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ELECTRONIC ENGINEERING

Design and Construction of Microcontroller Based Selective Calling System on Radio Transceiver

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***Abstract*— The main objective of this paper is to upgrade the ordinary radio transceivers as a selective calling transceiver by using microcontroller. The base station and remote station controller cards are designed and constructed for any type of radio transceiver. In this project, the overall circuit diagram for the proposed system and the Dual Tone Multi Frequency (DTMF) technique are explained. The DTMF generating function and decoding are mainly described in this project. The DTMF generating function can generate the DTMF tones which can be accepted on the MT 8870D DTMF receiver specification. In addition, robust algorithm and program flow chart for base station and remote station controller cards are developed. The experimental test results of DTMF generator portion and the overall system are also provided. The significant advantages of the proposed system are more secure and reliable than the ordinary radio communication.**

***Keywords*— DTMF, Robust Algorithm, Remote Station, Base Station**

I. INTRODUCTION

At Myanmar Railway transportation, the accuracy and effectiveness of the communication devices are very important. The SSB radio transceivers are widely used in the Myanmar Railway Stations.

The main purpose of this project is to add the selectable function to the radio transceiver. To implement this purpose, the base station and remote station controller cards are needed to construct and connect with the radio transceivers. The overview of selective calling system is shown in Fig. 1.

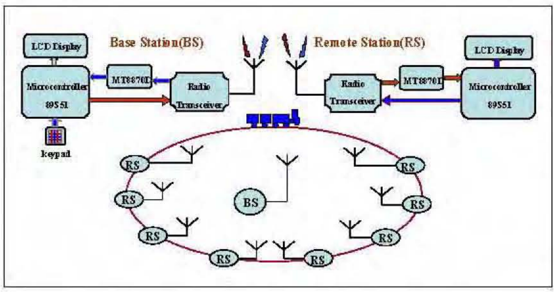

Fig. 1 Overview of Selective Calling System

The controller cards are designed and constructed by using 89S51 microcontrollers, DTMF Tone receiver, LM 324 operational amplifier IC, LCD display and other components. In order to achieve the high security and reliability of the system, the single Remote Station and the group remote station ID Number are assigned to five DTMF tone pairs. The block diagrams of the Base Station and Remote Station are shown in Fig. 2 and Fig. 3.

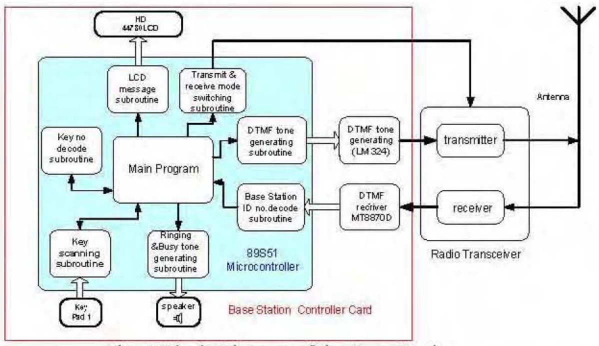

Fig. 2 Block Diagram of the Base Station

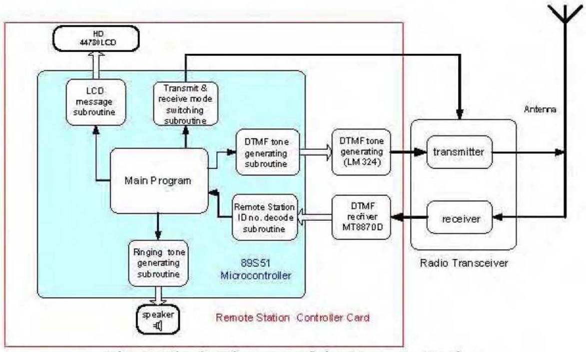

Fig. 3 Block Diagram of the Remote Station

The block diagrams show the Base Station and Remote Station main devices and their connection. The DTMF receiver, the radio transceiver and LCD display are common devices for the Base Station and Remote Stations. The input and output pin of the microcontroller are assigned with the following port sharing diagram. The diagram is shown in Fig. 4.

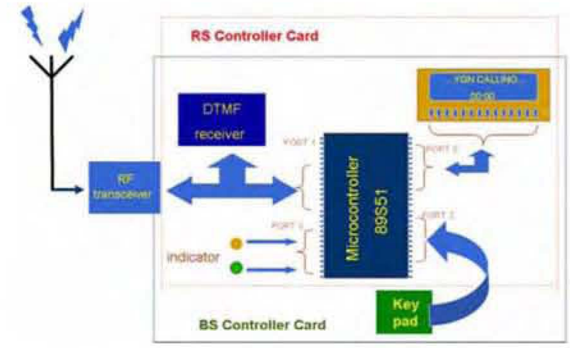

Fig. 4 Port Sharing Diagram of 89S51 for BS and RS Controller Cards

The microcontroller has four I/O ports (32 I/O pins). The port zero (P0) is used for LCD display. The keypad is connected with the port two (2). The port one (P1) is used for DTMF transmission and receiving portions. The port three (P3) pins are used for transmit and receive mode changing relay switch and indicator lamps.

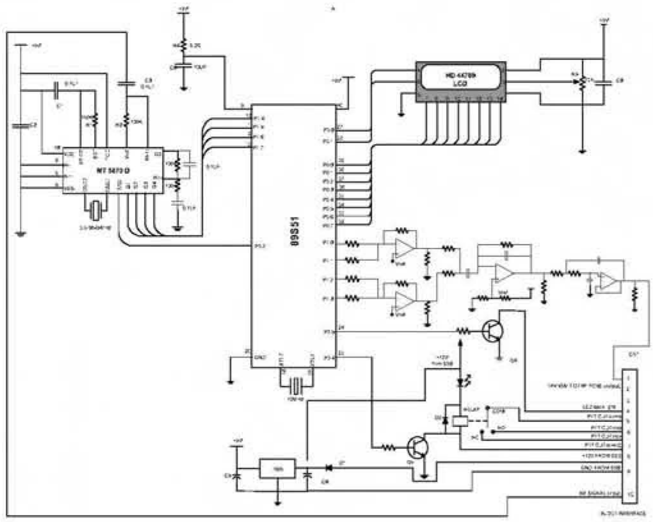

Fig. 6 Remote Station Circuit Diagram

II. SYSTEM DESCRIPTION

In this project, the base station and remote station controller cards are designed and constructed for any type of radio transceiver. These controller cards are implemented with two main portions namely hardware and software. The hardware portion consists of 89S51 microcontroller reset circuit, DTMF receiving circuit, DTMF generating circuit, relay switching circuit and regulated power supply circuit. The remote station hardware configuration is the same with the base station except the keyboard connection.

The software implementation for the base station and remote station microcontroller is quiet different. The flow charts represent the main operation of the controller cards. The assembly programming language is used to implement the microcontroller operation.

A. Hardware Portion

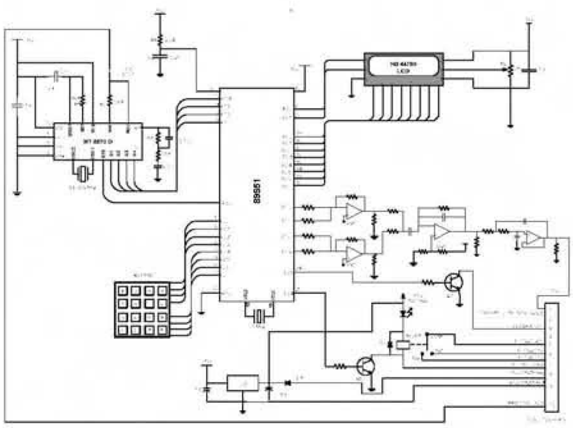

Fig. 5 Base Station Circuit Diagram

B. Software Portion

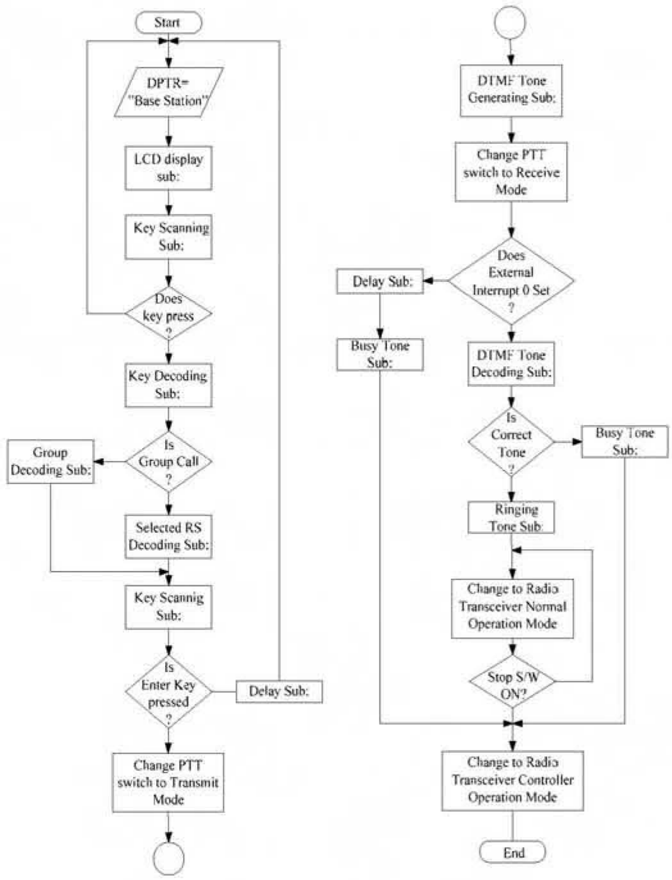

Fig. 7 Base Station Flow Chart

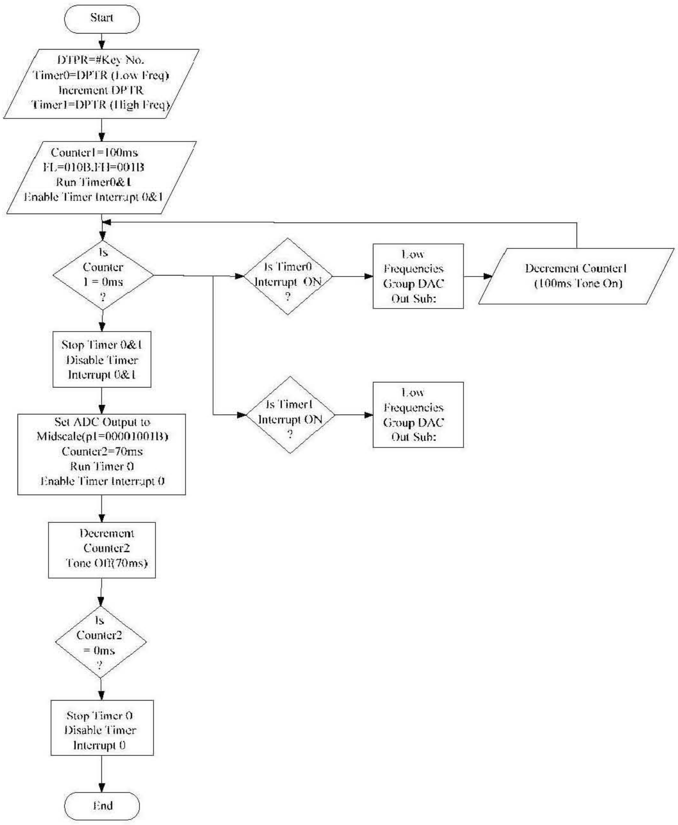

Fig. 8 DTMF Tone Generating Flow Chart

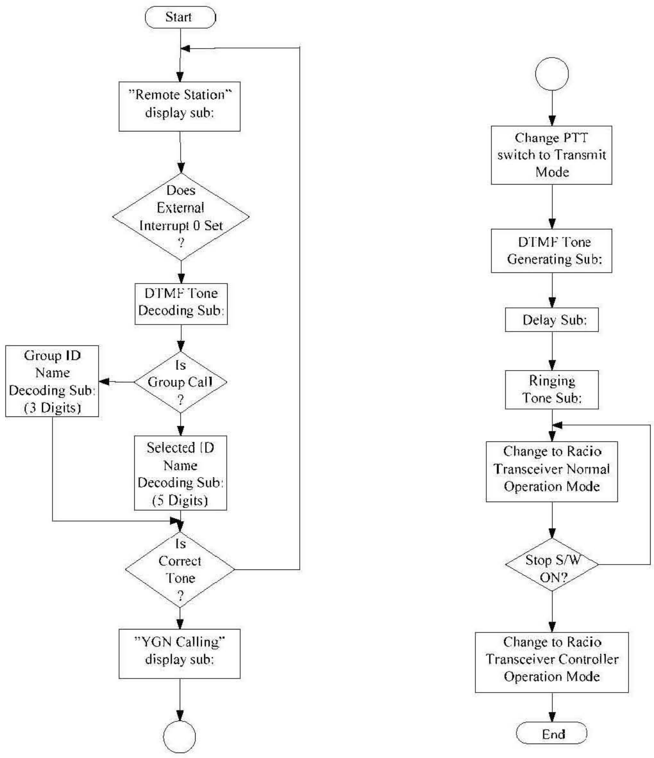

Fig. 9 Remote Station Flow Chart

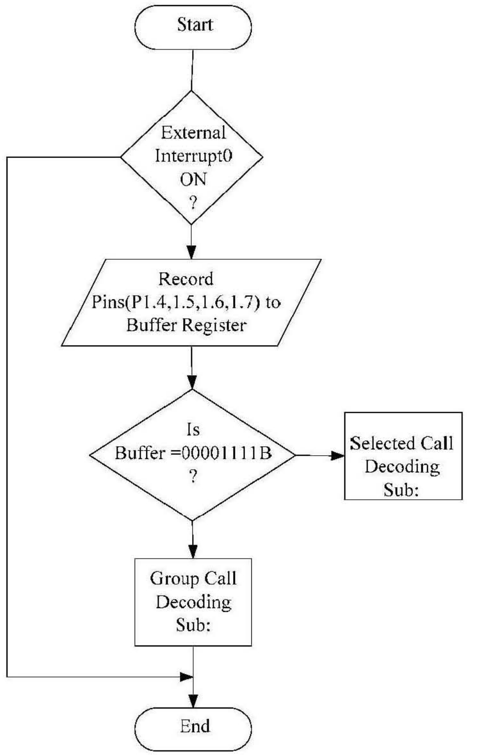

Fig. 10 DTMF Tone Decoding Flow Chart

III. METHODOLOGY

A. Dual Tone Multi Frequency (DTMF)

The tone is represented by a unique pair of sine wave tones. The relationship of the keypad numbers and the tones is shown in Fig. 11 and Table I The numbers are arranged in a four-row-by-four-column rectangular matrix. Each row and column has a unique tone. When a key corresponding to a digit is pushed, the tones for its row and column are transmitted. The technical name for this scheme is dual tone multi Frequency (DTMF).

TABLE I
KEYPAD NUMBERS AND THEIR DTMF TONE PAIR

Key Number	**DTMF Tone pair**	**Key Number**	**DTMF Tone pair**
1	697 Hz & 1209 Hz	9	852Hz & 1477 Hz
2	697 Hz & 1336 Hz	0	941Hz & 1336 Hz
3	697 Hz & 1477 Hz	G1	697 Hz & 1633 Hz
4	770 Hz & 1209 Hz	G2	770 Hz & 1633 Hz
5	770 Hz & 1336 Hz	G3	852 Hz & 1633 Hz
6	770 Hz & 1477Hz	G4	941Hz & 1209 Hz
7	852 Hz & 1209 Hz	G5	941 Hz & 1447Hz
8	852Hz & 1336 Hz	ENTER	941 Hz & 1633 Hz

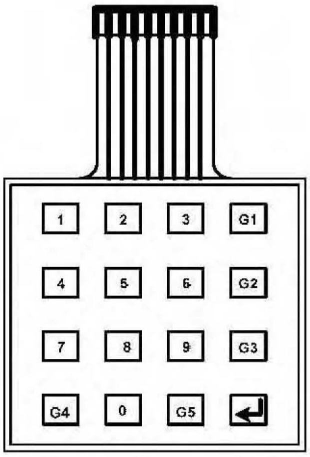

Fig. 11 Keypad Diagram

B. *DTMF Tones Generating Function*

In this project, the frequencies are divided into two group to produce the DTMF signalling tones. They are low group (697Hz, 770Hz, 852Hz and 941Hz) and high group (1209Hz, 1336Hz, 1447Hz and 1633Hz). A unique DTMF tone pair consists of one high-group and one low-group tone. In this paper, sixteen DTMF tones namely 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, A, B, C, D, E and F are produced by using two timer T0 and T1 of the 89S51 microcontroller. To produce the DTMF tones, DAC (Digital to Analog Converter) circuit for low group and high group frequency is used. In this project, DAC function is accomplished by two bit resolution because the I/O pin of microcontroller is needed to share the other application. To construct the low group DAC and high group DAC, the microcontroller I/O pin P1.0, P1.1, P1.2 and P1.3 are used. The DTMF tone generating function is accomplished by the following idea.

To convert the digital value to the analog voltage, the practical result can be accomplished with the digital to analog conversion (DAC). The basic DAC circuit diagram is shown in Fig. 12.

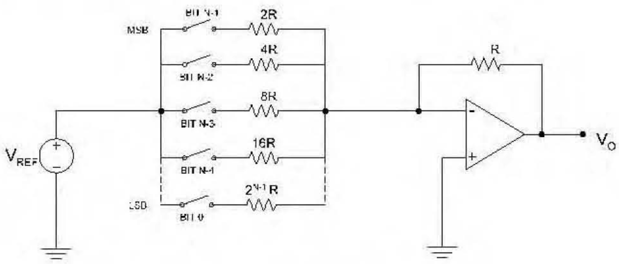

Fig. 12 Basic Digital to Analog Conversion

The output V_O of an N-bit D/A converter is given by the following equation:

$$V_O = (a_{N-1}\,2^{-1} + a_{N-2}\,2^{-2} + a_{N-3}\,2^{-3} + \ldots + a_0\,2^{-N})\,V_{REF} \quad (1)$$

For two bit resolution,

$$V_O = (a_1 2^{-1} + a_0 2^{-2})\,V_{REF} = (2a_1 + a_0)\,V_{REF}/4 \quad (2)$$

The three voltage levels 0V, 1.25V, 3.75V and 5V are chose to produce from two bit DAC to the step sine wave. They are assigned with the digital values 00, 01, 10 and 11. This is shown in Fig. 13. The Fig. 14 shows the two bit DAC to the analog sinusoidal wave transformation.

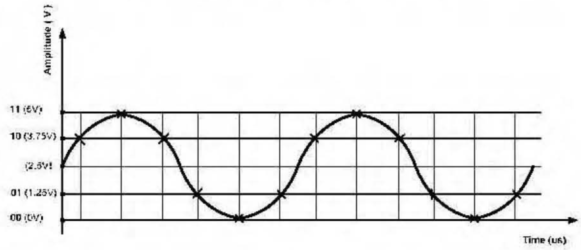

Fig. 13 Analog Voltage Level for Digital Value

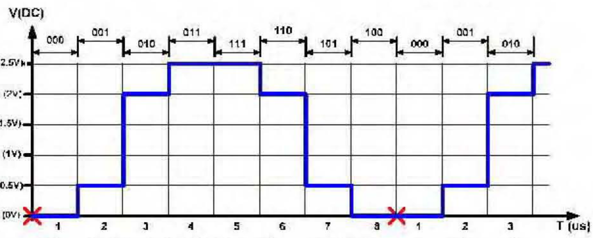

Fig. 14 Two Bit DAC to Sinusoidal Wave Transformation.

To produce the desired sinusoidal wave form, R1 and R2 are needed to choose.

$R/R_2 * Vref = 3.75$

$Vref = 5V$

$$R_2 = 4R/3 \quad (3)$$

$$R_1 = 3R_2 = 4R \quad (4)$$

The DTMF tones generating circuit is shown in Fig. 15 and Fig. 16.

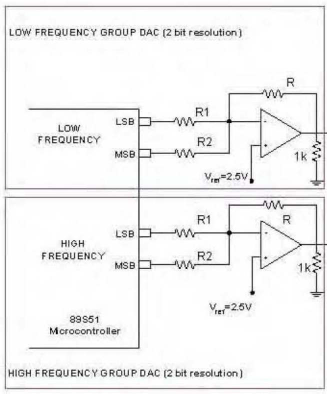

Fig. 15 Digital to Analog Conversion Circuit

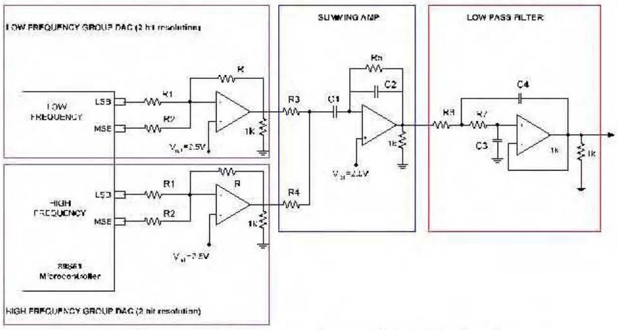

Fig. 16. DTMF Tones Generating Circuit Diagram

The DAC uses 3 bits per channel internal to the Microcontroller and counts as follows 000 001 010 011 100 101 110 111 using bit 2 as the sign and complementing bits 0 & 1. Thus the outputs of the 000 001 010 011 111 110 101 100 are 00 01 10 11 11 10 01 00. The timer 0 and timer 1 interrupt function of the microcontroller are used to generate the DAC values.

For 2 bit resolution digital to analog sine wave conversion, the following equation is used.

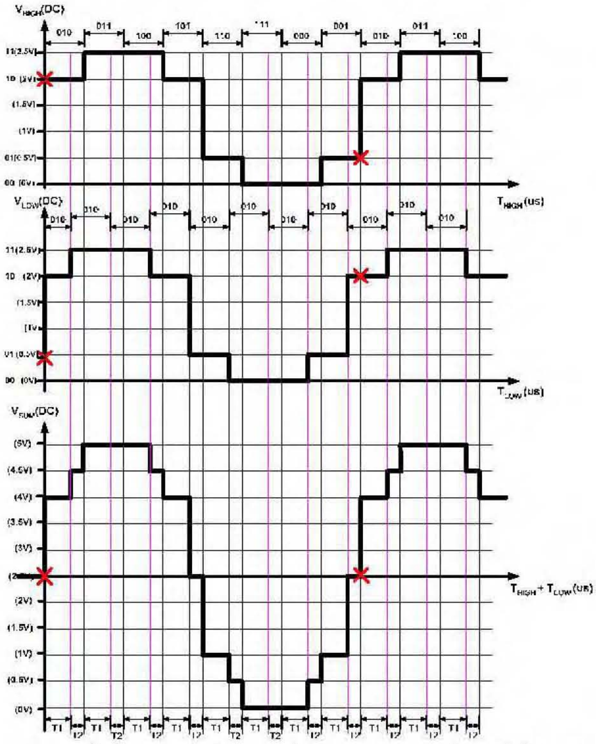

Fig. 17 Timing Diagram for Low and High Group Frequencies

From this consideration, the following formula is achieved.

$$f = [\{(f_{osc}/12)/\text{bits-per-cycle}\}/\text{desired-freq}] \quad (5)$$

which,

f_{osc}	=	11.059 MHz
bit per cycle	=	8 bit/cycle

To produce the DTMF tones, the low and high frequencies group sinusoidal wave are needed to equal the phase angle. It is very important fact for the DTMF tones generating function. The DTMF tones are generated by using the timer 0 and timer 1 of the microcontroller. The timing diagram is shown in Fig. 17.

A. DTMF tones decoding function

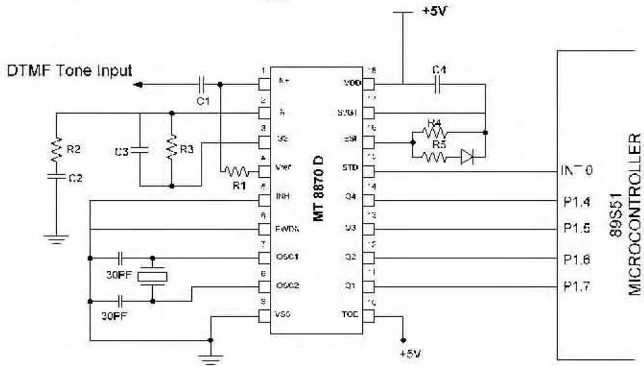

Fig. 18 DTMF Tone Decoding Circuit Diagram

Component values are chosen according to the formula:

$$t_{REC} = t_{DP} + t_{GTP} \quad (6)$$
$$t_{ID} = t_{DA} + t_{GTA} \quad (7)$$
$$t_{GTP} = (R_P C_1)\ln[V_{DD}/(V_{DD}-V_{TSt})] \quad (8)$$
$$T_{GTA} = (R_1 C_1)\ln(V_{DD}/V_{TSt}) \quad (9)$$
$$R_P = (R_1 R_2)/(R_1+R_2) \quad (10)$$

IV. TEST AND RESULTS

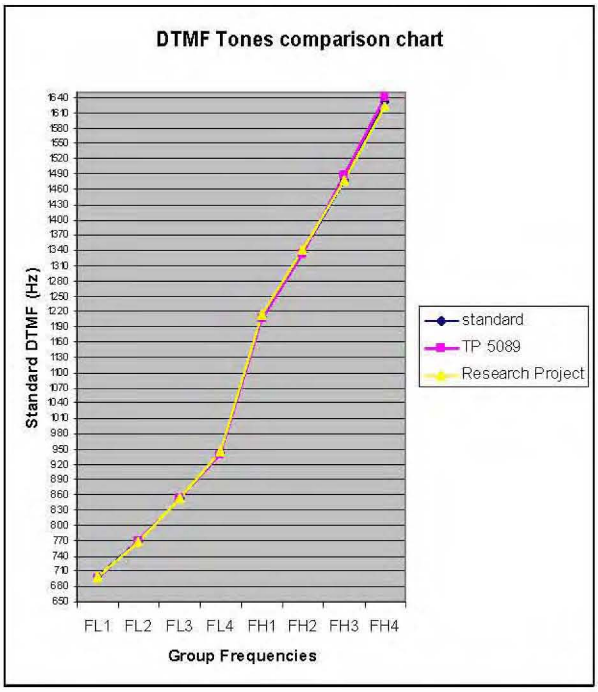

Fig. 19 DTMF Tone Comparison Diagram

TABLE II
COMPARISON OF DTMF TONES

Tone group frequencies		Standard DTMF (Hz)	Tone output frequency	
			Research Project	TP 5089
Low group	FL1	697	698.2	694.8
	FL2	770	768	770.1
	FL3	852	853.3	852.4
	FL4	941	944	940.0
High group	FH1	1209	1212.6	1206.0
	FH2	1336	1339.5	1331.7
	FH3	1477	1476.9	1486.5
	FH4	1633	1622.5	1639.0

V. DISCUSSION AND CONCLUSION

The system is designed and constructed with two types of controller cards which can operate with any type of radio transceiver. In this system, they are interfaced with the SSB radio transceivers. The propagation time, distance and other communication delay time are not considered in this system. The output power and frequency range depend upon the type of the operated radio transceiver.

In this project, the DTMF tones are generated with the two bit resolution DAC technique because of the microcontroller I/O pins are needed to allocate for other functions. In order to produce the smooth DTMF tones, the resolution of the DAC must be high. The DTMF generating function can be modified with high resolution technique DAC by using the adequate microcontroller pins.

This project can detect the five DTMF tones. As a result, this system can be extended to many Remote Stations (16^{5} =1048576). The Remote Station identification (ID) number can be increased or decreased for any applications. The operation time depend upon the detection of the Remote Station ID number.

ACKNOWLEDGEMENT

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