcd_gotoxy(1,1);
     lcd_putc('\f');
     lcd_putc("HEART");


     lcd_putc('\n');
     lcd_putc("FAILURE");
     delay_ms(1000);

     lcd_gotoxy(1,1);
     lcd_putc('\f');
     lcd_putc("DETECTOR");
     delay_ms(1000);
     output_bit(STAND_BY,1);

      //{
      while(1)
         {
          if (input(TX_TRIG))         //transmitter output is high
            {
               //do
               //{
      loop1:
               output_bit(STAND_BY,0);
               lcd_gotoxy(1,1);
```

```
        lcd_putc('\f');
        lcd_putc("WARNING!!");
        delay_ms(700);


        output_bit(SIREN,1);       //siren activated
        //delay_ms(1000);
        lcd_gotoxy(1,1);
        lcd_putc('\f');
        lcd_putc("SIREN");
        lcd_putc('\n');
        lcd_putc("ACTIVATE");
        delay_ms(700);

        output_bit(PHONE_LINE,1);       //Phone line activated
        //delay_ms(1000);
        lcd_gotoxy(1,1);
        lcd_putc('\f');
        lcd_putc("PHONE LI");
        lcd_putc('\n');
        lcd_putc("NE ACTIV");
        delay_ms(5000);

        output_bit(SIREN,0);
        lcd_gotoxy(1,1);
        lcd_putc('\f');
        lcd_putc("DIAL:019");
        lcd_putc('\n');
        lcd_putc(" 9043268");
        delay_ms(1000);

        output_bit(PHONE_NO_0,1);       //Dial 1st number
        output_bit(BEEP,1);
        delay_ms(500);
        output_bit(BEEP,0);
        output_bit(PHONE_NO_0,0);
        delay_ms(500);

        output_bit(PHONE_NO_1,1);       //Dial 2nd number
        output_bit(BEEP,1);
        delay_ms(500);
        output_bit(BEEP,0);
        output_bit(PHONE_NO_1,0);
        delay_ms(500);

        output_bit(PHONE_NO_9,1);       //Dial 3rd number
        output_bit(BEEP,1);
        delay_ms(500);
        output_bit(BEEP,0);
        output_bit(PHONE_NO_9,0);
        delay_ms(500);

        output_bit(PHONE_NO_9,1);       //Dial 4th number
        output_bit(BEEP,1);
        delay_ms(500);
        output_bit(BEEP,0);
        output_bit(PHONE_NO_9,0);
        delay_ms(500);

        output_bit(PHONE_NO_0,1);       //Dial 5th number
        output_bit(BEEP,1);
        delay_ms(500);
        output_bit(BEEP,0);
        output_bit(PHONE_NO_0,0);
        delay_ms(500);
```

```
output_bit(PHONE_NO_4,1);      //Dial 6th number
output_bit(BEEP,1);
delay_ms(500);
output_bit(BEEP,0);
output_bit(PHONE_NO_4,0);
delay_ms(500);

output_bit(PHONE_NO_3,1);      //Dial 7th number
output_bit(BEEP,1);
delay_ms(500);
output_bit(BEEP,0);
output_bit(PHONE_NO_3,0);
delay_ms(500);

output_bit(PHONE_NO_2,1);      //Dial 8th number
output_bit(BEEP,1);
delay_ms(500);
output_bit(BEEP,0);
output_bit(PHONE_NO_2,0);
delay_ms(500);

output_bit(PHONE_NO_6,1);      //Dial 9th number
output_bit(BEEP,1);
delay_ms(500);
output_bit(BEEP,0);
output_bit(PHONE_NO_6,0);
delay_ms(500);

output_bit(PHONE_NO_8,1);      //Dial 10th number
output_bit(BEEP,1);
delay_ms(500);
output_bit(BEEP,0);
output_bit(PHONE_NO_8,0);
delay_ms(500);

delay_ms(500);
output_bit(VOICE_REC,1);      //Voice recorder activated
//delay_ms(100);
lcd_gotoxy(1,1);
lcd_putc('\f');
lcd_putc("VOICE ");
lcd_putc('\n');
lcd_putc("ACTIVATE");
//delay_ms(1000);
delay_ms(10000);

output_bit(VOICE_REC,0);

output_bit(SIREN,1);
output_bit(PHONE_LINE,0);      //Phone line deactivated
lcd_gotoxy(1,1);
lcd_putc('\f');
lcd_putc("PHONE");
lcd_putc('\n');
lcd_putc("DEACTIVE");
delay_ms(2000);
{
while(1)
{
lcd_gotoxy(1,1);               //Display blinking "WARNING!" w
lcd_putc('\f');
lcd_putc("WARNING!!");

if (input(TX_TRIG))
```

```
            goto loop1;
            delay_ms(1000);
            lcd_gotoxy(1,1);
            lcd_putc('\f');
            lcd_putc("  ");

            if (input(TX_TRIG))
            goto loop1;
            delay_ms(1000);

            if (input(TX_TRIG))
            goto loop1;
            }
            }

            //}
           // while(1);
           //     {

              }
        //}
      else(!input(TX_TRIG));     //transmitter output is low
         {
            lcd_gotoxy(1,1);      //Display Stand By mode
            lcd_putc('\f');
            lcd_putc("STAND BY");


            lcd_putc('\n');
            lcd_putc(" MODE...");
            delay_ms(300);


         }



      }
   }
```

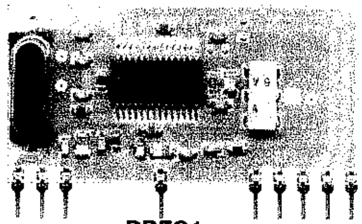
APPENDIX VI

FM TRANSMITTER & RECEIVER HYBRID MODULES.

FM-RTFQ SERIES FM-RRFQ SERIES

- FM Radio Transmitter & Receivers
- Available As 315 or 433 or 868MHz
- Transmit Range Up To 250m
- Miniature Packages
- Data Rate upto 9.6Kbps
- No Adjustable Components
- Very Stable Operating Frequency
- Operates from –20 to +85°C

RTFQ1



RRFQ1

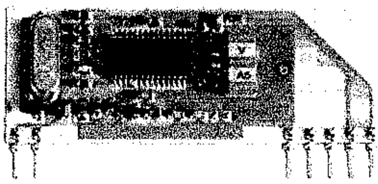
Transmitter

- 3-12 Supply Voltage
- SIL or DIL Package

Receiver

- PLL XTAL Design
- CMOS/TTL Output
- RSSI Output
- **Standby Mode (max 100nA)**
- 5V Supply Voltage

RTFQ2



RRFQ2

Applications

- Wireless Security Systems
- Car Alarms
- Remote Gate Controls
- Remote Sensing
- Data Capture
- Sensor Reporting

Description

These miniature RF modules provide a cost effective high performance FM Radio data link, at either 315, 433.92 or 868MHz. Manufactured using laser trimmed Thick Film ceramic Hybrid the modules exhibits extremely stable electronic characteristics over an Industrial Temperature range. The hybrid technology uses no adjustable components and ensures very reliable operation.
This transmitter and receiver pair enables the simple implementation of a data link at distances upto 75 metres in-building and 250 metres open ground.

These modules will suit one-to-one and multi-node wireless links in applications including car and building security, EPOS and inventory tracking, remote industrial process monitoring and computer networking. Because of their small size and low power requirements, both modules are ideal for use in portable, battery-powered applications such as hand-held terminals.

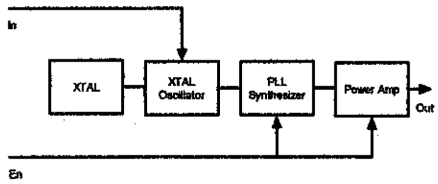
Transmitters

There are two versions of transmitter:

RTFQ1; A Dual in Line Package operating at 3.3V. This provides the most rugged mechanical fixing to the host PCB. Power Down mode is also available.

RTFQ2; A Single in Line Package incorporating a voltage regulator for 3-12V operation. (Compatible with many other RF transmitter modules available)

Transmitter Block Diagram



Part Numbering

Part Number	Description
FM-RTFQ1-315	DIL FM Transmitter Module 315 MHz
FM-RTFQ1-433	DIL FM Transmitter Module 433.92 MHz
FM-RTFQ1-868	DIL FM Transmitter Module 868.35 MHz
FM-RTFQ2-433R	SIL FM Transmitter Module 433.92 MHz 3-12V I/P
FM-RTFQ2-868R	SIL FM Transmitter Module 868.35 MHz 3-12V I/P

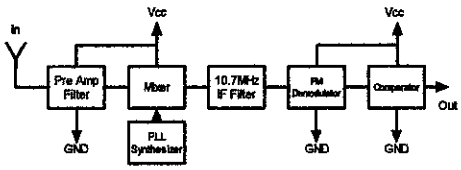
Receivers

There are two versions of receiver:

RRFQ1: A Single in Line Package with sleep / Power down mode.

RRFQ2: A Single in Line Package, pin compatible with many other receivers

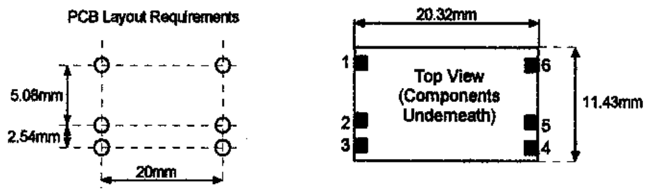
Receiver Block Diagram



Part Numbering

Part Number	Description
FM-RRFQ1-315	SIL FM Receiver Module 315 MHz
FM-RRFQ1-433	SIL FM Receiver Module 433.92 MHz
FM-RRFQ1-868	SIL FM Receiver Module 868.35 MHz
FM-RRFQ2-433	SIL FM Receiver Module 433.92 MHz
FM-RRFQ2-868	SIL FM Receiver Module 868.35 MHz

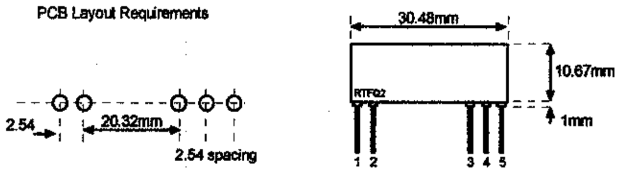
RTFQ1 Mechanical Dimensions



Module Thickness 2mm

Pins on "0.1 pitch
Pin Dimensions :
0.25mm x 0.50mm

RTFQ2 Mechanical Dimensions



Module Thickness 2mm

Pins on "0.1 pitch
Pin Dimensions :
0.25mm x 0.50mm

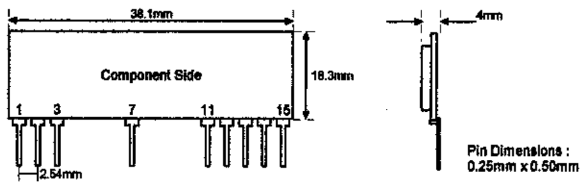
Pin Description

RTFQ1	RTFQ2	Name	Description
1	N/A	En	Enable (active high)
2	5	IN	Data input
3	1	GND	Ground, Connect to RF earth return path
4	3	Vcc	Supply Voltage
5	4	GND	Ground, Connect to RF earth return path
6	2	EA	External Antenna

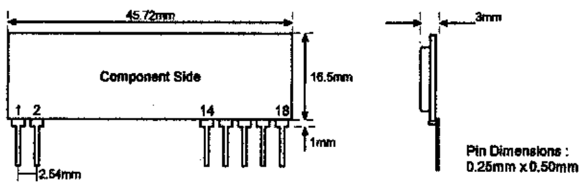
Technical Specifications

Electrical Characteristics	MIN	TYPICAL	MAX	DIMENSION
Supply Voltage RTFQ1	2.1	3.3	4.00	V
Supply Voltage RTFQ2	2.5		12.00	V
Supply Current		7	8	mA
Standby Current (IN = EN = Low)			100	nA
Frequency		315.0 433.92 868.35		MHz
RF Output into 50Ω (Vcc=3.3V)		+5 / +5 / +1		dBm
Initial Frequency Accuracy	-35	0	+35	KHz
FM Deviation	25	30	35	KHz
Harmonic Spurious Emissions		-50		dBc
Input High Voltage RTFQ1	1.5		Vcc	V
Input High Voltage RTFQ2	1.5		5.5	V
Power up Time (En to full RF)			1	mS
Power up Time (Power on to full RF)			5	mS
Max Data Rate			9.6	KHz
Operating Temperature	-25		+80	°C

RRFQ1 Mechanical Details



RRFQ2 Mechanical Details



Pin Description

RRFQ1	RRFQ2	Pin Description
1	16	+Vcc
2,7,11	2,15	GND
3	1	Data In (Antenna)
12		NC
13	14	Received Signal Strength Output
N/A	17	AF Output
14	18	Data Out
15	N/A	Power Down 0V = Standby 5V = Operating

RSSI Output*

RF In (dBm)	RSSI (V)
-120	1.20
-110	1.32
-100	1.50
-90	1.78
-80	2.06
-70	2.35
-60	2.62
-50	2.72
-40	2.75

RSSI Output

The RSSI provides a DC Voltage proportional to the peak value of the receive data signal. This output can be used as an indicator for the received signal strength to use in wake-up circuits etc.

An RC circuit is normally used to provide the timing for the RSSI signal. The modules have a 10nF capacitor internally connected to GND, therefore a pull down resistor (to GND) connected to the RSSI pin may be used to generate a simple RC network time constant for the RSSI signal output.

Please note that the maximum output current is typically 950µA, the discharge current is lower than 2µA

Technical Specifications

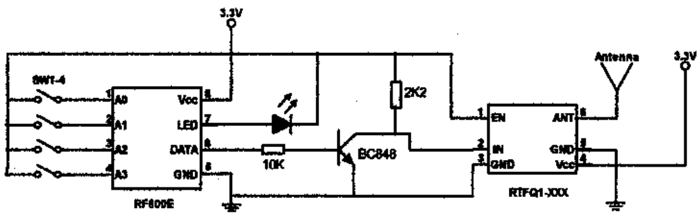
Electrical Characteristics	Min	Typical	Max	Dimension	Notes
Supply Voltage (Vcc)	4.5	5	5.5	V	
Supply Current (Operating)		5.7	6.8	mA	
Supply Current (Standby)			100	nA	
Receiver Frequency		315.00 433.92 868.35		MHz	
R.F Sensitivity (100% AM) 315 ,433MHZ versions 868MHz versions		-103 -100		dBm	
3dB Bandwidth		+/-150		KHz	
Data Rate	300		9,600	Hz	
Turn on Time			5	mSecs	1
Turn on Time		8		mSecs	2
Level of Emitted Spectrum			-70	dBm	
Low Level Output Voltage			0.8	V	I = 200uA
High Level Output Voltage	Vcc-1			V	I = 200uA
RSSI Output		0.95		mA	
Operating Temperature Range	-25		+80	°C	

Notes
1. Time from PD pin going high to stable data. (RRFQ1 only)
2. Time from Power ON to stable data.

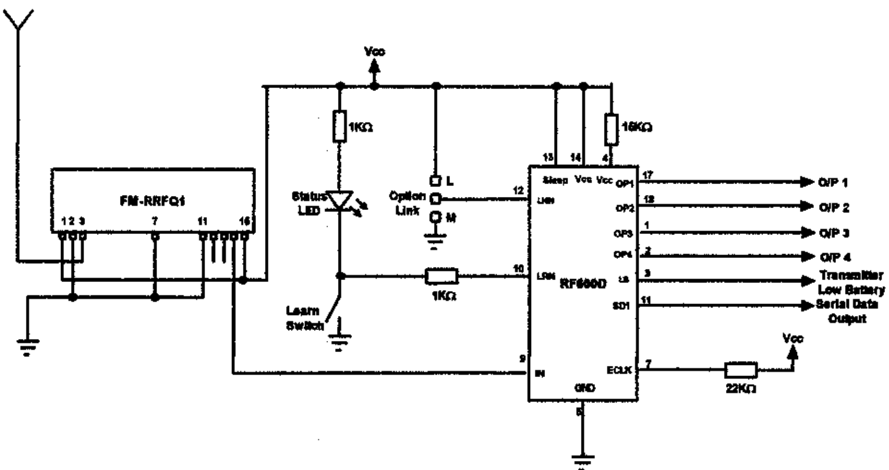
Typical Application

The following circuits show a remote control system with 'self learning feature' for more information please see Datasheet DS600

Transmitter Circuit



Receiver Circuit



Prototyping Hints:

It is essential when building any Low Power Radio System that you have a 'clean' DC power source. Typically the ripple voltage should be less than 10mV Peak to Peak. Normally a 470uF decoupling capacitor is sufficient de-coupling for an AC derived DC power source.

Never place a Transmitter or Receiver directly into Vero-Board or any similar prototyping board. This will severely restrict the range. Rather, use small lengths of wire from the prototyping board to the pins of the Transmitter or Receiver.

A useful antenna, for testing purposes, for both the Transmitter and Receiver on 433MHz is to use a piece of wire 17.3cm long (23.8cm at 315MHz) soldered directly to the antenna pin.

For more information or general enquiries, please contact;

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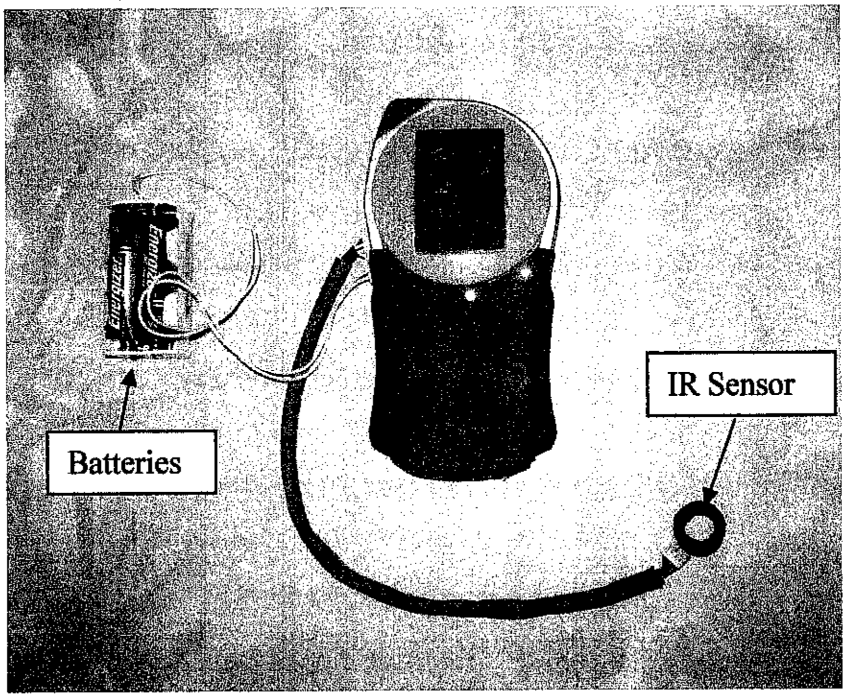
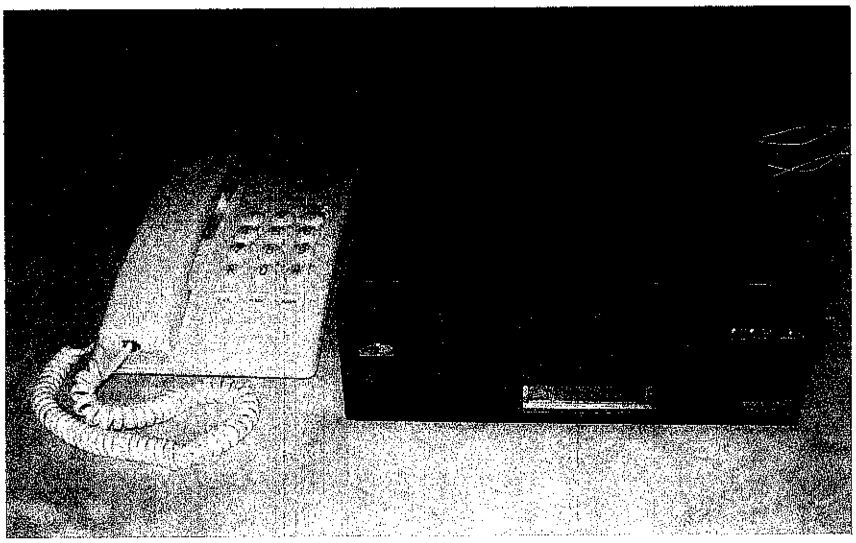
RF Solutions is a member of the Low Power Radio Association

APPENDIX VII

The Picture of the Project Casing/Prototype



The transmitter part



The Receiver Part