ABSTRACT

Multilingual Infra Red Sign Identity and Guidance System (MIRSIGS) consists of two devices and is a specific communication system to be used in buildings and public places as a navigational aid for the vision impaired. The concept consists of a sign add-on device that allows signs to communicate with vision impaired users through hand held devices. These sign add-on devices will give the signs the ability to identify themselves upon request, and to transmit a guidance tone.

The hand held device will allow the user to *hear* if a sign is within the vicinity through the use of the guidance tone played to the hand held devices earphone. The identity of the sign can be requested by pressing the 'Request' button, located on the users hand held device. The sign responds to this 'Request' by transmitting its unique 8-bit identity code word modulated into the same waveform as the guidance tone using Binary Frequency Shift Keying (BFSK). The guidance tone will amplitude modulate this BFSK signal.

Information describing the sign will be stored on a ChipCorder$^{(R)}$ within the hand held device. This allows hand held devices to be produced in many languages without the need for any changes to the sign circuitry.

The proposed MIRSIGS was designed, implemented and tested. The prototype system successfully provided both directional information and sign identification to the user. Once implemented, it was found that the guidance tone played through the earphone does become louder as the hand held device is pointed towards the sign add-on device, as well as when the hand held device is approaching the sign add-on device. The identity code word was successfully generated, modulated, transmitted, demodulated and stored without errors.

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NOMENCLATURE

List of Acronyms

AC - Alternating Current

AM - Amplitude Modulation

BASK - Binary Amplitude Shift Keying

BFSK - Binary Frequency Shift Keying

BJT - Bipolar Junction Transistor

BPF - Band Pass Filter

BPSK - Binary Phase Shift Keying

DC - Direct Current

DIP - Dual In Line Package

DIP switch - Dual In Line Package of switches.

DSB-SC-AM - Double Side Band, Suppressed Carrier, Amplitude Modulation

FIFO - First-in First-out

FM - Frequency Modulation

HIGH - A voltage level that indicates a logic '1' (usually 5V)

HPF - High Pass Filter

IC - Integrated Circuit

IR - Infra Red

IrDA - Infra red Data Association

LED - Light Emitting Diode

LOW - A voltage level that indicates a logic '0' (usually 0V)

LPF - Low Pass Filter

MIRSIGS - Multilingual Infra Red Sign Identity and Guidance System

OOK - On-Off Keying

Op Amp - Operational Amplifier

PLD - Programmable Logic Device

PM - Phase Modulation

SOIC - Small-Outline Integrated Circuit

List of Symbols

A_{BPFmax} - Maximum (normalized) allowed amplitude of signal in passband.

A_{BPFmin} - Minimum (normalized) allowed amplitude of signal in passband.

A_{max} maximum magnitude of sinusoidal signal.

A_{min} minimum magnitude of sinusoidal signal.

C Capacitor external to XR-2206 that defines the BFSK output frequencies, along with R_1 and R_2.

C_{LPF} - Capacitor value in envelope detector (LPF).

C_0 - Capacitor external to the XR-2211 used to set f_O, along with R_0.

C_x - Capacitor external to one-shot that defines the output pulse width, along with R_x.

$d_i(t)$ baseband equivalent of signal.

f_1 frequency used to represent a binary '0', 50kHz.

f_2 - frequency used to represent a binary '1', 40kHz.

F_{bw-} - Parameter to define passband in filter design, defined in Figure 5.11.

F_{bw+} - Parameter to define passband in filter design, defined in Figure 5.11.

F_{dev} - Frequency deviation, Talking Signs^{TM} devices.

F_{sw-} - Parameter to define stopband in filter design, defined in Figure 5.11.

F_{sw+} - Parameter to define stopband in filter design, defined in Figure 5.11.

F_{tone} - Frequency of the 555 timer square wave output.

F_c Carrier Frequency, Talking Signs^{TM} devices.

F_c - Centre frequency of frequencies, used in BPF design.

F_m - Frequency of message signal, Talking Signs^{TM} devices.

f_O - VCO free running frequency of XR-2211 (centre frequency).

I - The current into the amplifiers inverting input of the transimpedance Op Amp stage.

M - Modulation Index

Q_A to Q_H - Parallel output pins from serial-in parallel-out shift register, Q_H being the most significant bit.

R_{1b} - Resistor external to the XR-2211 used to set the driving current of the current controlled oscillator.

R_{A2} - Resistor in series with the inverting input of the inverting Op Amp stage used to set the gain.

R_{atone} - Resistor external to 555 timer that defines T_{1tone}.

R_{btone} - Resistor external to 555 timer that defines T_{2tone}.

R_{F2} - Feedback resistor of the inverting Op Amp stage used to set the gain.

R_{F-ISD} - Feedback resistor of the inverting Op Amp stage used to set the gain.

R_{ir} - Resistor in series with IR LED to set the maximum current driven through IR LED.

R_{LPF} Resistor value in envelope detector (LPF).

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1.0 INTRODUCTION

1.1 Introduction

A person's effective mobility depends firstly upon orientation. To be effectively mobile a person has to know where they are, and what surrounds them. Most people in society accomplish this viewing printed signs, which provide identification or directions. In a sense, signs make up a list of choices for travellers, displaying their options at any point in their travels. Signs not only direct travellers, but can also provide cautions and reminders about important characteristics of the environment.

In Australia it is estimated that approximately 2% of people are vision impaired [7]. With the current population being estimated at 19.2 million [8], this amounts to 384,000 people. In the United States, the National Centre for Health Statistics estimates that 4.3 million people have difficulty reading signs from normal viewing distances. This takes into consideration people with corrected vision (glasses, contact lenses etc.). An additional 2.3 million people have a disability that involves the loss of intermediate & distance vision only. Thus an estimated 6.6 million out of 275.6 million people [8] (2.4% of the population) in the United States are unable to read printed signs from normal distances. It is also estimated that in the United Kingdom, about 1 million people from the population of 59.75 million are legally blind or partially sighted [8] (1.7% of the population).

Other disabilities that may prevent a person from reading a printed sign include; strokes, head-injuries, dyslexia, autism, and those not sufficiently educated in reading (These are people who can not understand, even though they can see the text).

All of the above mentioned people are disadvantaged as they can not see signs or labels. Thus they have no choice but to depend on strangers for accurate and concise information. However, this is seldom accomplished due to sighted people not understanding blindness, or the needs of vision impaired people. In addition, asking strangers for directional advice raises safety concerns for the vision impaired. Most vision impaired people dislike depending on strangers and hence do not access unfamiliar areas.

The term accessible may be defined by the following examples:

- A route is accessible to a person if they can determine their own location, and know in which direction the destination is located. For example, a building entrance would be accessible if it can be found.
- A telephone is accessible to a person if they are able to locate it whether they are on a sidewalk, across the street, or in the lobby of an airport.
- Public transport is accessible to a person if they can locate the bus stop and determine when they are arriving at their desired destination.
- A building is accessible to a person if they can independently and safely locate offices, shops, elevators and emergency exits within the environment.

1.2 MIRSIGS

Multilingual Infra Red Sign Identity and Guidance System (MIRSIGS) is a system designed to assist the vision impaired to navigate through buildings and public places. This system comprises of two physical devices, a hand held device including an earphone to be used by the vision impaired as a navigation tool, and a sign add-on device that extends the functionality of a standard sign to be used by the vision impaired.

The user will *hear* if a sign is within their vicinity (on demand) by the existence of the 1kHz guidance tone that is played to their earphone. The direction can then be located by listening to the strength (volume) of the guidance tone as the tone becomes louder when the hand held device is pointed directly towards the sign. The strength of the tone also increases as the user approaches the sign.

An important feature of MIRSIGS is the ability to send a ‘Request’ to the sign. When the sign detects the 'Request' signal, it will send its identify in the form of a BFSK signal, constructed from the signs 8-bit identity code word. The hand held device demodulates this signal and uses the 8-bit identity code word to address the location of the ChipCorder$^{(R)}$ storing a voice signal describing the sign. A description of the sign, in the form of a voice signal will be played back in the language of the hand held device.

The MIRSIGS sign add-on device can be placed at any convenient location and does not need to be physically attached to the sign itself. The placement of the add-on device will usually be between the roof directly above the sign, and the sign itself. The decision of the placement of the add-on device depends mainly on the height of the sign and 'moving' or 'stationary' obstacles within a reasonable distance of about 10 metres. In other words, line of sight needs to be achieved as much as possible.

MIRSIGS can be used in conjunction with any existing sign, as well as signs placed especially for vision impaired travellers. Current systems that should include an add-on device include signs indicating street crossings, traffic signs, bus stops and directional (navigational) signs (eg. Toilets to the right). MIRSIGS should also be present in buildings and other public places such as halls, galleries, parks and sports stadiums. Ultimately, MIRSIGS should be implemented anywhere and everywhere to communicate helpful information to the vision impaired.

1.3 Objectives

The main objectives of this project are threefold:

- To design, implement and test an infra red (IR) link for data transfer.
- To design, implement and test a sign add-on device capable of:
  - Transmitting a guidance tone continuously.
  - Providing a signal identifying itself (using an 8-bit identity code word), when queried.
- To design, implement and test a hand held device that is capable of:
  - Playback of the guidance tone for direction finding purposes.
  - Querying signs for their identity
  - Receiving the 8-bit identity code word transmitted by a sign.
  - Playing back the signs identity through the users earphone.

To achieve the objectives stated above, MIRSIGS was designed and implemented.

1.4 Outline of Thesis

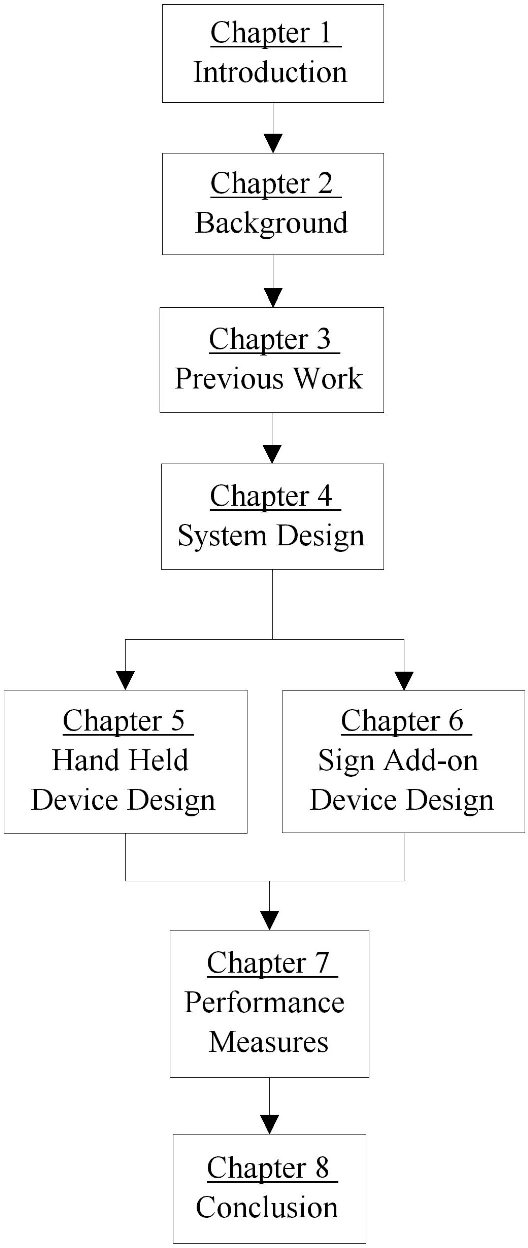

Figure 1.1: Outline of Thesis

2.0 BACKGROUND

2.1 Radio Transmission

There are a number of methods for transmitting a mixed-mode signal. In cases where system devices must be portable and free to roam, it is not possible to use physical channels such as coaxial cable or optical fibre. The two primary methods of implementing a wireless link are radio and IR. Radio transmissions propagate through obstacles, and transmission can not always be characterised as being directional. Therefore transmission may propagate in all directions. For example, a radio signal originating in one room will propagate through walls into neighbouring areas or rooms, allowing receivers in adjacent rooms to receive this transmitted radio signal. It is important to note that within the space of a room, the received signal amplitude is not a function of the distance. Therefore, if radio transmission was used in a communication system for the vision impaired, the signal strength detected by the hand held device would remain the same, irrespective of the distance to the transmitter.

In Australia, and most nations, radio channels are in high demand. As a result there are licensing requirements for radio channels which are expensive. Different nations also have different types of channels. These channels are sometimes of different band widths, which may make it impossible to obtain the same channel in many nations. It would also be difficult to obtain the same channel in multiple nations due to the fact that most channels are already occupied. Therefore, using radio transmission introduces licensing difficulties and costs that do not exist for (certain) alternative transmission methods.

2.2 Infra Red Transmission

The characteristics of IR propagation differ significantly to radio transmission. IR transmissions are blocked by (almost) any opaque obstacle. Therefore, IR transmissions are only suited for applications which can provide direct line of sight. The received amplitude of an IR transmission is proportional to both the distance from the transmitter, and the orientation of the receiver. If the receiver is pointed in the wrong direction, the received amplitude would be significantly less than if pointed directly towards the transmitter. Also, the received signal strength would be significantly stronger when located closer to the transmitter.

The IR spectrum is somewhat unused due to its relatively short range and line of sight properties. It is not regulated by any authorities, and can therefore be used without licensing and at no cost.

Using single IR LED's (Light Emitting Diodes), propagation is cone shaped as shown in Figure 2.1. The centre of the cone possesses the maximum signal strength, with the signal strength decreasing as the radius from the cone centre increases. The signal strength at all points within the cone also decreases with increased distance from the transmitter. This directional characteristic of IR transmission prevents the signal from propagating to adjacent areas or rooms. Thus, if a sign is fixed on a wall above an exit doorway, the signal propagating from the sign could only be received in the area facing the sign.

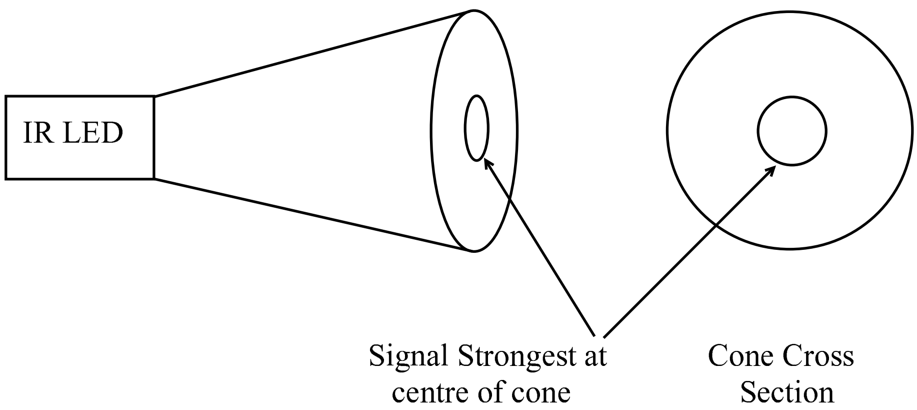

Figure 2.1: Visualisation of Infra Red Cone Shaped Propagation

2.3 Ultrasonic Transmission

Ultrasonic waves propagate at frequencies close to the human audible frequency. The dispersion pattern of an ultrasonic transmission is similar to that of IR transmission, but more likened to a 'tear drop' shape. The main disadvantage of ultrasonic transmission is its relatively short range (when propagating in air). Ultrasonic transmitters would require a large amount of power to match the transmission range of IR LED's. To be comparable to radio transmission, ultrasonic would require an enormous amount of power to achieve the same transmission distance. When ultrasonic transmitter are transmitting with such an amount of power, echoes can be heard from the reflections of the transmission. Ultrasonic transducers may also be difficult to acquire.

2.4 IrDA

The Infrared Data Association (IrDA) is an international, non-profit association of companies that creates and promotes interoperable, low cost IR data interconnection standards. The IrDA has defined an entire protocol for the wireless transfer of data. Currently, devices designed according to IrDA standards can operate up to 4Mbps and cost around US$3 to 6. The maximum range of these devices varies from 0.3 metres to approximately 4 metres. Therefore, the IrDA standard is not practical for use in applications where the data transmission range required is greater than 4 metres.

2.5 Modulation Techniques Considered In MIRSIGS

2.5.1 Continuous Amplitude Modulation

Conventional amplitude modulation (AM), or double side band single carrier amplitude modulation (DSB-SC-AM) is the primary form of amplitude modulation. This form of modulation encodes information into the carrier signal by modifying its amplitude [4].

The degree to which the message signal modifies the carrier signal depends on the modulation index *M*. *M* is the amplitude of the modulating signal divided by the amplitude of the carrier signal [4]. The value of *M* can be calculated using Equation 2.1, where A_{max} is the maximum peak amplitude, and A_{min} is the minimum peak amplitude of the signal. Figure 2.2 shows a 40kHz carrier signal amplitude modulated by a 10kHz sine wave message signal, with M=0.2.

$$M = (A_{max} - A_{min})/(A_{max} + A_{min}) \tag{2.1}$$

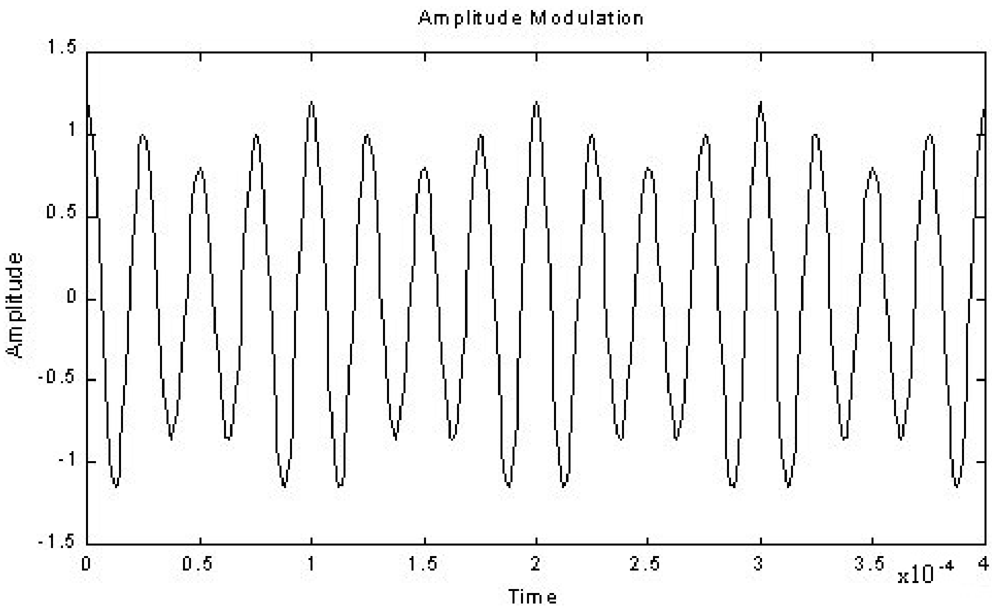

Figure 2.2: A 10kHz Sine Wave Amplitude Modulating a 40kHz Carrier Signal, where *M*=0.2

2.5.2 Envelope Detector

An envelope detector is an effective, yet simple device which is used to recover the original message signal from a received AM waveform. This device does not require a local carrier wave at the receiver matched in frequency or phase to the carrier of the transmitter. Envelope detectors can recover the message signal only if $M \leq 1$, and if the received signal is narrowband. A signal is termed narrowband if the carrier frequency is significantly larger than the message bandwidth. A DSB-SC-AM signal can be demodulated by recovering either the positive or the negative envelope [4].

2.5.3 Continuous Angle Modulation

With Angle Modulation, the carrier amplitude remains constant and the message signal is modulated into the carrier signal by modifying its phase, in response to the message signal. Two examples of angle modulation are phase modulation (PM) and frequency modulation (FM). The main different between PM and FM is how the phase of the carrier signal is varied in response to the message signal. With FM the instantaneous frequency is varied linearly with the modulating (message) signal and with PM a phase term of the carrier varies linearly with the modulating signal. It is important to note that PM and FM transmissions are not affected by signal strength. PM and FM are robust forms of continuous modulation and are only compromised when the received signal strength decreases to such a level that the noise is of comparable amplitude. This is because it becomes increasingly difficult to determine the transmitted signal from the noise. Since the receivers demodulate received PM and FM signals of different magnitudes equally, these methods are not as advantageous if distance information needs to be extracted from the signal [4].

2.5.4 Binary Amplitude-Shift Keying (BASK)

BASK is a form of AM used for binary transmission. With BASK, the carrier amplitude is keyed between two predetermined levels. In general, on-off keying (OOK) is used with a modulation factor of $M=1$. With OOK a binary '0' is represented by a BASK output of amplitude zero, and a binary '1' is represented by a BASK output and amplitude equal to the input carrier waveform. This basic form of BASK can be extended where any two amplitude levels can be used to represent binary '0' and binary '1'. Figure 2.3 shows a BASK signal generated where a binary '1' is represented by the full amplitude of the carrier signal (A) and a binary ‘0’ is represented by 0.25 of the carrier signal amplitude (0.25A).

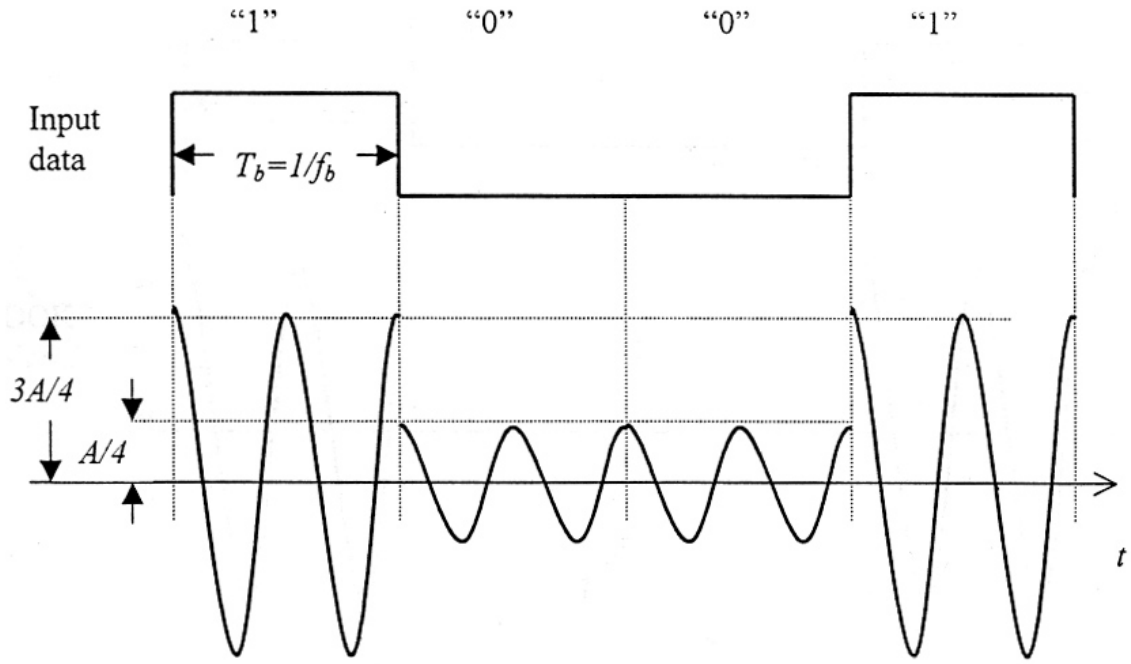

Figure 2.3: Construction of a BASK Signal, M=0.25

As using BASK modifies the amplitude level, it is a poor choice of modulation to modulate a carrier signal which is also undergoing continuous AM. This is because they both modify the amplitude of the carrier signal to represent their respective message signals [4].

2.5.5 Binary Frequency-Shift Keying (BFSK)

BFSK is a form of frequency modulation (FM) where two discrete frequencies are used to represent binary ‘1’s and ‘0’s. For example, a binary ‘1’ can be represented by a BFSK sinusoidal signal of frequency 40kHz, while a binary ‘0’ can be represented by a BFSK sinusoidal signal with a frequency of 20kHz. When a message signal modulates a carrier signal using BFSK, the amplitude of the carrier signal is unaffected. This technique is one of the most robust for sending binary data, especially as noise does not considerably affect the frequency of the transmitted signals. In the presence of forms of noise which affect a signals frequency, such as ‘Doppler’, a received signal can still be demodulated successfully if the BFSK frequencies are chosen such that the frequency difference between them is much greater than the expected 'Doppler' noise. Therefore, binary data can be transmitted with almost 100% accuracy for received signals with amplitudes above the amplitude of the noise [4].

BFSK can also be generated using OOK and two oscillators; one of frequency f_1, used to represent a binary '0' and the other of frequency f_2, used to represent a binary '1', as shown in Figure 2.4. The resultant waveforms are illustrated in Figure 2.5.

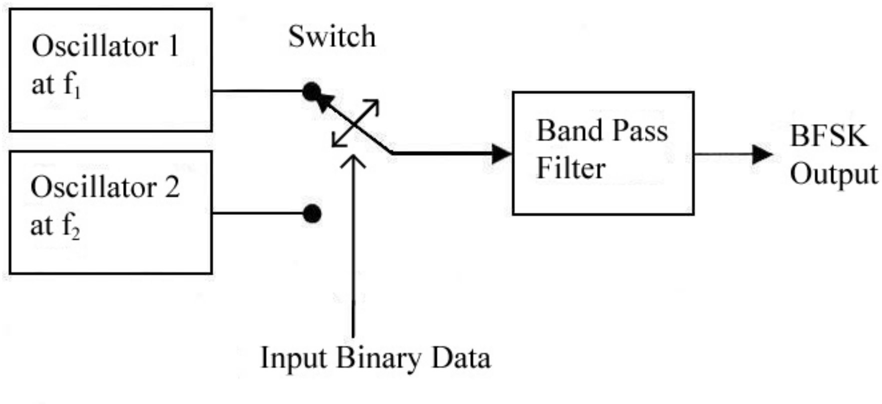

Figure 2.4: Generating a BFSK Signal

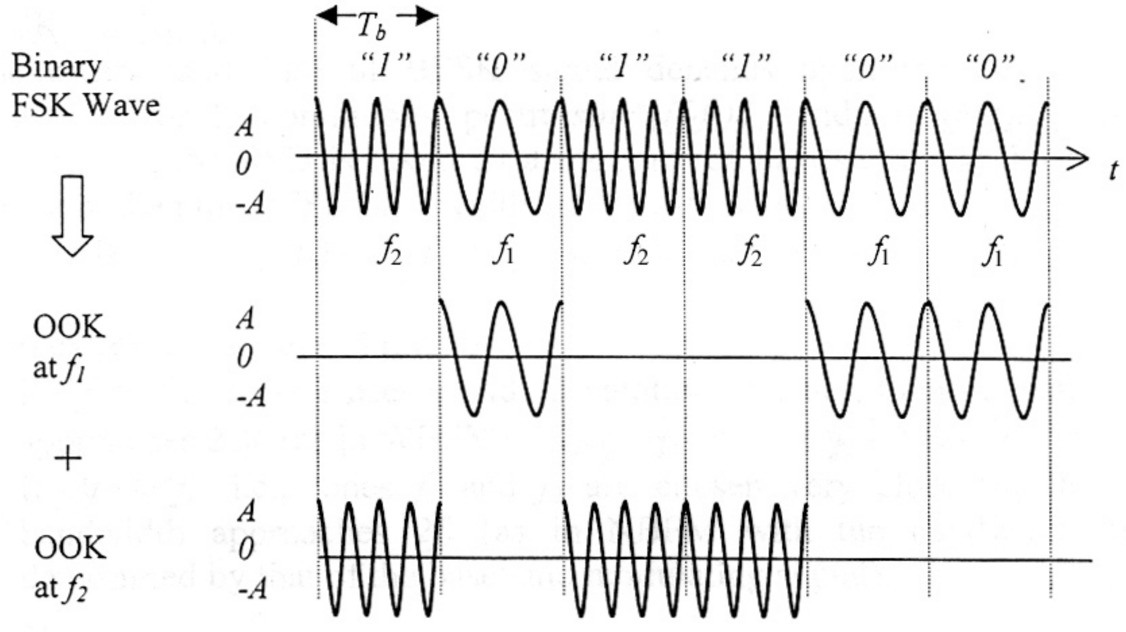

Figure 2.5: Construction of a BFSK Signal Using OOK

2.5.6 Binary Phase-Shift Keying (BPSK)

In BPSK, both the frequency and the amplitude of the carrier signal are unchanged. The binary data is modulated into the carrier by changing between two values of the phase angle, to represent binary '1's and '0's. The best choice for this phase change in terms of achieving the minimum (achievable) bit error rate is 180 degrees (Π radians) as shown in Figure 2.6, where a binary message signal is converted into a baseband signal $d_i(t)$, which is used to generate the BPSK waveform. A BPSK signal with a modulation index of M=1 can be generated similarly to a BFSK signal where M=1. The difference is that the two signals which are keyed-between are of the same frequency, but out of phase by 180^o, as illustrated in Figure 2.7.

A disadvantage of BPSK is the necessity of a reference carrier signal at the receiver for phase comparisons in the decoder decision circuitry. However, this reference carrier signal can be extracted from the received signal, requiring more complicated circuitry than BASK or BFSK demodulation. The bandwidth of BPSK is the same as that of OOK BASK, and smaller than the bandwidth of BFSK [4].

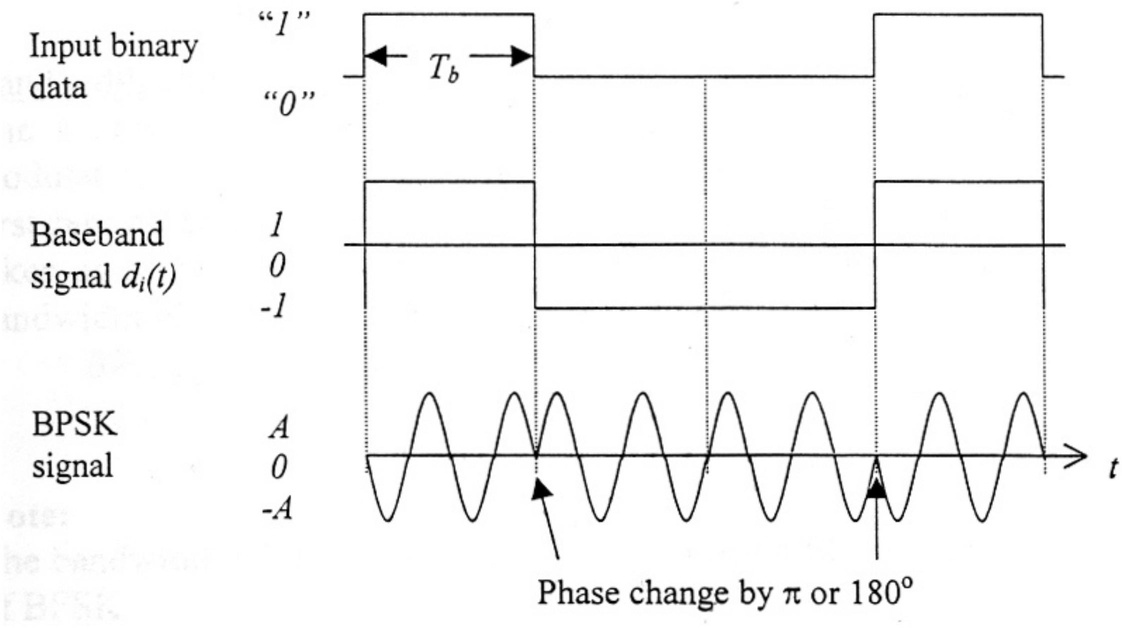

Figure 2.6: Construction of BPSK Signal Using OOK

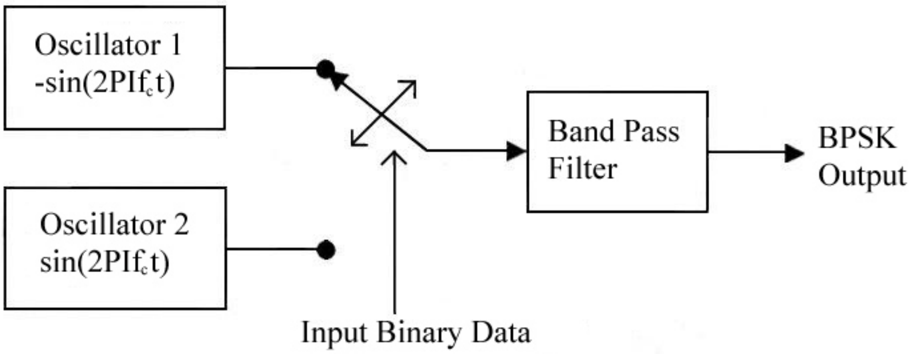

Figure 2.7: Generating a BPSK Signal

3.0 PREVIOUS WORK

3.1 Introduction

Several devices have been proposed and some implemented in the past to assist travel for the vision impaired. Primary examples include traffic light chirps and cuckoos [1], the Ultrasonic Sign Post System [6], Electronic Destination Signs [3] and Talking Signs^{TM} [11].

3.2 Traffic Light Chirps and Cuckoos

In Australia, pedestrian crossings at traffic lights include signs (lights) for pedestrians. A green flashing man indicates it is safe to cross, and a red man signals not to cross. Most of these crossings also include the use of chirps [1]. Chirps are used to indicate to both sighted and the vision impaired pedestrians when to cross by using two different sounds. A faster chirp indicates to cross, and a slow chirp indicates not to cross.

This system has been very effective and has become a standard for pedestrian crossings in many cities [12]. Its advantages are its simplicity to use and its low cost. The disadvantage of this system is its limited ability. It can be used at any pedestrian crossing, but can not be used to identify signs, identify the direction of the sign, or guide vision impaired travellers.

3.3 Ultrasonic Signpost System

The Ultrasonic Signpost System was proposed by the Toyohashi University of Technology, Toyohashi, Japan, at *The First Joint BMES/EMBS Conference*, in Atlanta, in 1999 [6].

3.3.1 Operational Details

This system consists of ultrasonic beacons and small hand held receivers. Ultrasonic beacons are mounted on landmarks needing identification in such a way that they transmit their signal downwards, in a conical shape, as illustrated in Figure 3.1. Hand held receivers are carried by the vision impaired travellers. As a hand held receiver comes within the transmission range, the beacon becomes activated and then emits an ultrasonic wave modulated with a streaming voice message. The hand held device demodulates the received signal and plays the voice message to the user through a loudspeaker.

Due to the relatively short transmission range of ultrasonic waves, ultrasonic transmission is not generally used. However, the Ultrasonic SignPost System uses ultrasonic transmission as its fundamental technology. This relatively short range capability means that a landmarks identity is only transmitted within a reasonable range, with the maximum transmission distance of the Ultrasonic SignPost System being three metres.

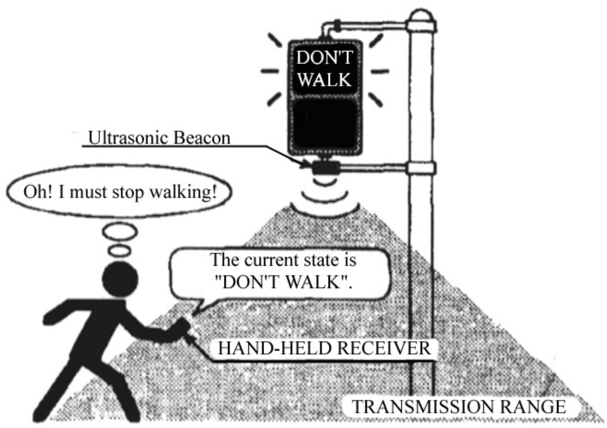

Figure 3.1: The Ultrasonic Signpost System

A prototype for The Ultrasonic SignPost System has been built and tested. However, it is not currently being produced as a commercial item. Before this system could be produced as a commercial item it would have to be further developed. Competing products, technological advantages and price are factors that would have to be considered. Due to the products limitations in comparison to competing products, this system is not likely to be further developed.

3.3.2 Limitations of the Ultrasonic Signpost System

Range

The maximum transmission range possible in this ultrasonic communication system is three metres. However, sighted people can read printed signs from distances of up to twenty metres. An ideal device should attempt to simulate this distance. Thus, a transmission range of three metres is minimal compared to the ideal. In practice this device leads to the vision impaired traveller not being able to sufficiently navigate using the system. This limitation of transmission distance is a characteristic of ultrasonic waves, discussed in Section 2.3.

Direction of Sign/Landmark

Although the Ultrasonic Signpost System assists in guiding the user towards the land mark, experimental results show a 0.4 metre mean error in orientation [6] with respect to the beacon. As the range of the system is 3 metres, a 0.4 metre mean error is considerable. Guiding a traveller towards a land mark once they are already within 3 metres of it suggests that the traveller already knows the direction the landmark is in, otherwise they would not have found it. An ideal communication device would identify direction and orientation to users from a distance of approximately 15 metres, with an orientation error significantly less than 0.4 metres.

Continuous Transmission to Loudspeaker

The Ultrasonic SignPost System continuously transmits a voice message to the loudspeaker of the hand held device. Each individual within listening range would hear this transmitted message of the landmarks identity, played continuously. This is unacceptable. An ideal communications system would not disrupt the people in the surrounding environment. Thus, for practical reasons, an earphone should be used rather than a loudspeaker. It is also important that the user is able to turn off the loudspeaker announcement at any time. This would be vital if the user was standing next to a landmark. A limitation of this method of continuous playing is if the user had the ability to turn the device off, it is likely that the user will forget to turn the device back on. Therefore, a more user friendly system is preferred.

Direction of Crossing

The Ultrasonic Signpost System, illustrated in Figure 3.1, does not provide the direction of the crossing to a user (consider a 'DON'T WALK' sign). A user will only be aware that the sign is close, and in which general direction (large mean error) the beacon is located. An ideal device will provide the user with the ability to determine the direction of crossings, and landmarks etc.

3.4 Electronic Destination Signs

Electronic Destination Signs for buses and trains are becoming increasingly popular . During the last decade, announcements on Perth trains have indicated the following stop to passengers. Electronic Destination Signs eliminate the need for the driver to verbally announce such information to passengers. Several alternative designs are considered:

- Announcements upon activation by the driver.
- Announcements upon activation by passengers (with buttons also located at disabled seats).
- Announce at discrete acceptable time intervals to minimise annoyance to already waiting customers.
- Automatic announcement at the appropriate time (this may be two minutes prior to the next stop).
- Alternatively, announcements can be made continuously.

Talking bus stops (and train stops are also valuable for the vision impaired. Several alternative designs of these types of Electronic Destination Signs are considered:

- The sign making an announcement when a person is detected as being within range.
- Announcements at discrete acceptable time intervals to minimise annoyance to already waiting customers.
- Alternatively, announcements can be made continuously.

There are many companies producing such signs, some intended for use by all travellers and some designed specifically for vision impaired travellers. An example of this product is made by Luminator Inc. In 1999 Luminator Inc. in Texas, launched a new product, expanding upon their existing Electronic Destination Signs to incorporate a speaker that broadcasts destination and route information for visually impaired passengers [3].

3.4.1 Limitations of Electronic Destination Signs

Limited Use

The Electronic Destination Signs broadcast system is ideal for buses and trains. However this system is limited to these uses. It can not be used or adapted to guide vision impaired travellers, as it is unacceptable to have signs and landmarks identifying themselves continuously aloud, or each time someone approaches it.

3.5 Talking Signs^{TM}

Talking Signs^{TM} is a product designed by a team of both the legally blind and sighted engineers at the Smith-Kettlewell Eye Research Institute, located in the California Pacific Medical Centre, in San Francisco, California [11]. Presently, Talking Signs Inc. owns the rights to these patented devices and is promoting their use throughout San Francisco, the United States, and the world. Talking Signs Inc. has pioneered the implementation of these IR communications systems since 1993. There are successful installations of this system in the United States, Europe, and Asia.

In 1998 these talking signs made the breakthrough from being an experiment to becoming a commercial product. A sub-unit of Mitsubishi Corporation is now producing Talking Signs^{TM} devices, marketing the transmitters and receivers throughout Japan. The cost of Talking Signs^{TM} is about US$1000 per transmitter (estimated price including installation), and US$265 per receiver.

3.5.1 Operational Details

The Talking Signs^{TM} system consists of fixed IR transmitters, which convey speech messages to small hand held receivers carried by vision impaired travellers. Since IR transmission is directional, when a user of Talking Signs^{TM} receives a message, they can also tell the direction from which the signal comes from. When the volume of the signal is strongest, the message is coming from the direction in which they are pointing the hand held receiver. Thus, vision impaired users can make their way to the destination by walking in the direction from which they receive the strongest signal. This means that there is no need to remember or follow directions.

This concept consists of short audio signals sent by invisible IR light beams from permanently installed transmitters to a hand held receiver that decodes the signal and delivers the voice message through a speaker or headphones. The Talking Signs^{TM} transmitter is located inside a 4 inch x 4 inch plastic box, and is placed at landmarks such as building entrances or printed signs. A voice message describing the sign or landmark is pre-recorded digitally on a chip within the transmitter (for outside transmitters). This voice message is modulated and transmitted on a IR beam of light, using IR diodes. The person using the receiver (hand held device) presses a button to hear the voice message through their speaker or headphones. The strength of the signal can also be used a homing beacon to find the sign or landmark to which it is attached.

This system was the first IR system to work effectively both indoors and outdoors. These Talking Signs^{TM} may be used where landmark identification, or directional assistance is required.

A user of Talking Signs^{TM} scans their surrounding environment with the hand held receiver. As individual signals are encountered, the user hears the messages. For example, when entering a lobby, the hand held device might detect the transmission 'information and security desk' whilst being pointed straight ahead, 'to elevators and public telephones' when pointed to the right, and 'stairs to second floor' when pointed to the left. These messages are short and simple to understand, and are repeated continuously.

The hand held receiver device includes an on-off switch, volume control and a socket for headphones. The device is powered by a 9V battery and includes a breakaway strap (neck strap), for when the user is not using the hand held receiver. The transmitters, representing landmarks or way finding information, are either powered by 12V DC, or connected to a centralised system, that is powered by the mains (power).

The application of Talking Signs^{TM} at intersections involves providing two types of information to the users; where the sign is located and the identification of the sign. The former is provided by the relative strength of the received signal, and the latter by the voice information transmitted.

This system is an information system and not a safety system. It is still advised that vision impaired users continue to use their walking aid, or guide dog [11].

3.5.2 Technical Details

A centralised system is typically used for large interior installations [13]. Up to ten transmitters (heads) are powered through a centralised control device, which holds up to ten transmitter cards. Each individual transmitter card carries an individually recorded message. The transmitter heads are then connected to their transmitter card in the control device using twisted pair (cable). These centralised systems have one transformer to step down the power to 12V DC. Standalone devices are normally used for exterior applications and for interior locations that can not be linked by cable to a control unit. Each standalone device carries its own power transformer and recorded card.

System Overview [13]

880 to 950 nm carrier, amplitude modulated with 25Khz (auxiliary frequencies to 300Khz) FM subcarrier.

Subcarriers

F_c = 25kHz (or auxiliary frequencies as described above), Index = 0.76

F_m = 330 - 3300Hz (voice bandwidth, 6.6kHz)

F_{dev} = 2.5kHz

Carrier

880-950 nanometres

System Operation

The system operates at 25kHz

Any fluorescent light should be specified with a ballast frequency higher than 30kHz.

3.5.3 Experiments and Basic Data Obtained

Many experiments have been implemented to determine the feasibility of Talking Signs^{TM}. One such experiment [2] involved 20 people with little or no vision who were asked to cross four complex intersections in San Francisco, both with and without the information provided by Talking Signs^{TM}. Participants received approximately 10 minutes of training using Talking Signs^{TM} at intersections before the experiment began. Participants included people using both white canes and guide dogs, with and without hearing loss, people who considered themselves to be excellent travellers and people who did not consider themselves to be good travellers.

Results are summarised in Table 3.1.

In conclusion to this experiment, the use of Talking Signs^{TM} at intersections significantly improved safety, precision, and independence in street crossing, for both familiar travellers, and less confident and unfamiliar travellers.

Talking Signs^{TM}	**With**	**Without**
Began crossing during walk phase	99%	66%
Started within crosswalk	97%	70%
Started with a heading towards the opposite corner	80%	48%
Reached the opposite corner within crosswalk	76%	56%
Found crosswalk with no assistance	99%	81%
Identified Walk phase with no assistance	100%	76%
Crossed street with no assistance	97%	81%
Knew shape of intersection	86%	46%
Knew type of intersection control	84%	50%

Table 3.1: Talking Signs: Experimental Data

3.5.4 Multilingual

Multilingual Talking Signs^{TM} are now being developed [13]. The system was not initially designed for such a purpose, however these new signs will allow users to scan their surrounding environment, and hear the recorded translation in their own language. The user first hears the recorded message in the original language, followed by a translation in their own language.

This new enhanced receiver can store up to four hours of recorded messages using flash memory card technology. This extended storage time also means that the information stored can provide a more comprehensive description, rather than short messages. For example, information about the environment surrounding the sign could be included, resulting in a more practical transmitter.

3.5.5 Limitations of Talking Signs^{TM}

Reception of Simultaneous Voice Transmissions

The primary problem of this system is that the sign transmits the information in the form of streaming words with the hand held device demodulating and playing back the voice to a headset. This means that if multiple signs (located close together) are transmitting voice at the same time the receiver will receive the messages together, superimposed, with differing volume levels according to distance and position. This superimposed reception of transmissions being played to the user is confusing, irritable and unacceptable.

Multilingual

Talking Signs^{TM} were originally designed to operate using only one language, being the language transmitted by the sign add-on device. Development to make these devices multilingual is now underway. It is proposed that after the user hears the voice in the language sent by the transmitter the hand held device will then play back the translated version in the language desired by the user. This upgrade from the original Talking Signs^{TM} system may include the need to design a translator that fits inside the hand held device, that can translate from multiple languages to the language of the user, all at a reasonable cost.

Installation

One of the important steps in the installation process of these Talking Signs^{TM} is the calibration process after installation. Due to the nature of IR light in building environments, care must be taken to calibrate and adjust each transmitter head. The cone of dispersion of each light beam must be set to the exact location required and eliminate any reflections.

Cost

As mentioned in Section 3.5, the cost of Talking Signs^{TM} is approximately US$1000 per transmitter (including installation), and US$265 per receiver. This is too expensive for the following reasons. Organisations such as councils, Governments, as well as private firms and organisations, will not be prepared to install Talking Signs^{TM} transmitters due to the large costs involved in installing multiple transmitters at any location. Also, at US$265 per receiver, many vision impaired users are unlikely to purchase the hand held devices. At such a price it would also be difficult for charity organisations to purchase a hand held device for every legally blind person (Note that there are an estimated 384,000 in Australia alone).

Power Consumption

Talking Signs^{TM} transmitter heads continuously transmit their message. This requires significant amounts of power as they are transmitting information that uses power even when there are no hand held devices to receive the information. Continuous transmission limits the life time of batteries, which are used to operate Talking Signs^{TM} located outside. The Talking Signs^{TM} centralised system transmitters run off mains power using a 12V DC step down transformer. Thus, in this application, power is not limited, however it can be expensive. Transmitters would be more efficient if they did not transmit when unnecessary.

Using a Centralised System

A driving force in the price of Talking Signs^{TM} transmitters is the fact that transmitters located close together are joined using a centralised system. This is not necessary as voice recording and modulation technology is relatively cheap. Thus, using the centralised system would not substantially reduce the cost (Note: centralised systems increase installation costs). The system would also be improved if wires were not required to be connected to the transmitters, making it more feasible to place the transmitters in existing buildings and structures. It would thus be more practical and more convenient (also possibly cheaper) if transmitters were completely independent of each other, with no twisted pair or any other type of cables attached.

3.6 Proposed Solution - MIRSIGS

MIRSIGS (Multilingual Infra Red Sign Identity and Guidance System) is a communication system for the vision impaired similar to that of the Talking Signs^{TM} system. However, there are fundamental differences and MIRSIGS does not have most of the disadvantages of the Talking Signs^{TM} system. MIRSIGS involves two devices: sign add-on devices which are to be placed on or near the signs being identified, and hand held devices to be carried by the user for travelling purposes. The sign add-on devices in MIRSIGS transmit two types of information: an 8-bit identity code word defining the sign, and a guidance tone indicating to the user the direction of the sign. Hand held devices only transmit code words and do not transmit any type of guidance tone. The 8-bit identity code words are designed to directly address a location on a voice chip which contains a description of the sign.

3.6.1 Advantages of MIRSIGS

MIRSIGS has many advantages over the devices previously discussed. These are in the areas of power consumption, installation, multilingual capabilities and the independent sign add-on devices. A main feature of design is its ability to separate out transmissions from different sign add-on devices.

No Superimposed Transmissions

The main advantage of MIRSIGS over the Talking Signs^{TM} system is that it does not transmit streaming voice, nor are there any simultaneous transmissions of any kind. To overcome the problem of receiving simultaneous and superimposed voice at the receiver, an 8-bit identity code word is transmitted by sign add-on devices upon request by hand held devices. Each sign transmits its identity code word at a set period of time after receiving the request. This set delay is designed to be defined by the identity code word itself. Therefore, if there is more than one sign within range the sign add-on devices will not transmit their identity code words simultaneously. Two of the same signs within transmission range of each other will not be allowed in this system. This is due to the fact that after the user determines which sign they wish to proceed towards, the hand held device will be transmitting the identity code word belonging to both of these sign add-on devices. The user will then hear the guidance tone from two conflicting directions and this is to be avoided.

Multilingual

The design of MIRSIGS allows for the simple implementation of multilingual devices. As voice messages are recorded on a chip inside the hand held devices and not stored in the sign add-on devices, any desired language can be recorded onto the voice chip. The only requirement is that at each defined location (address) on the voice chip there is voice that describes the sign. This allows successful identification of signs in any language as the 8-bit identity code words are universal. Only the message recorded on the voice chip inside the hand held device needs to be different.

If the location in which a vision impaired user is travelling is such that two languages are commonly used, or the user does not speak local languages, the user simply needs to purchase (or use) a hand device containing the language that they desire to hear. This reduces the restrictions of the system.

Installation

Sign add-on devices are required to be placed such that the IR cone of dispersion is directed in the intended direction, and to prevent reflections. This is a simple procedure as MIRSIGS will include IR LED banks which can be adjusted using a screw driver. They can be adjusted in such a away that they are pointed in the correct direction and such that there will be no reflections. Tests should be carried out upon installation to ensure effectiveness of MIRSIGS in the environment.

Power Consumption

The complete MIRSIGS will provide the ability for both the hand held devices and the sign add-on devices to be battery operated. It is also desirable to have long usage intervals between battery charges. This will be made possible by designing the system such that sign add-on devices run in a low power consumption mode until they receive a request from a hand held device. When such a request is received, the sign add-on device powers on and services the request. At the completion of the service, the device powers down again to a minimal power consumption level. Hand held devices will also only consume power whilst the vision impaired user is actively using the device. Power consumption therefore will be minimal for normal operation of both devices. This will be implemented in design by considering power consumption at every stage during the design process. Sign add-on devices will also have the ability to operate using mains power.

Independent Transmitters

The design of MIRSIGS will be such that each sign add-on device is capable of running from battery or mains power. Therefore the decision to use batteries or mains power can be made individually at each location (at the time of installation). If sign add-on devices are reused, then this decision can be evaluated again. For example, if the devices are to be installed during the construction of a new building, it may be financially advantageous and more convenient to operate the sign add-on devices from mains power. However, for existing buildings, it will be more convenient, and may be financially advantageous to use batteries. The independence of transmitters also means that no cables need be connected to the sign add-on devices.

4.0 MIRSIGS SYSTEM DESIGN

4.1 The Approach

The approach to system design was focused on three main areas; cost, simplicity in design, and power consumption. The cost is to be minimised and the design is to be as simple as possible. This is to allow the final product to be as inexpensive as possible. Minimal power consumption is another important factor that must be considered in the prototype design process to enable more efficient power management and integration at a later date.

4.2 Infra Red

For MIRSIGS to operate successfully, the chosen transmission type should enable the vision impaired user to distinguish in which direction the sign is in and whether or not they are approaching it directly. The transmission must also contain information defining the sign to the user.

Consider the sign transmitting both a guidance tone and its 8-bit identity code word to hand held devices, and consider that within the size of a room, the received amplitude of radio transmissions is not a function of the distance to, or orientation of the receiver. Taking this into account, if radio propagation was used then there would be no way of telling where the sign is located and the user would not be able to determine either the direction of the sign, or distance from the sign. Also, since radio transmission propagates through walls, the user would not know if the transmission they have detected is from a sign in the same room, or an adjacent room. Licensing issues can also be a problem when considering radio transmission as the same channel could not be purchased, licensed, and used in every nation. Different countries operate at different frequencies and use different frequency bands. This would therefore restrict hand held devices to their local zone. Perhaps this could be overcome by designing multi-channel hand held devices. However, this increases the complexity of using the system, the difficulty in the design of the system, and the cost of the system. For these reasons radio transmission is a poor choice for this application.

IR transmission however is ideal as it is extremely directional. The strength of the received signal at the hand held device would vary proportionally according to the direction in which the hand held device was pointed. It would also vary proportionally according to the distance between the hand held device and the transmitter (the sign add-on device). This allows the user to correctly identity the direction of the sign, as well as whether or not they are approaching it directly. Due to the directional characteristics of IR propagation, varying the strength and direction of the transmission cone could ensure that there are minimal transmission reflections off obstacles, and that the transmitted signal would not propagate through doors that may be next to or below the transmitting sign add-on devices. The strength of transmission could be varied to allow signs to be 'heard' from an appropriate distance, according to the environment and type of sign. IR propagation would not be detected in adjacent rooms due to the fact that IR propagation is blocked by most opaque obstacles. However due to this fact that IR propagation is blocked by most opaque obstacles, such as trees, pillars and people, the sign add-on devices would need to be placed in an appropriate position, as discussed in Section 1.1.

The operation of hand held devices would also use IR transmission successfully as only sign add-on devices within distance, and in the direction to which the hand held device is oriented, would receive transmissions sent by hand held devices. IR transmission also simplifies the use of hand held devices, simplifies design, and thus decreases the cost (as compared to radio) as no channel needs to be licensed or paid for.

For these reasons IR transmission was chosen over radio transmission.

4.3 Choice of Modulation

Some of the different types of modulation available were discussed in Section 2.5. Since the signal transmitted by the sign add-on devices will be required to include the 8-bit identity code word and the guidance tone, suitable and compatible forms of modulation must be chosen.

Modulating the amplitude of the received signal is reserved for the guidance tone, to make use of IR propagation properties, as discussed below. Therefore, modulation techniques which alter the signals amplitude, including BASK, may not be used to modulate the 8-bit identity code word. The amplitude of the carrier wave is unchanged in both BFSK and BPSK modulation. The 8-bit identity code word information not being stored in the amplitude of the carrier signal is advantageous as it means that the resultant BFSK or BPSK signal can be amplitude modulated by the guidance tone signal as required, without conflicts between the two types of modulation used.

BPSK is more efficient than the BFSK in terms of bandwidth, however BPSK requires more complex circuitry in the receiver. Therefore, an initial choice must be made between bandwidth and more complex circuitry. As there are no bandwidth limitations in this application; simple, cost efficient circuitry is to be used. Therefore, BFSK was chosen as the keying technique to be used.

Since the amplitude of a received IR transmission is proportional to both the distance from the transmitter and the direction in which the receiver is pointed, amplitude modulation was chosen to convey the guidance tone. This will result in the guidance tone becoming louder both when the hand held device is closer to the sign add-on device, and when it is pointed towards the sign add-on device. An amplitude modulation factor of M=0.2 was chosen such that at most one third of the BFSK signal would be compromised. Thus, the guidance tone will continuously amplitude modulate the BFSK signal, which is of a constant frequency when the identity code word is not being sent.

4.4 Choice of Frequencies

Fluorescent lights emit IR radiation at 100kHz, and the sun produces IR radiation at very low frequencies, which can be considered to be a constant (compare to DC) level of radiation. BFSK frequencies of 40kHz representing a binary '0', and 50kHz representing a binary '1' were chosen, as they are far from significant naturally occurring noise in the IR spectrum. This means a BPF in the receiver could quite successfully remove unwanted noise, leaving a clean BFSK signal to demodulate. These frequencies are somewhat arbitrary as there are a large range of frequencies in the IR spectrum that are far from significant naturally occurring noise. Thus, other frequencies could be chosen as long as there is a sufficiently large difference between these frequencies so that any frequency-affecting noise would not cause errors in demodulation. The frequency of the guidance tone was chosen to be 1kHz. This frequency was chosen as it is well within the audible range of the human ear (approx 18kHz max), and is not irritable to listen to. A frequency such as 2kHz could also have been chosen, being compatible with these guidelines.

As an example, when the 8-bit identity code word 10101100 is being sent, the AM-BFSK signal transmitted will appear as illustrated in Figure 4.1 (Note: This illustration uses different BFSK and AM frequencies for illustrational purposes).

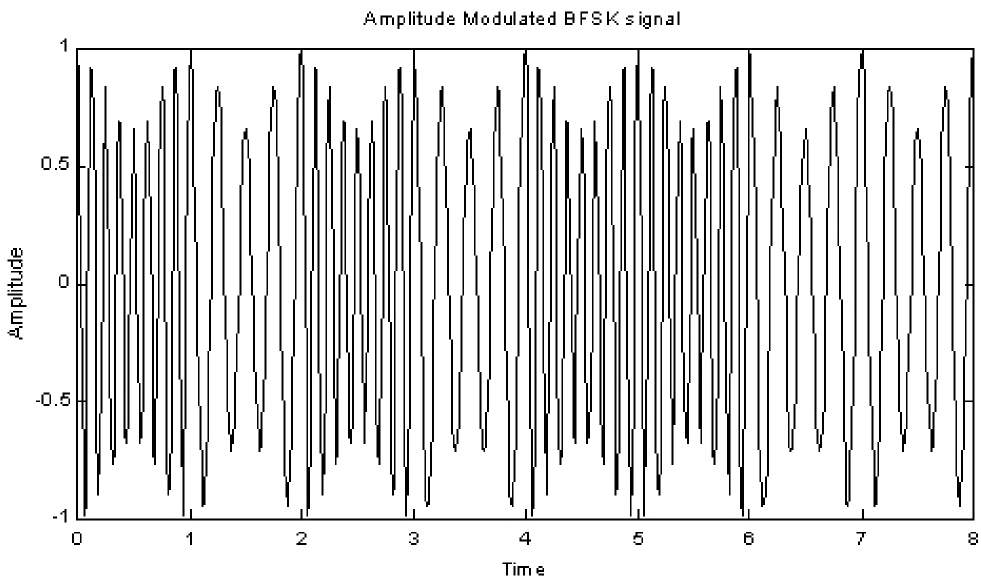

Figure 4.1: Amplitude Modulated BFSK Signal, M=0.2

4.5 Hand Held Device

The operation of the hand held device in this prototype implementation is to; playback the guidance tone continuously streamed by sign add-on devices, and to request identity code words from sign add-on devices at the demand of the user. The hand held device requests the signs 8-bit identity code words by sending a 'Request' code word, which is reserved for this operation. This code word was arbitrarily chosen to be '10110011' for the prototype. As decided in Section 4.3, BFSK will be used to construct the hand held device's data signal. In the prototype, the hand held device will only send the one exact same transmission (being the 'Request' code word above), upon user demand. The user will perform this 'Request' by pressing a button on the hand held device labelled 'Request' in Braille.

The hand held device will be able, upon receipt of a sign identity code word, to demodulate and interpret the signs identity. This is done by using the signs 8-bit identity code word to directly address a location on a ChipCorder$^{(R)}$ which contains a description of the sign. The ChipCorder$^{(R)}$ is located within the hand held device circuitry. As shown in Figure 4.2, the hand held device will also include a power switch, volume control, and a button to enable the playback of the guidance tone. This guidance tone button is used, as it is preferred by the user to hear the playback whilst they are holding the button, rather than the guidance tone being played continuously when the power switch is on. Predicted dimensions of the final hand held device are also illustrated in Figure 4.2.

4.5.1 BFSK Transmitter

As the hand held device only transmits the 'Request' code word, which is always the same, the code word is physically set by tying the bits HIGH or LOW, and can not be easily changed. As shown in Figure 4.3, This 8-bit identity code word is then modulated, resulting in a BFSK signal, which is then transmitted through a bank of IR LED's, driven by the IR LED driver circuitry.

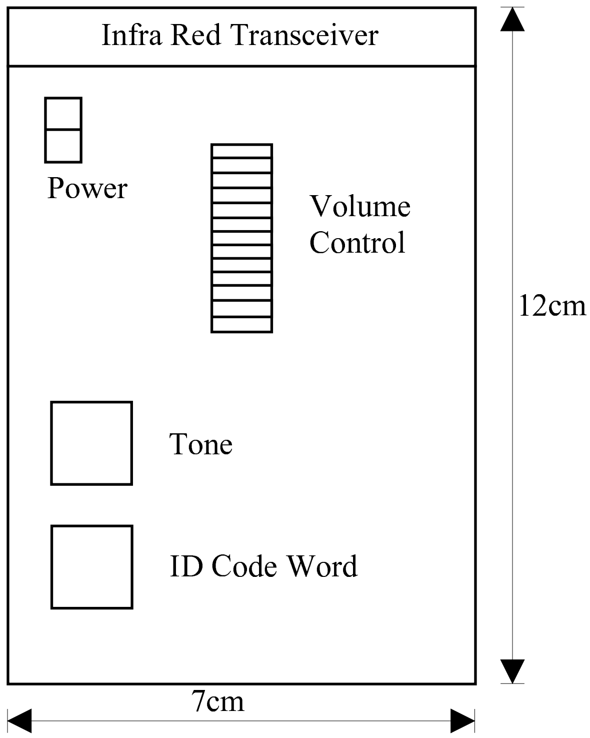

Figure 4.2: Illustration of Hand Held Device

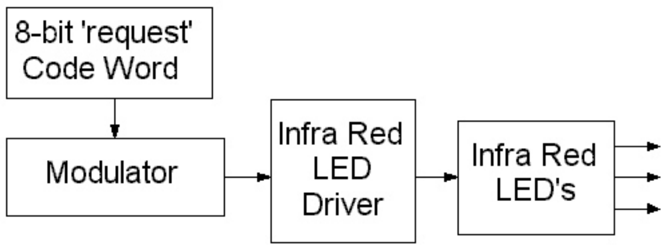

Figure 4.3: Hand Held Device Transmitter Block Diagram

4.5.2 AM-BFSK Receiver

The hand held receiver must have the ability to receive the amplitude modulated BFSK (AM-BFSK) signal and demodulate both the 8-bit identity code words and the guidance tone. Thus, after the IR signal is received, it must pass through two separate paths. The top path of Figure 4.4 extracts the guidance tone from the signal using an envelope detector. Either the positive or negative envelope can be used. This signal is then amplified and played through the speaker. The bottom path represents the demodulation of the 8-bit identity code word using a BFSK demodulator after band pass filtering the received signal to remove unnecessary noise. The recovered 8-bit identity code word is then used to directly address the location on the ChipCorder$^{(R)}$ containing the description of the sign. The ChipCorder$^{(R)}$ then plays back a description of the sign through the speaker. An earphone is designed to be used in place of the speaker in the final system. However the prototype system uses a speaker.

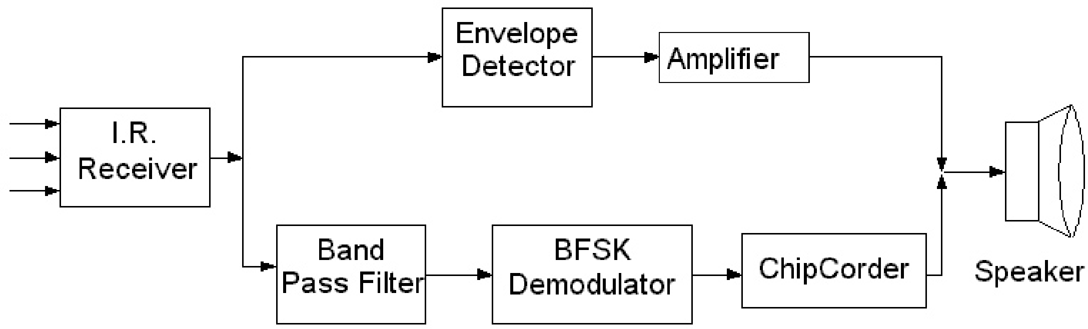

Figure 4.4: Hand Held Device Receiver Block Diagram

4.6 Sign Add-on Device

The sign add-on device transmits two types of information. It transmits its own 8-bit identity code word upon receiving the 'Request' code word (10110011) from hand held devices as discussed in Section 4.5, and it transmits the guidance tone, which in the prototype, streams continuously. When no 8-bit identity code word is being sent, a 40kHz carrier is amplitude modulated using a modulation factor of M=0.2. This signal is different however, when an 8-bit identity code word is being transmitted. In this case, instead of the carrier being 40kHz, this signal will be constructed using BFSK, and be of frequencies 40kHz and 50kHz. This signal will act as the carrier and continue to be amplitude modulated. Externally, as illustrated in Figure 4.5, sign add-on devices will be small in size (expected dimensions shown), and include an adjustable bank of IR LED's. This bank is adjustable to allow the direction of the cone-shaped propagation to be set upon installation, as discussed in Section 3.6.1. The sign add-on device must also have the ability to receive and distinguish the 'Request' code word (from other code words), and for the prototype, ignore all other code words.

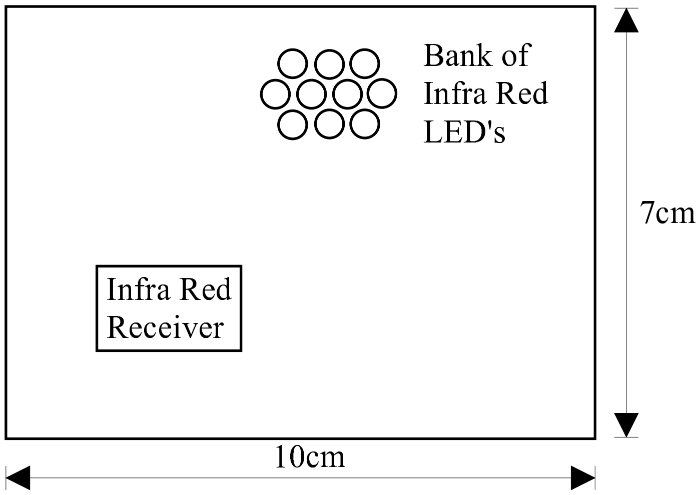

Figure 4.5: Illustration of Sign Add-on Device

4.6.1 AM-BFSK Transmitter

The sign add-on device's transmitter includes a mixed mode modulator which constructs a BFSK signal using the signs 8-bit identity code word and then amplitude modulates this with the guidance tone, which is generated within the sign add-on device. As shown in Figure 4.6, this AM-BFSK signal is then transmitted through a bank of IR LED's, driven by the IR driver circuitry.

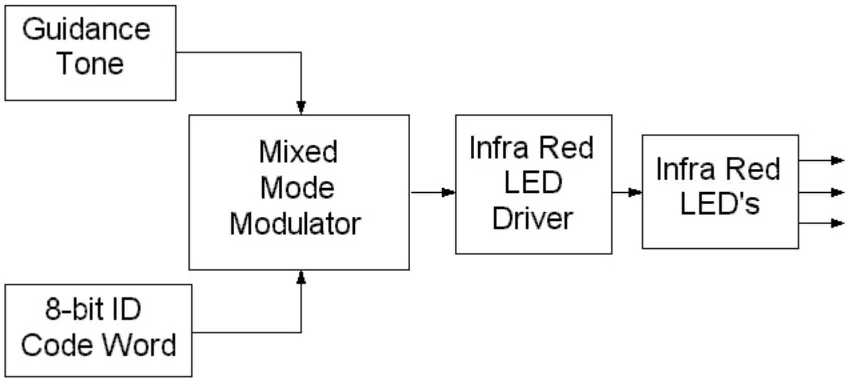

Figure 4.6: Sign Add-on Device Transmitter Block Diagram

4.6.2 BFSK Receiver

The receiver of the sign add-on device only needs the ability to receive signals, and identify the 'Request' code word (10110011). Similar to the bottom path of the hand held devices receiver in Section 4.5.2, the received IR signal is demodulated using a BFSK demodulator after being band pass filtered to remove unnecessary noise. The resultant signal is then compared to the locally stored copy of the 'Request' code word. If the received code word is identified as the 'Request' code word then the sign add-on device must transmit its own 8-bit identity code word within the carrier signal (which is amplitude modulated by the guidance tone), without interrupting the continuous transmission. This is done by sending a control pulse to the transmitter circuitry to trigger this operation (illustrated in Figure 4.7).

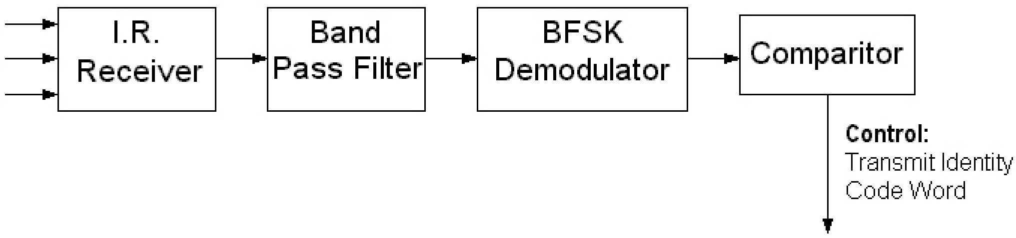

Figure 4.7: Sign Add-on Device Receiver Block Diagram

5.0 DETAILED DESIGN - HAND HELD DEVICE

5.1 System Clock

The clock speed for the prototype MIRSIGS was arbitrarily chosen to be 100Hz. This system clock was implemented using a 555 timer [28] which can be set to produce an ideal clock signal (square wave). Characteristics of the square wave, such as the high voltage duration (T_1), the low voltage duration (T_2) and the duty cycle are defined by external components. A 100Hz square wave with a 50% duty cycle was produced (T_1 equal to T_2). This was achieved using Equations 5.1, 5.2, 5.3 and 5.4, setting $R_a = R_b$, $T_1 =$ 5ms, $T_2 =$ 5ms and F = 100Hz. A diode [21] was used to simplify design, requiring that only one value of resistance needed to be calculated and used [15]. The calculated external component values used were C = 0.1uF, and $R_a = R_b =$ 78kΩ, and the circuit configuration is shown in Figure 5.1. The 'LM555 Timer' used has a maximum power dissipation of 25mW when operated with supply voltage of 5V.

$$T_1 = ln(2)(R_a)C \tag{5.1}$$

$$T_2 = ln(2)(R_b)C \tag{5.2}$$

$$T = T_1 + T_2 = 2T_1 = 1/F \tag{5.3}$$

$$F = 1/T = 1/(ln(2)(R_a + R_b)C) \tag{5.4}$$

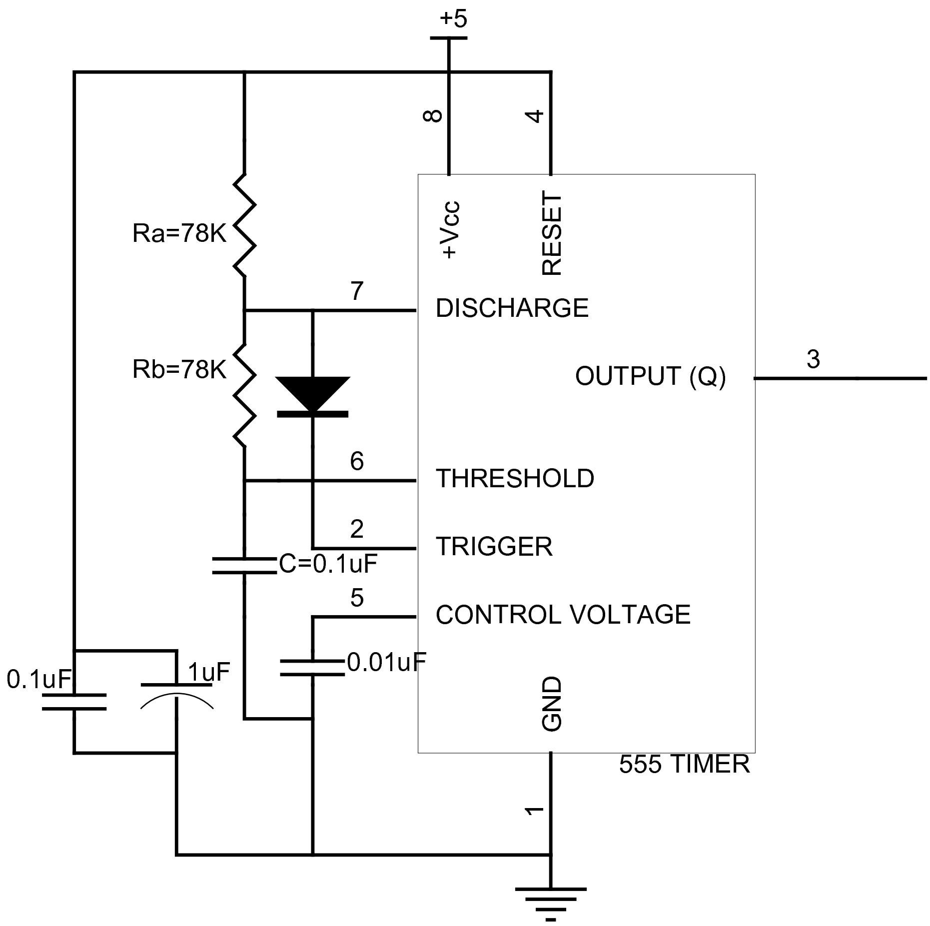

Figure 5.1: 100Hz System Clock Circuit Configuration

5.2 Modulation of 'Request' Code Word

The XR-2206 is an integrated monolithic function generator, capable of producing quality sine, square, triangle, ramp and pulse waveforms with high accuracy and stability [32]. The output waveform of the XR-2206 can be both amplitude and frequency modulated by an external reference applied to pins 1 and 9 (pinout diagram shown in Table 5.2). The frequency of operation is defined by the external components. This flexible modulation IC costs approximately AU$12 and has a frequency range from 0.01Hz to 1MHz. This IC was chosen to modulate signals in both the hand held device and the sign add-on device prior to transmission. BFSK signal generation using the 'Request' code word is achieved by choosing values of C, R_1 and R_2 using equations 5.5 and 5.6, with f_1 and f_2 defined as 50kHz and 40kHz respectively (as previously selected). The output of the XR-2206 is phase-continuous during transitions. If keying reference voltage at pin 9 is $\geq$ 2V then only R_1 is activated, and if the voltage at pin 9 is $\leq$ 1V, only R_2 is activated. Therefore a LOW voltage at pin 9 means a 40kHz signal will be generated, and a HIGH voltage present at pin 9 means a 50kHz signal will be output from the XR-2206, on pin 2 (output pin).

$$f_1 = 1/(R_1 C) \tag{5.5}$$

$$f_2 = 1/(R_2 C) \tag{5.6}$$

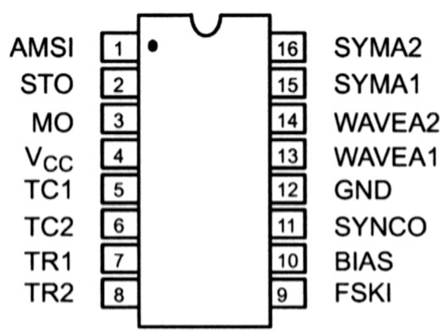

Figure 5.2: XR-2206 Pin out Diagram

The XR-2206 Monolithic Function Generator is available in a choice of 4 packages,

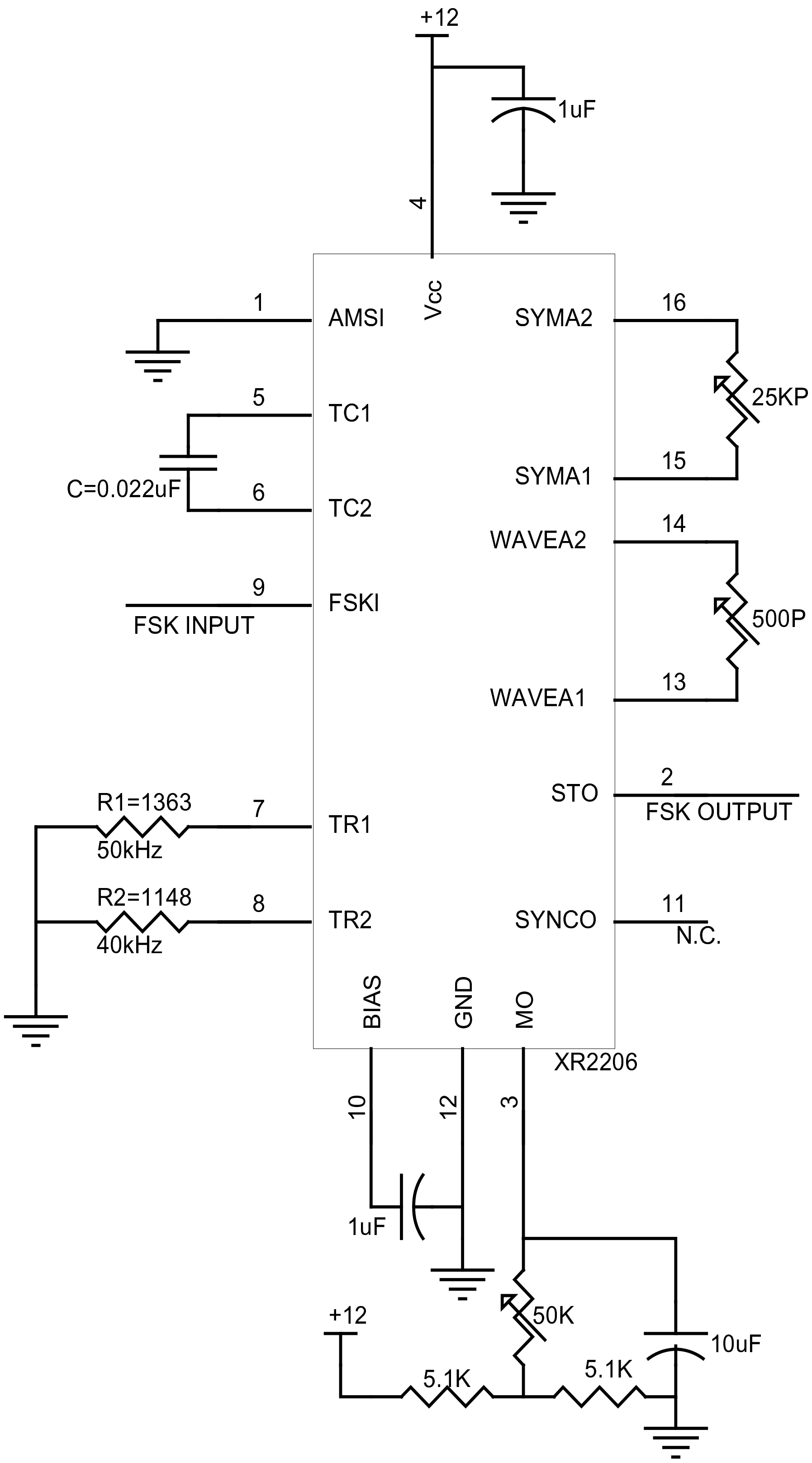

Figure 5.3: XR-2206 Schematic Diagram

all with 16 pins. The smallest of these is the SOIC package that is only 10.5mm x 7.6mm x 2.65mm in size. In the prototype a DIP package was used. These IC's both have a maximum rated power dissipation of 750mW at 25°C, with a derating factor of an additional 5mW/°C for temperatures greater than 25°C. They also are capable of operating with voltage supplies between 10V and 26V (12V is used in this prototype).

The resistor R_3, connected to pin 3, is used to adjust the maximum output amplitude. For sinusoidal wave output (as was used) the maximum output amplitude is approximately 240mV per kΩ of R_3. Therefore, for the 50kΩ used, the maximum output amplitude is approximately 12V.

5.3 Serial Code Word Generation

The XR-2206 requires the 'Request' code word to be in serial form and to be connected to pin 9 (see Figure 5.4). The XR-2206 should only receive this signal when the user presses the 'Request' button. The design used for this operation involved the use of a 'DM74LS221 Dual Non-Retriggerable One-Shot' [20] and a 'MC74HC165A 8-bit Serial or Parallel-Input, Serial-Output Shift Register [18]'.

The one-shot is used to supply a HIGH voltage pulse for 80ms to the shift register. This particular dual one-shot IC is capable of pulse widths in the range of 30 nanoseconds to 70 seconds, is internally compensated for V_{cc} and temperature variations, and has both A and B inputs. Pin A is active-LOW trigger, and pin B is active HIGH trigger, as shown in Table 5.1. The A input is grounded as it is not used and the triggering HIGH pulse (which occurs upon receiving a 'Request' code word) is connected to the B input. The clear input can terminate the output pulse at a predetermined time independent of the timing components, but is not used in this design.

The value of C_x may vary from 0 to 1000uF and for polarised capacitors the positive side should be connected to the C_{EXT} pin (pin 6 or 14). The pulse width was designed to be 80ms by selecting values for R_x and C_x (connected as shown in Figure 5.5), using

Equation 5.7, and setting $t_W = 80$ms. Values of $R_x = 24.24\text{k}\Omega$ and $C_x = 3.3$uF were used.

$$t_W = Ln(2)R_x.C_x \tag{5.7}$$

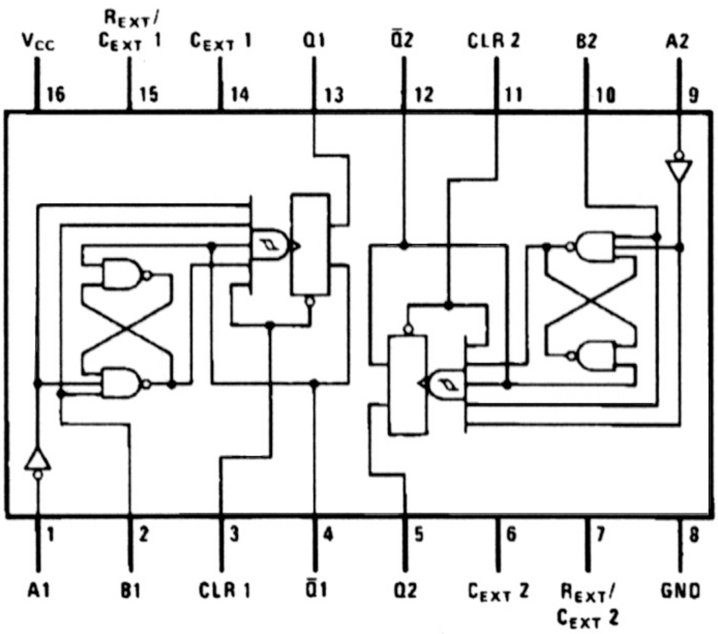

Figure 5.4: Dual One-Shot Pin out Diagram

Inputs			Outputs	
CLEAR	**A**	**B**	**Q**	$\bar{\mathbf{Q}}$
L	X	X	L	H
X	H	X	L	H
X	X	L	L	H
H	L	↑	⎍	⊔
H	↓	H	⎍	⊔
↑ (Note 2)	L	H	⎍	⊔

Table 5.1: Dual One-Shot Function Table

The 'MC74HC165 parallel-in serial-out shift register' is an 8-bit shift register with outputs from the last stage. Data can be loaded into the register in either parallel or serial form. When there is a LOW voltage present at the Serial Shift/$\overline{ParallelLoad}$ pin (pin 1) data is loaded asynchronously in parallel from pins A to H (pins 11 to 14 and 3 to 6), and

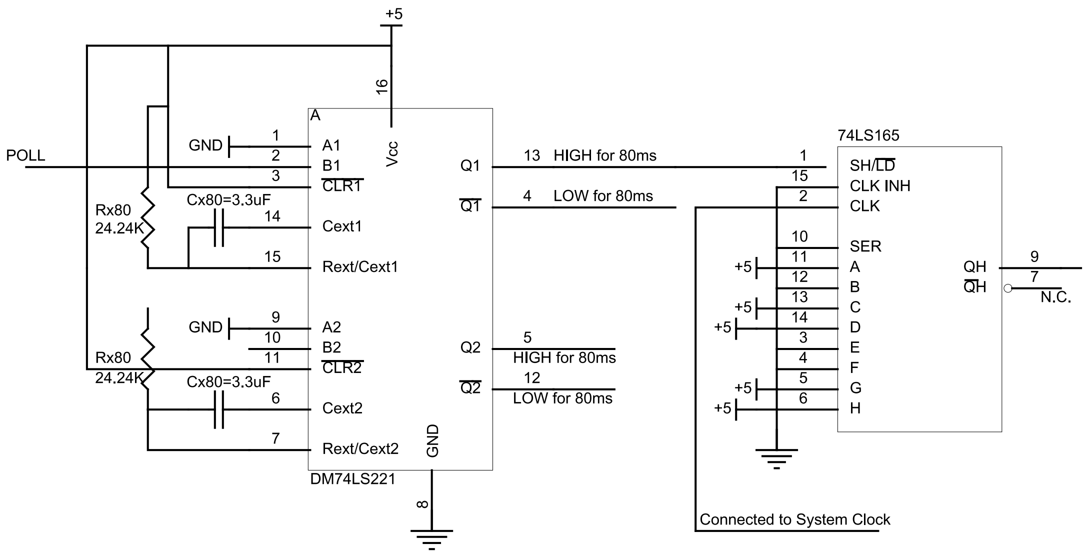

Figure 5.5: Serial Code Word Generation Circuitry (Hand Held Device)

when this voltage is HIGH, data is loaded serially from the S_A input pin (pin 10) on the rising edge of the clock or clock inhibit pins (pin 2 or 15). The pinout diagram is provided in Figure 5.6 and such operations of the MC74HC165 can be seen in Figure 5.2.

The 'Request' code word is defined by directly connecting the parallel input pins to HIGH and LOW voltages, such that the code word was 10110011 as previously defined. The clock inhibit pin (pin 15) was grounded such that only a rising edge at the clock pin (pin 2) would clock inputs when in serial mode. This rising edge is provided every 10ms by connecting the system clock to the clock input pin (pin 2). The output of the one-shot was connected to the Serial Shift/Parallel Load pin (1). This output voltage is normally LOW and goes HIGH for 80ms when a HIGH voltage is applied to the B input of the one-shot. This 'normally' LOW voltage at pin 1 of the shift register asynchronously loads the parallel data (the 'Request' code word) into each of the shift registers' eight internal stages. When this voltage goes HIGH for 80ms, the data begins to be serially loaded from the Serial Data input, pin 10. The Serial Data input is grounded, resulting in all 8 stages in the shift register being cleared after 8 clock pulses. Since the clock speed is 100Hz, within the 80ms that the Serial Data is allowed to clock into the stages only eight outputs are obtained from the output Q_H (pin 9). Pin 10 ($\overline{Q_H}$) is the logical complement of pin 9. The output (Q_H) was directly connected to the FSK input pin of the XR-2206 modulation IC (pin 9), so that this serial data is used to key (construct) the BFSK signal. When no keying signal is being applied to this input pin (by the shift register), the voltage level applied is LOW, resulting in a constant frequency signal of 40kHz.

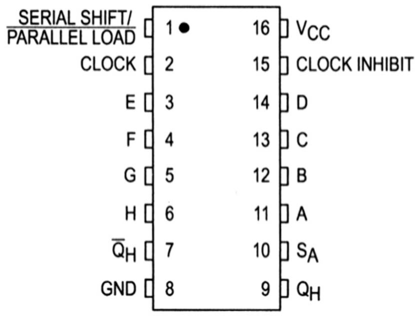

Figure 5.6: Serial or Parallel-In, Serial-Out Shift Register Pin out Diagram

Inputs					Internal Stages		Output	
Serial Shift/ $\overline{\text{Parallel Load}}$	Clock	Clock Inhibit	S_A	A – H	Q_A	Q_B	Q_H	Operation
L	X	X	X	a … h	a	b	h	Asynchronous Parallel Load
H	$\uparrow$	L	L	X	L	Q_{An}	Q_{Gn}	Serial Shift via Clock
H	$\uparrow$	L	H	X	H	Q_{An}	Q_{Gn}	
H	L	$\uparrow$	L	X	L	Q_{An}	Q_{Gn}	Serial Shift via Clock Inhibit
H	L	$\uparrow$	H	X	H	Q_{An}	Q_{Gn}	
H	X	H	X	X	No Change			Inhibited Clock
H	H	X	X	X				
H	L	L	X	X	No Change			No Clock

X = don't care Q_{An} – Q_{Gn} = Data shifted from the preceding stage

Table 5.2: Serial or Parallel-In, Serial-Out Shift Register Function Table

The MC74HC165 (shift register) has a minimum setup time (t_{su}) of 20ns and a minimum hold time (t_h) of 5ns. The hold time is satisfied because the one-shot operation ensures that HIGH inputs will last for 80ms and because the system clock speed is 100Hz in this prototype. This equates to the HIGH being held for a minimum of 70ms after the clock pulse. This is substantially more than the required 5ns. The setup time, t_{su} may not always be met, since the one-shot does not know the existence and independent operation of the system clock. The one-shot outputs an 80ms HIGH pulse after receiving a HIGH input at its B input (pin 2). As mentioned in Section 5.1, the high voltage duration (T_1), which is equal to the low voltage duration (T_2), is 5ms. Thus statistically, $t_{su} = 20$ns will not be met once for every 250,000 attempts.

The voltage source used for the DM74LS221 and the MC74HC165 is 5V. The maximum power consumption of the MC74HC165 is 750mW for DIP and 500mW for SOIC, neither having derating factors for temperatures below 65°C (at which: 10mW/°C and 7mW/°C respectively). The power consumption of the DM74LS221 was not provided.

5.4 Infra Red Transmitter

The IR LED's used were of type 'Z3235'. These were chosen arbitrarily due to their price and availability, as the type and range of the IR LED's to be used is not within the scope of this project. The $12V_{p-p}$ BFSK signal to be transmitted was generated by the XR-2206 and output on pin 2. After removing any existing DC voltage with a coupling capacitor, the sinusoidal signal swings around zero volts, from a minimum of -6V to a maximum of +6V. To make the entire signal-swing positive, 6V DC is then added to the signal. This is due to the fact that IR LED's can not propagate signals representing negative currents or voltages applied to them, as they cannot transmit negative light. A MPSA14 BJT transistor in a common-collector configuration then drives current, proportional to the voltage connected to its base junction [9], to the load (connected to the emitter), with the collector connected to 12V. The IR LED's have a maximum forward current rating of 50mA, thus the values of the load resistors (R_{ir}) must be chosen such that the current through them is $\leq$ 50mA.

Using simple circuit analysis of the design, which is shown in Figure 5.7, an expression of the maximum voltage across each R_{ir} resistor (V_{IRmax}) was calculated using Equation 5.8. V_{Bmax} is the maximum voltage level at the transistors base junction (use 6V), V_{BE} is the voltage drop from the transistor base junction to its emitter junction (measured to be about 1V for the MPSA14 [27]), and V_{LED} is the voltage drop across an IR LED. The voltage drop across the IR LED is specified on the data sheet as 1.2V. The resistance to be used of 75Ω is calculated in Equation 5.10. Thus the BFSK signal generated by the XR-2206 is effectively converted into a current waveform by the transistor and the R_{ir} resistors and is then propagated into space with a cone shape, by the IR LED's.

$$V_{IRmax} = V_{Bmax} - V_{BE} - V_{LED} Volts \tag{5.8}$$

$$V_{IRmax} = 6V - 1V - 1.2V = 3.8Volts \tag{5.9}$$

$$R_{IR} = 3.8V/0.050mA = 76\Omega \approx 75\Omega \tag{5.10}$$

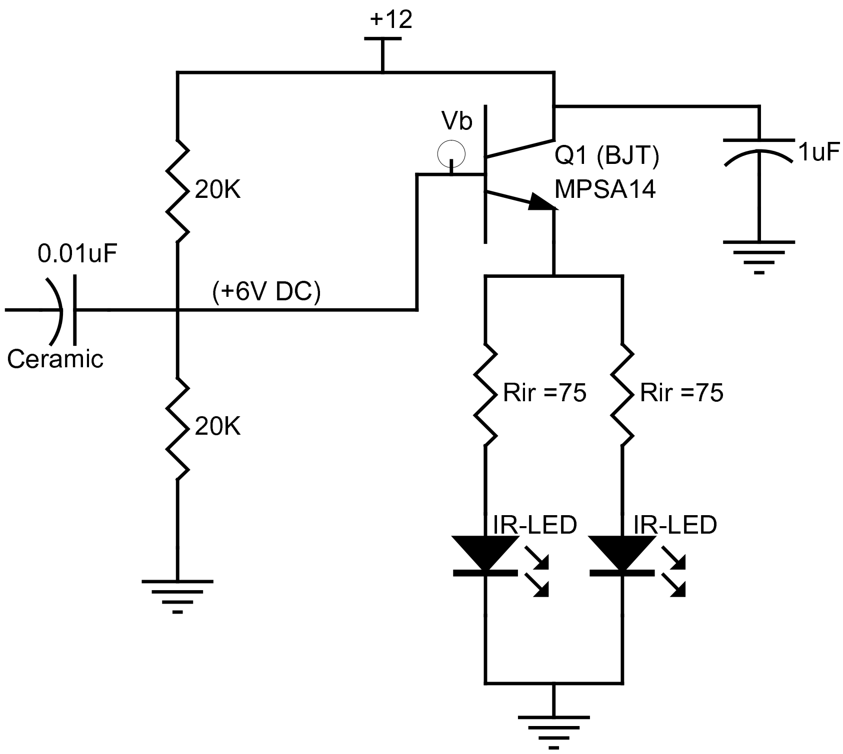

Figure 5.7: Infra Red Signal Driver and Transmitter

5.5 Infra Red Receiver

The receiving photodiode and subsequent signal amplification circuitry is shown in Figure 5.8. The key idea behind this design is that when IR light is incident on the photodiode, current will flow. When the level of light incident is at maximum, the photodiode will act as a short circuit, making the input to the amplifier stage 12V. Since the IR signal transmitted is a sinusoidal signal, this voltage will also be sinusoidal.

The LF351 Op Amp [23] is connected in a transimpedance configuration [16]. In this configuration an Op Amp functions as a current to voltage converter. The LF351 JFET

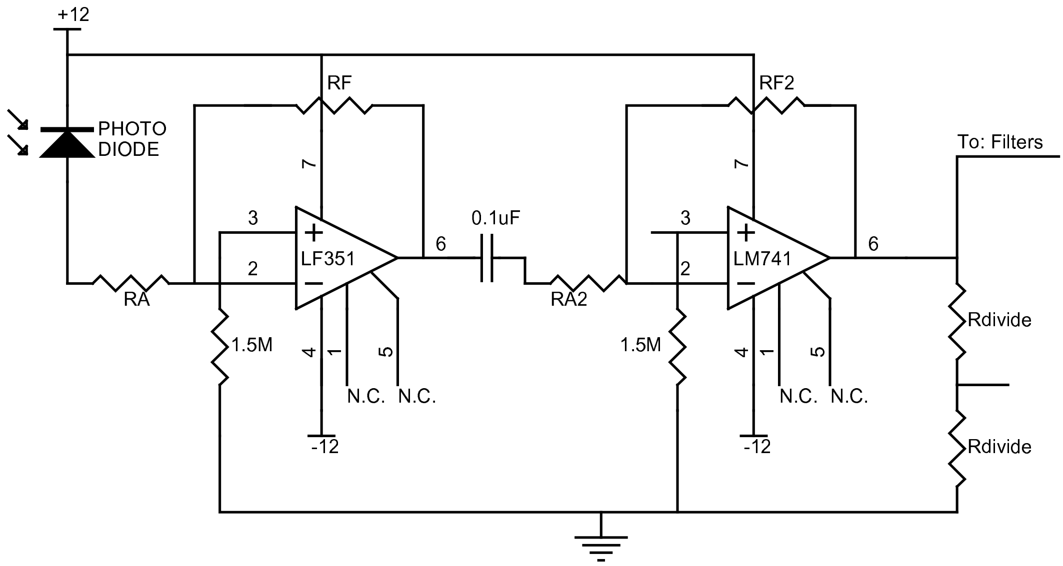

Figure 5.8: Infra Red Signal Receiver

low noise Op Amp has a typical gain-band width product of 4MHz, a voltage gain of up to 15,000, and is compatible with voltage supplies of $\pm 5V or \pm 12V$ (5V is used in this design). The LM351 is a JFET type Op Amp which means its input impedance is significantly high, in the order of $10^{12}\Omega$. This was used to reduce loading on the photodiode (such that it requires low currents from the photodiode). The transimpedance amplifier stage's feedback resistor, R_F, is 36kΩ, so that the instantaneous output voltage at any point in time can be calculated using Equation 5.11, where I is the current into the amplifiers inverting input. However, the voltage signal at the output of the LF351 Op Amp will be very small. Therefore an inverting amplifier stage (using a LM741 Op Amp [24]) added to provide a signal of the required strength. At the receiver stage of the process continuously inverting the signal has no effect on the information, as both the top and bottom envelopes contain the AM, and such an inversion does not affect frequency. The amplification of an Op Amp in the inverting amplifier stage configuration is calculated using Equation 5.12. Resistor values of R_{A2} = 55kΩ and R_{F2} = 220kΩ were chosen so that the signal amplitude at the output was both reasonable and compatible with the input voltage needed by the MAXIM BPF IC (MAX274). The coupling capacitor between these two Op Amp stages that can be seen in the complete circuit diagram (Figure 5.8) is used to remove any DC voltage. The output of this Op Amp is to be connected to the BPF. The maximum power dissipation of the LF351 and the LM741 is 500mW per IC, with no derating factors for temperatures under 90°C.

$$V_{out} = -R_F I Volts \tag{5.11}$$

$$V_{out} = -R_{F2}/R_{A2} Volts \tag{5.12}$$

5.6 Guidance Tone Demodulator

The 1kHz guidance tone is extracted from the modulated signal using an envelope detector, which is also known as a low pass filter (LPF). A simple LPF consists of a connected diode, resistor and capacitor, as shown in Figure 5.9. The diode eliminates the negative side band of the AM-BFSK signal. Values of the resistor and capacitor must be chosen so that the LPF sufficiently attenuates frequencies above 1kHz, without the considerable attenuation of 1kHz frequency components. A -3dB frequency of 2kHz was chosen to preserve the amplitude of the 1kHz guidance tone, and to provide large attenuation of 40kHz and 50kHz signal components. Values of R_{LPF}=1.8kΩ and C_{LPF}=0.047uF were therefore chosen, yielding a -3dB frequency of 1.9kHz.

$$f_{-3dB} = 1/(2.\Pi.R.C) \tag{5.13}$$

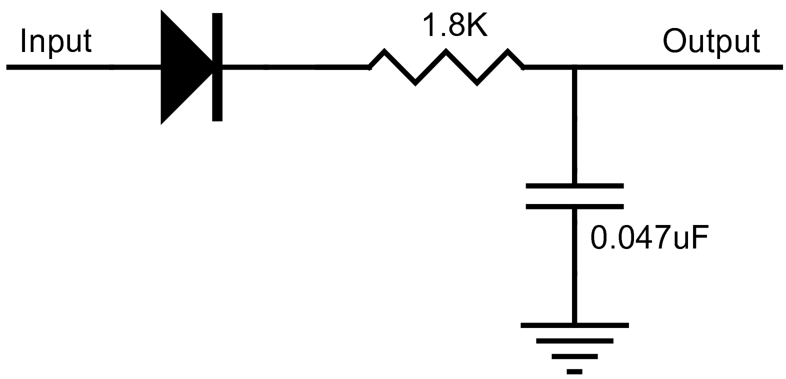

Figure 5.9: Envelope Detector Circuit

Active envelope detectors are known to be more efficient in attenuating high frequency signal components. If the signal produced by the above designed envelope detector decidedly contained too much noise, an active envelope detector should be considered.

5.7 Guidance Tone Preamp and Speaker

After the guidance tone has been extracted by the envelope detector, any prevailing DC voltage needs to be removed before the signal is played to the speaker (earphone). This is achieved by using a coupling capacitor, leaving only the 1kHz AC component of the signal. The signal is then amplified with a simple non-inverting amplifier stage [16], using the common LM741 Op Amp [24], with an adjustable gain. The gain is made adjustable by using a potentiometer for RF_{preamp}, initially set to 100kΩ. This potentiometer is the volume control of the guidance tone on the hand held device. The speaker is then connected between the Op Amp's output and ground, as shown in the circuit diagram (Figure 5.10).

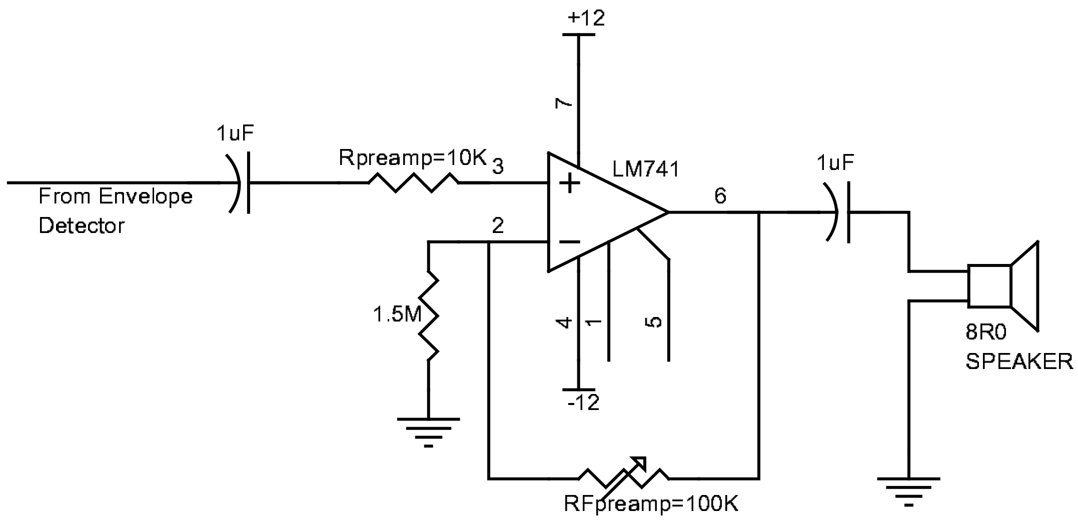

Figure 5.10: Preamp and Speaker Circuit Diagram

5.8 Band Pass Filter

A band pass filter is needed to remove unnecessary noise at frequencies other than 40kHz and 50kHz. The 'MAX274: 4th- and 8th-Order Continuous-Time Active Filter' [25] BPF IC was chosen over alternatives such as cascading low pass and high pass active filters using Op Amps for a number of reasons. BPF's are easy to design using the MAX274 as design software (MAXIM Filter Design Software v1.01[26]) is available, which takes standard filter design parameters and shows the amplitude response, phase response, and circuit diagram for up to four filter types. These parameters are: A_{BPFmax} = the maximum (normalized) allowed amplitude of signal in passband, A_{BPFmin} = the minimum (normalized) allowed amplitude of signal in passband, and F_c, F_{bw-}, F_{bw+}, F_{sw-} and F_{sw+}, which define stopbands and passbands of the filter design as shown in Figure 5.11.

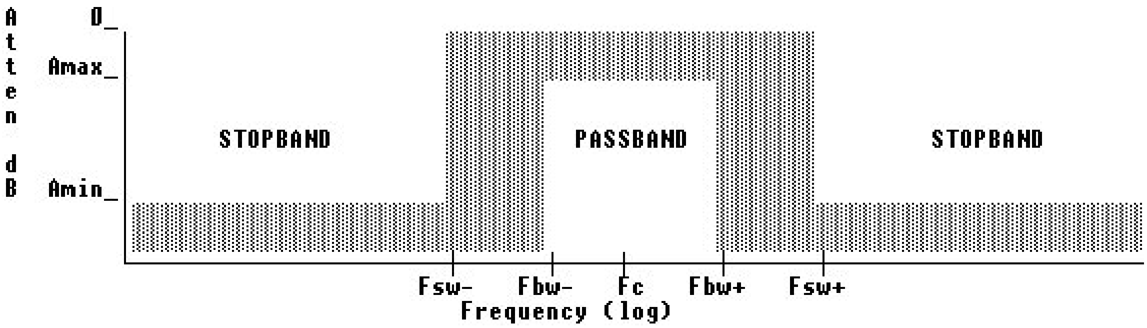

Figure 5.11: Illustration of Band Pass Filter Design Definitions

At first, initial values of A_{BPFmax} = -2dB, A_{BPFmin} = -20dB, F_c = 45kHz, F_{bw-} = 40kHz, F_{bw+} = 50kHz, $F_{sw-} \cong$ 36kHz and $F_{sw+} \cong$ 54kHz, were set, (as illustrated in Figure A.1 of Appendix A). The software then adjusted the latter two values in order to yield the first four successfully. The magnitude response was plotted for the three types of BPF's available for design (using the MAX274) in Figure 5.12. The Butterworth BPF is of 8th order, while the Chebyshev and Elliptic BPF's are of 6th order.

Butterworth was chosen due to its frequency response. The roll-off at frequencies below 40kHz and above 50kHz exhibited the best attenuation. The next step was to go to the 'Implement filter in hardware (MAX274/5)' section of the software, and load the

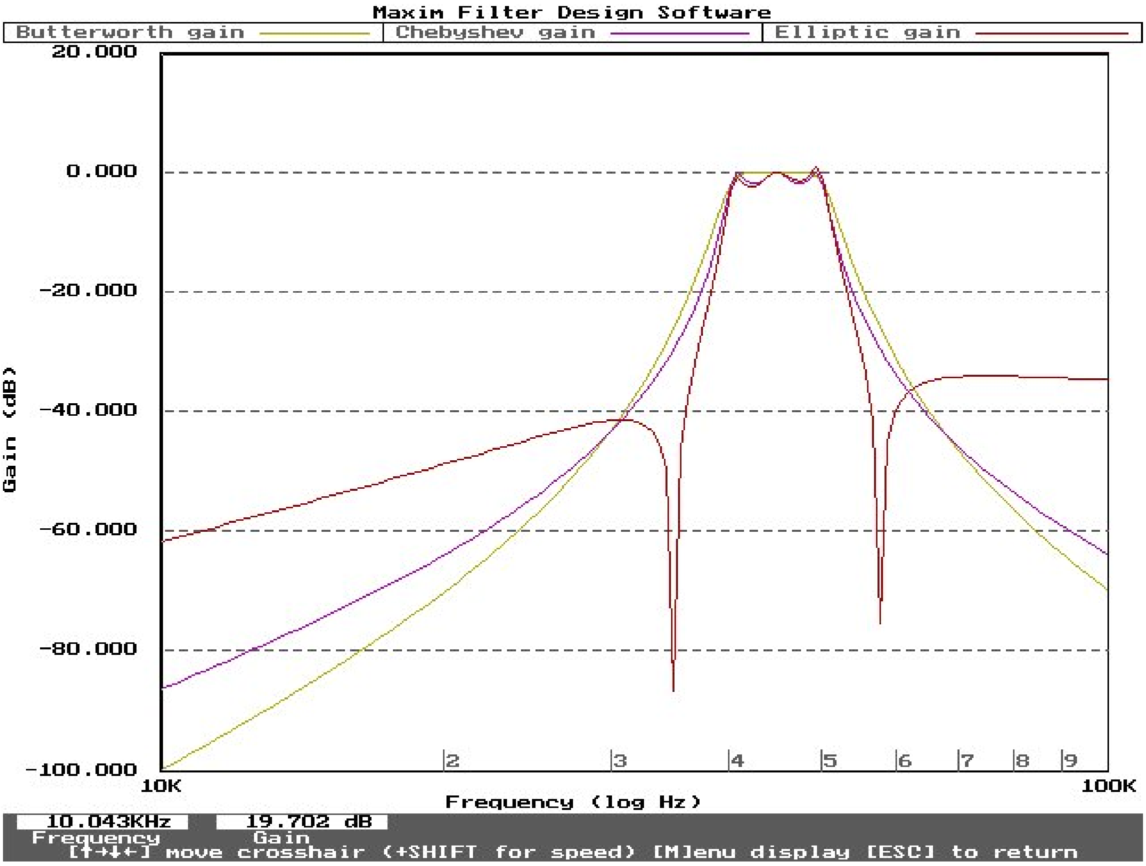

Figure 5.12: Band Pass Filter Choices for MAX274

Butterworth filter design (this can be seen in Figure A.2, in Appendix A). The 8th order Butterworth BPF is constructed by cascading four 2nd order Butterworth BPF's. Resistor selection was then performed individually for each of the four stages. The software presented a circuit diagram including the resistances to be used in the design. The values of the resistors were manually set to standard 1% tolerance values available in Australia. The final resistor values for each of the four stages are shown in Figures A.3, A.4, A.5 and A.6 (of Appendix A). The final values can also be seen in the circuit diagram (Figure 5.13).

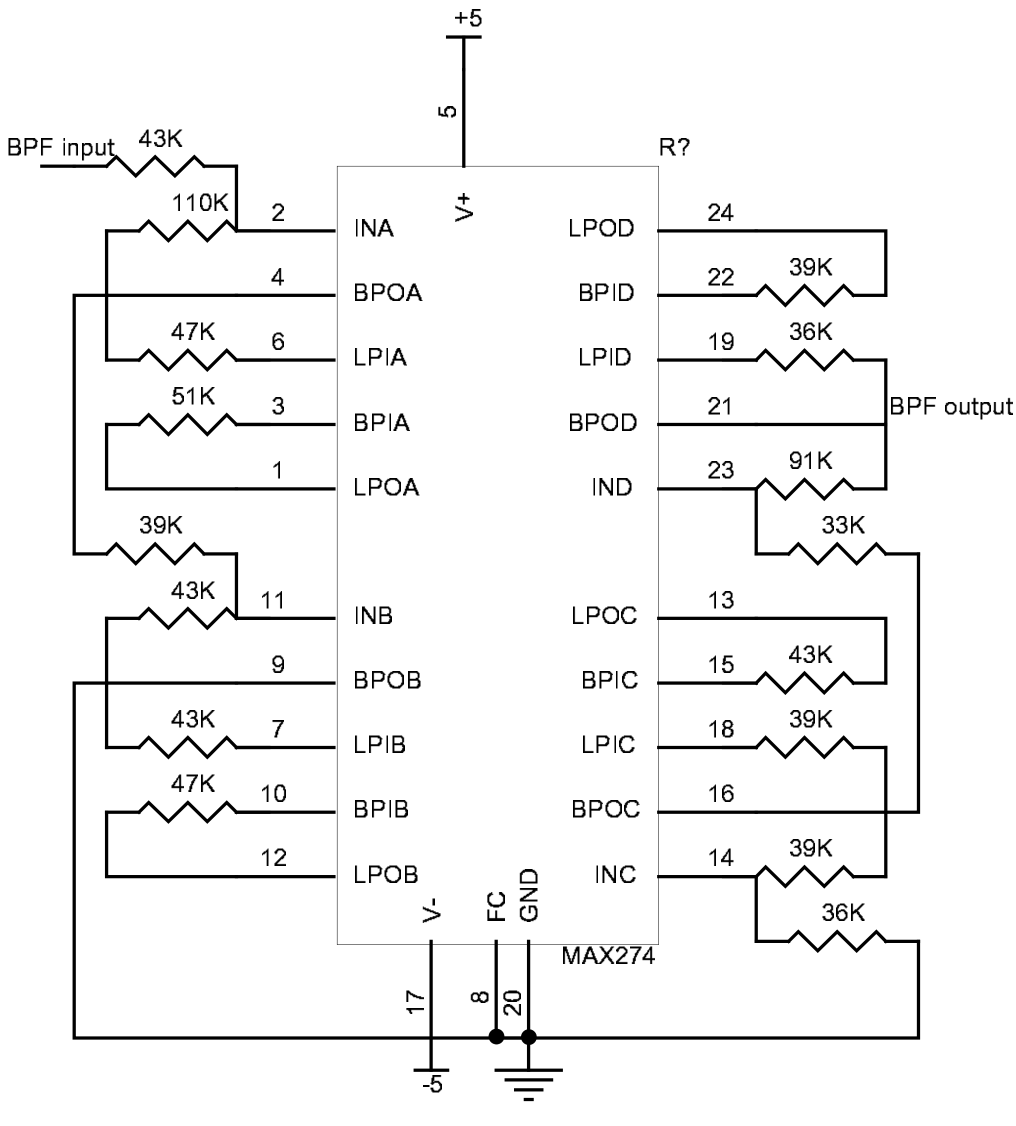

Figure 5.13: Band Pass Filter Circuit Diagram

Magnitude and phase response's were then plotted for the Butterworth 8th order BPF.

Figure 5.14 shows the magnitude response at the output of each of the four 2nd order Butterworth BPF's, and Figure 5.15 shows the magnitude and phase response of the complete 8th order Butterworth BPF designed.

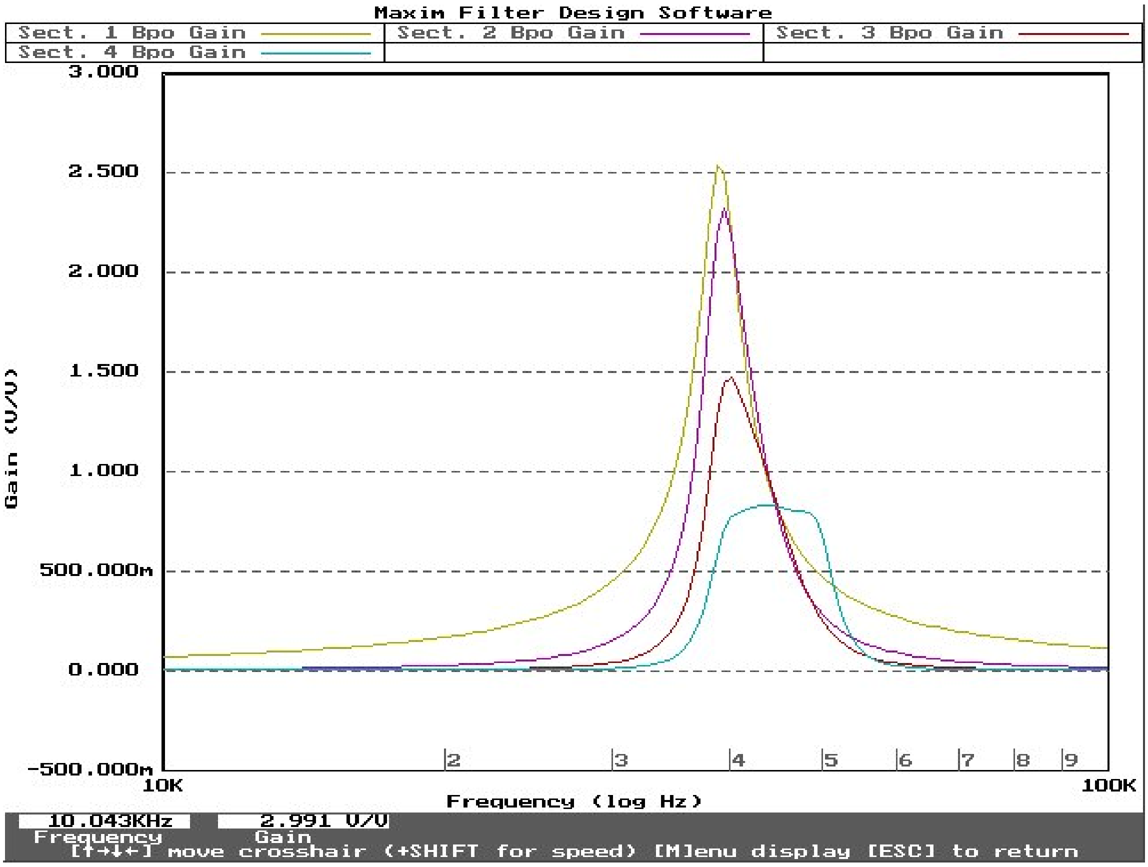

Figure 5.14: Band Pass Filter Magnitude at Each Stage

5.9 BFSK Demodulator

The XR-2211 FSK Demodulator is a monolithic phase-locked loop (PLL) system specially designed for communication applications and can easily be designed to demodulate BFSK signals [33]. This includes the signal generated by the XR-2206 monolithic function generator in Section 5.2. The X2206 has wide supply voltage range (from 4.5V to 20V) and a wide frequency range (from 0.01Hz to 300kHz), sufficient for voltage supply of 12V, and the frequencies of 40kHz and 50kHz, which make up the signal to be demodulated. It also has the ability to detect and demodulate analogue input signals anywhere between

Figure 5.15: Overall Band Pass Filter Magnitude and Phase Response

10mV and 3V. External components are used to set the parameters (such as centre frequency and bandwidth) necessary to demodulate the BFSK signal.

The input voltage applied to pin 2 (see Figure 5.16 for pin out diagram) may not be more than 3V as higher voltages may damage the IC. The supply voltage (V$_{cc}$) was chosen to be 12V, to match the XR-2206 (modulator IC used) supply voltage. The XR-2211 uses a preamplifier as a limiter to amplify all signals over 10mV to a constant HIGH voltage. This enables the XR-2211 to treat signals of different amplitudes equally, as it is only concerned with the frequency of the input signal, not the amplitude. The precision voltage controlled oscillator (VCO) within the XR-2211 IC is a current controlled oscillator with its normal input current set by a resistor to ground (R_0), and its driving current with a resistor from the phase detector (R_{1b}). An FSK comparator, also internal to the XR-2211 IC, is used to determine if the VCO is driven above or below the centre frequency. According to whether the input frequency is above or below the centre frequency (defined by external components), a HIGH or LOW signal will be output at the FSK output pin (pin 7). The output pin is an open collector logic state which requires a pull-up resistor (R_L), connected to V$_{cc}$ for correct operation. The FSK output pin is at a HIGH state for an input frequency $\leq f_O$ (40kHz), at a LOW state for an input frequency $\geq f_O$ (50kHz), and indeterminate if no input signal is present.

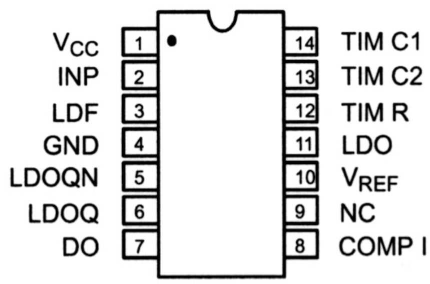

Figure 5.16: XR-2211 Monolithic FSK Demodulator Pin out Diagram

By choosing values of R_0 and C_0, f_O (the VCO free-running frequency) can be defined by Equation 5.14, where C_0 is the timing capacitor across pins 13 and 14, and R_0 is the external timing resistor. R_0 must be between 10KΩ and 100KΩ for optimum stability. The VCO frequency can be fine tuned by adjusting R_X. The placement of R_X and all external components is shown in Figure 5.17.

$$f_O = 1/(R_0 C_0) Hz \tag{5.14}$$

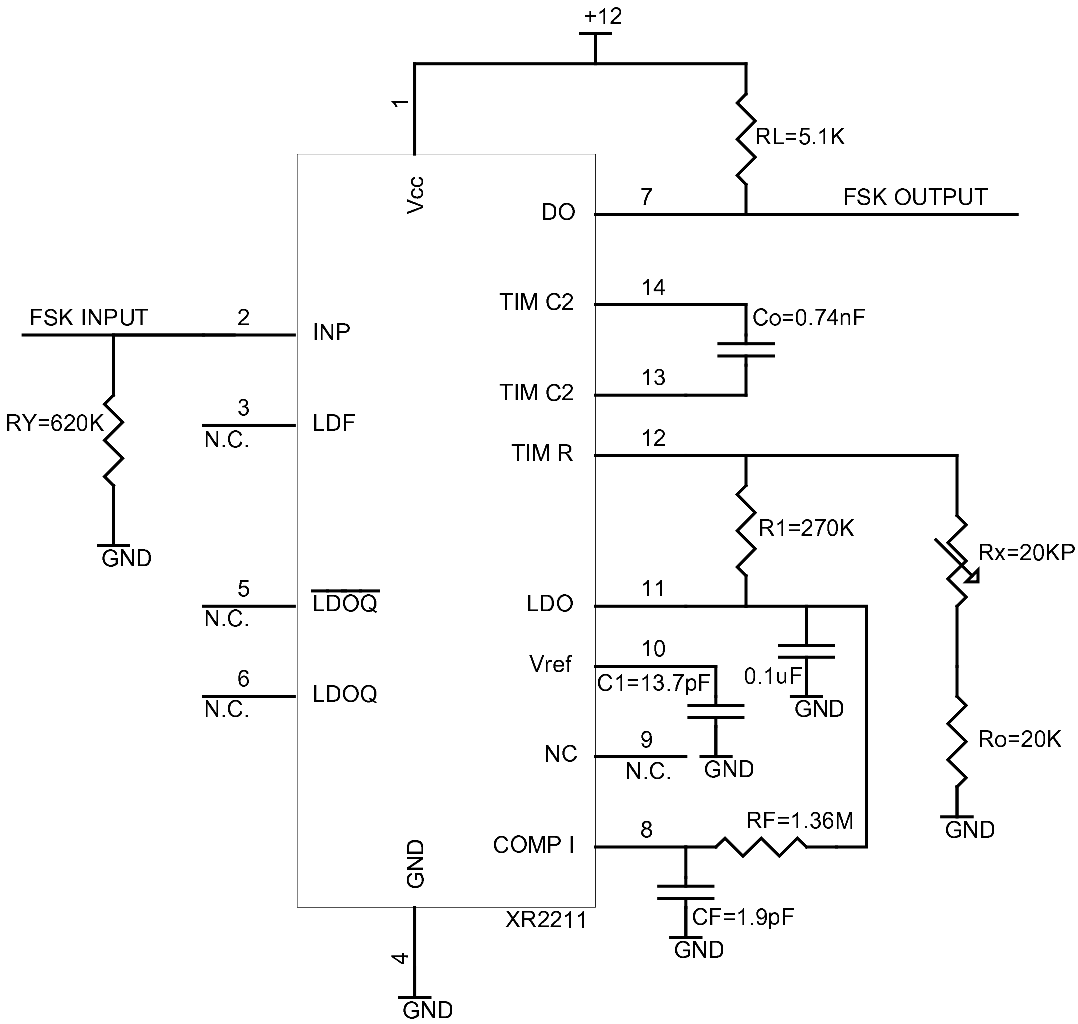

Figure 5.17: XR-2211 Monolithic FSK Demodulator Circuit Diagram

The value of each external component was determined using the design equations and instructions provided in the XR-2211 data sheet [33]. These calculations are attached in Appendix B, and the final values can be seen in Figure 5.17.

5.10 ISD ChipCorder$^{(R)}$

A digital storage device is required to store and playback voice. This device will be regularly accessed to play back voice, however it will rarely be recorded to. A re-recordable voice storage medium is desired, to enable the updating of sign descriptions, without having to replace hardware components.

A company called Information Storage Devices (ISD) specialises in two products, one of which they call the ChipCorder$^{(R)}$. There are many series of the ChipCorder$^{(R)}$ available, some of which are listed in Table 5.3 with their available storage lengths.

The ISD ChipCorder$^{(R)}$ provides high quality, single chip record/playback solutions to short duration message applications [22]. When configured with external components, the features of the ChipCorder$^{(R)}$ include; a push button interface for playback, automatic power down mode, zero power message storage, fully addressable to handle multiple messages, on chip clock source, single 5V power supply, and they are available in DIP or SOIC packaging.

Family Name	**Time Lengths Available.**	**Sampling Frequencies**
ISD 1100	10 - 12 seconds	6.4 and 8 kHz
ISD 1200	10 - 12 seconds	6.4 and 8 kHz
ISD 1400 Series	16 - 20 seconds	6.4 and 8 kHz
ISD 2500	32 - 64 seconds	4 - 8 kHz
ISD 4004 Series	2 - 16 minutes	4 - 8 kHz
ISD 33000 Series	1 - 4 minutes	4 - 8 kHz

Table 5.3: Time Lengths of ISD Families

It can be seen that the time lengths of the ISD devices vary from 10 seconds to 16minutes. A length of 16 minutes would be practical for the final product. However for the prototype, a 20 second IC (ISD1400 series) duration would be sufficient.

The sampling rates are known for each time length and are inversely proportional to the time length (since the physical properties of each model are the same for each time length) as can be seen in Table 5.3. For example, if 16 minutes of voice was to be recorded using the ISD4004 series, the sampling rate would be half (4kHz) that of a recording duration of 8 minutes (8kHz). Halving the sampling rate reduces the quality. However, from speech samples provided by ISD [14], it was determined that a 4kHz sampling rate is acceptable for the MIRSIGS application, thus the ISD4004 series 16 minute (4kHz) IC is to be used in the final system, and the ISD1400 series 20 second (4.6kHz) IC is to be used in the prototype. The lesser duration IC is used in the prototype due to its availability. Both the ISD4004 and ISD1400 series operate the same, with only the duration (and addresses) being different. For this reason the ISD1400 series 20 second 4.6kHz IC may be used in the prototype to simulate the ISD404 IC to be used in the future.

The ISD1420 IC has 160 distinct addressable segments, providing resolutions of 100ms. This is sufficient for the recording of a sign description, which would have a minimum of approximately 500ms. ISD estimates that the ChipCorders$^{(R)}$ can be re-recorded onto up to 100,000 times with life times of up to 100 years. ChipCorders$^{(R)}$ are also ideal for hand held battery powered applications such as the hand held and sign add-on devices. This is due to the fact that ChipCorders$^{(R)}$ feature an automatic power down mode, where the IC enters standby mode immediately following each record or playback cycle. The ISD 1420 ChipCorder$^{(R)}$ is operated from a 5V supply. In record mode the maximum power dissipation is 67.5mW, while in stand by mode the maximum power dissipation is reduced to 1.25mW.

The above properties, along with the low price, (and other specifications that ISD have designed these ChipCorders$^{(R)}$ to meet) make the ChipCorder$^{(R)}$ the most suitable storage device found for the MIRSIGS prototype (and the final system).

Implementation of the ISD ChipCorder$^{(R)}$ is trivial and was not performed as it has been done in a number of past projects ([10] & [5]), and design instructions are provided on the data sheet.

5.11 Voice Amplifier and Speaker

The ISD voice recorder chip has a speaker output which can be directly connected to an 8Ω speaker. This has been found to provide insufficient volume in the past [10], so amplification is needed. A simple LM741 Op Amp was used in the non-inverting configuration [16]. By using a potentiometer for R_{F-ISD}, the volume was made adjustable by the user. The SP+ output (pin 14) of the ISD device is to be connected to the input of the non-inverting amplifier stage, and the SP- output (pin 15) is to be connected to ground.

Therefore, in this prototype system there are two volume controls and two speakers, one for the guidance tone, and one for the playback of voice (which was not implemented). In the final system however this will not be the case. Only one speaker shall be used, being connected to the output of a non-inverting amplifier as was shown in Figure 5.10. However, the signal coming from the ISD ChipCorder$^{(R)}$ shall first be amplified with a set value of gain before it is input to this amplifier stage. The amplification factor will be determined by using the prototype so that the guidance tone and the voice playback are of both of reasonably equal volume before entering the final amplifier stage.

6.0 DETAILED DESIGN - SIGN ADD-ON DEVICE

6.1 System Clock

The system clock speed of both the hand held device and the sign add-on device must match. Therefore the system clock circuitry used for the sign add-on device was the same as that used for the hand held device, and is discussed in Section 5.1.

6.2 Modulation of Identity Code Word and Guidance Tone

The XR-2206 has the ability to amplitude modulate a BFSK signal which it produces using the data provided on pin 9, as discussed in section 5.2. In the hand held device BFSK was used to construct a signal representing the 8-bit 'Request' code word. In the sign add-on device, BFSK is used to construct a signal representing the 8-bit identity code word of the sign which it defines. This carrier signal, which may be of one frequency (if there is no FSK input to pin 9), or two frequencies (40kHz and 50kHz), is amplitude modulated by applying the appropriate modulating signal (voltage) to pin 1. The amplitude of the waveform output from the XR-2206 varies linearly with this applied voltage. The characteristic of the amplitude modulation is shown in Figure 6.1, which shows that amplitude modulation is nil if the voltage applied to pin 1 is less than $V_{cc}/2$ - 4 V, or greater than $V_{cc}/2 + 4$ V. Since the voltage supply, V_{cc}=12V in this application, no amplitude modulation will result unless the amplitude modulating signal is between 2V and 10V. As the applied voltage passes $V_{cc}/2$ (6V), the phase of the output signal is reversed 180 degrees. Since a sinusoidal amplitude modulation factor of M=0.2 is needed, a sinusoidal with a minimum of $V_{cc}/2 - 4 = 2$ V, and maximum of $V_{cc}/2 - 2*(4)/3 = 3.33$ V is to be generated, and applied to pin 1 of the XR-2206. The intended shape of this resulting waveform (but using different frequencies) was shown in Figure

4.1 for input data of '10101100'.

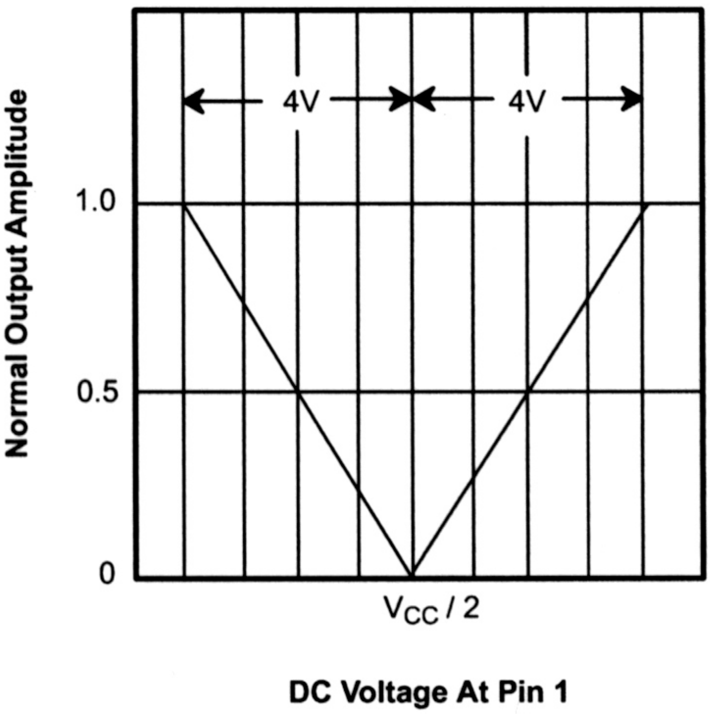

Figure 6.1: Normalised Output Amplitude, Function of Input Signal (at pin 1)

6.3 Serial Code Word Generation

The 8-bit identity code word of the sign add-on device is determined by the sign that it is identifying. Since different signs have different 8-bit identity code words, it is desirable that the sign add-on device has the ability to define any sign, and the ability for this code word to be easily changed. This was done by using DIP switches. The code word generation circuitry for the sign add-on device is the same for the hand held device, except instead of tying the inputs of the parallel-in, serial-out shift register to HIGH or LOW voltages, an 8-bit DIP switch was used, enabling the sign add-on device to define any sign, by adjusting eight small switches. The circuit diagram of this can be seen in the complete schematic diagram of the sign add-on device transmitter module in Appendix C.

6.4 Tone Generation

The tone must be generated according to the requirements of the XR-2206 Monolithic Function Generator because this IC is performing the amplitude modulation. As mentioned in Section 6.2, this needs to be a square (or sinusoidal) signal with a peak to peak voltage of 1.33V, the minimum being at 2V, and the peak being at 3.33V.

This signal was generated using a 555 timer, which is primarily used to generate clock signals, and outputs a square wave with characteristics defined by external components. The 555 timer was developed to output a square wave with a 50% duty cycle, where the high voltage duration is equal to the low voltage duration (i.e. $T_{1tone} = T_{2tone}$). Since a signal with a frequency F_{tone} of 1kHz is desired, the external components where chosen such that the period of a high and low duration combined equal 1ms (i.e. $T_{1tone}+T_{2tone} = 1ms$). This was done using the circuit configuration shown in Figure 6.2, where a diode is used to simplify design, as in Section 5.1 [15]. Arbitrarily choosing a capacitance of C = 0.04uF, the resistors R_{atone} and R_{btone} were calculated to be 18.033KΩ, using Equations 6.3 and 6.4.

$$T_{1tone} = ln(2)(R_{atone})C_{tone} \tag{6.1}$$

$$T_{2tone} = ln(2)(R_{btone})C_{tone} \tag{6.2}$$

$$T_{tone} = T_{1tone} + T_{2tone} = 2T_{1tone} = 1/F_{tone} \tag{6.3}$$

$$F_{tone} = 1/T_{tone} = 1/(ln(2)(R_{atone} + R_{btone})C_{tone}) \tag{6.4}$$

The square wave generated by the 555 timer is output with an amplitude of 5V, with a minimum of 0V and a maximum of 5V. This signal is required to be converted before being connected to the XR-2206 input. Since the 5V AC needed to be reduce to 4V, and the 2.5V DC component needed to be reduced to 2V, the AC and DC components were reduced together, using one voltage divider. The resistor values used for this voltage divider were 20kΩ and 82kΩ (closest standard resistor value to 80kΩ), such that 80% of the signal remained.

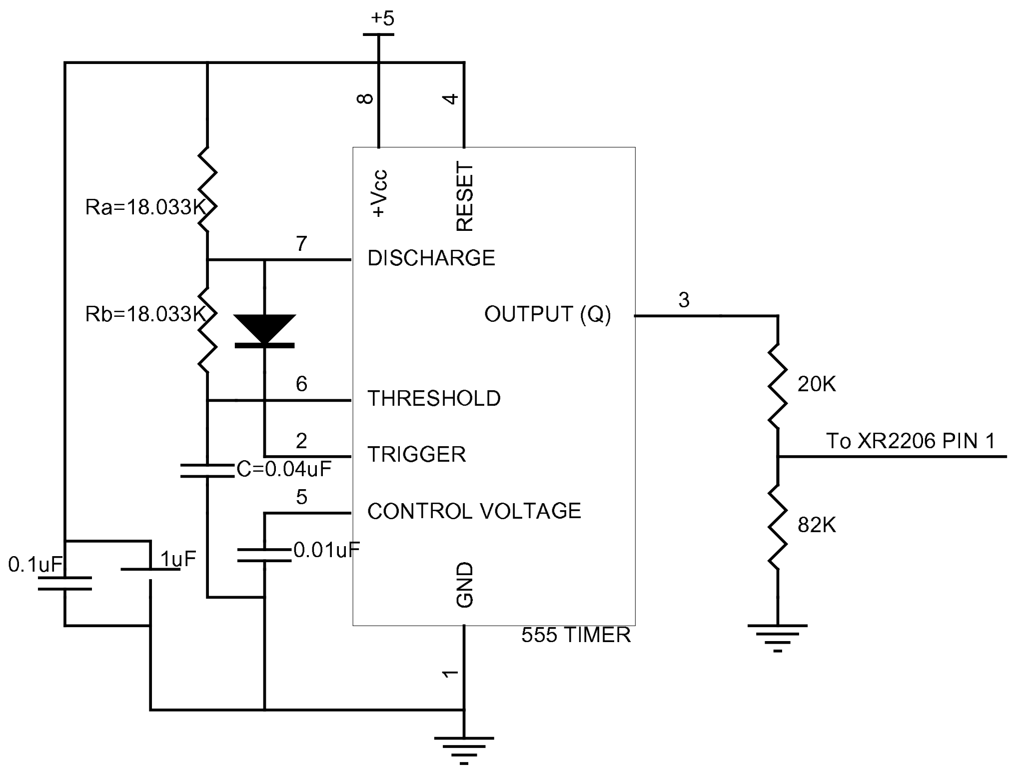

Figure 6.2: 1kHz Square Wave 555 Timer Circuit configuration

6.5 Infra Red Transmitter and Receiver

For the prototype, the IR transmitter and the IR receiver circuitry used for the sign add-on device was the same as that used for the hand held device, and is discussed in Sections 5.4 and 5.5 respectively.

6.6 Band Pass Filter

Since the hand held device and the sign add-on device both operate using the same BFSK frequencies, the BPF circuitry used for the sign add-on device was the same as that used for the hand held device, and was discussed in Section 5.8.

6.7 BFSK Demodulator

Once a signal had been received by the hand held device, two types of information were extracted. They were the 1kHz guidance tone and the 8-bit identity code words. However, for the sign add-on device, only code words need to be demodulated and an envelope detector is not required. As the hand held device and the sign add-on device both operate using the same BFSK frequencies, the BFSK demodulator is the same for both devices (see Section 5.9 for this design).

6.8 Comparison Circuitry

Once the sign add-on device has successfully received and demodulated an 8-bit identity code word, it must compare this code word to the 'Request' code word. If the code word received is found to be equal to the 'Request' code word, then a HIGH output is needed to trigger a one-shot, which will cause the sign add-on device's 8-bit identity code word to be modulated and transmitted.

When the 8-bit identity code word is demodulated from the received signal it is in serial form. To be compared with the 'Request' code word, it must be converted to parallel form. This is done using a 'MC74HC164 Serial-Input, Parallel-Out Shift Register [17]', as shown in Figure 6.3. The clock supply to this shift register is to be the 100Hz system clock, as discussed in Sections 5.1 and 6.1. The power supply to the shift register (V_{cc}) is 5V, and the 'B' input to the shift register (pin 2) was tied HIGH, allowing serial code words to be clocked into the shift register as soon as they become available (positive triggered). Once the code word has been clocked into the shift register, it will appear on the output pins (Q_H to Q_A), with pin Q_H being the first bit of the binary code word. At this point in time, if this binary code word matches the 'Request' code word, stored locally, then the comparison circuitry must provide a HIGH voltage on a control line, such that the sign add-on device then transmits its own 8-bit identity code word.

The logic diagram of the comparison circuitry used is shown in Figure 6.4. There is one X-NOR gate for each of the 8-bits of the code word. One input to each gate is tied HIGH or LOW, defining the 'Request' code word. The other input to each gate is the received 8-bit identity code word in parallel form. The truth table of the X-NOR gate (74HC7266) [31] defines that the output is only HIGH when both inputs are equal. This is the basis for the comparison. The results from the 8 individual bit-comparisons are then input to an AND gate. The truth table of the AND gate defines that the output is only HIGH when all inputs are HIGH. Since an 8-input AND gate was not accessible, two 4-input AND gates (74HC21) [19], and one 2-input AND gate (74HC08) [30] were used as shown in Figure 6.4. This logic arrangement could also be implemented using a small programmable logic device (PLD). However, in this prototype IC's were used. The schematic diagram of this logic arrangement is shown in the complete schematic diagram of the sign add-on devices receiver module in Appendix C.

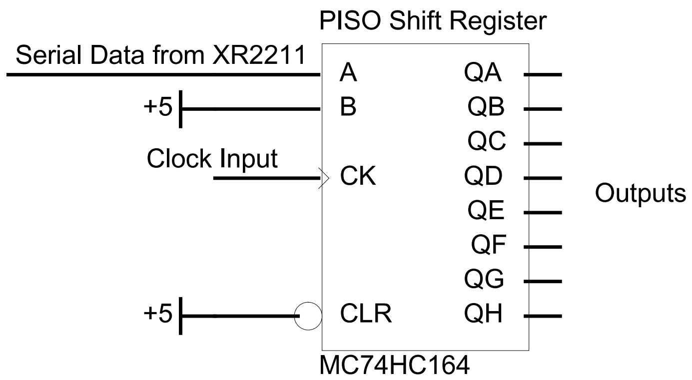

Figure 6.3: Serial-Input Parallel Output Shift Register

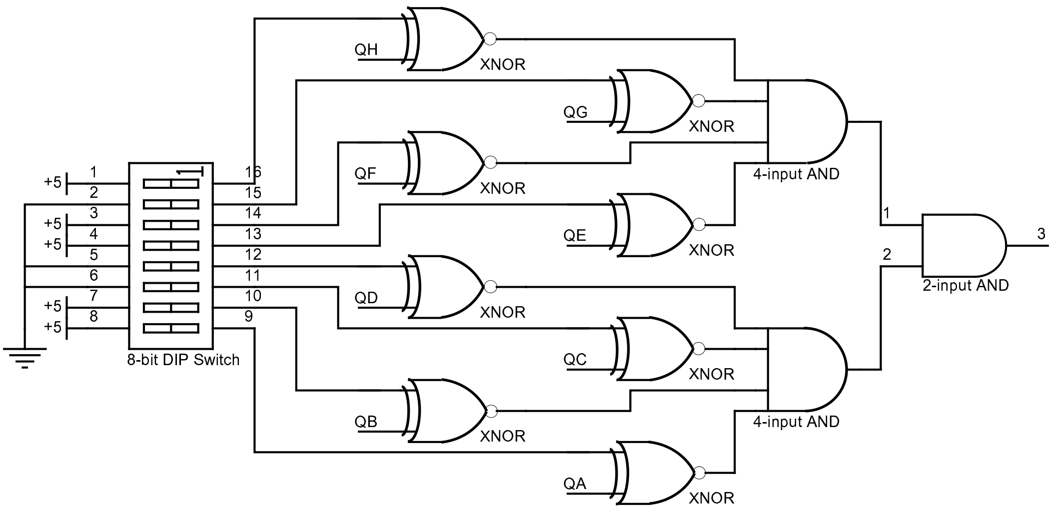

Figure 6.4: Comparison Circuitry Logic Diagram

6.9 Response Time

The time taken for the 8-bit signal to be clocked into the shift register is 80ms (since the bit length is 10ms), plus approximately 73ns in propagation and output transition time. The propagation delay of the AND gate IC's and the X-NOR IC are less than 14ns and 115ns respectively. Therefore it takes a little over 80ms for the code word to be compared. Thus in the prototype the code word would be sent almost instantaneously (80ms) after receiving the correct 'Request' code word. This will not be the case with the final MIRSIGS. The 8-bit identity code word of the sign add-on device will arbitrarily define the period that the device must wait, before sending its 8-bit identity code word. As an 8-bit system provides a possible 256 different code words, and each code word will be designed to be transmitted at a different time, the worst case (longest wait) for the final system (with a system clock of 100Hz) would be 20.5 seconds. Therefore in the final system, the (system) clock baud rate needs to be increased. Based on these preliminary calculations, and an 8-bit identity code word, a system clock 50 times faster would suffice (5kHz).

7.0 SYSTEM PERFORMANCE AND SPECIFICATIONS

7.1 Performance Measures

The performance measures of MIRSIGS prototype were tested according to measures of performance defined as follows:

• Code Word Recovery - Firstly, the user must be able to distinguish the identity of the sign. This is done only if the 8-bit identity code word is successfully generated, modulated, transmitted, received, demodulated and stored. This 8-bit identity code word must be demodulated without errors or it will not successfully address the location on the ChipCorder$^{(R)}$ which contains a description of the correct sign.

• Orientation - (Direction) It is important for the user to have the ability to determine in which direction the sign is located in order for them to approach it.

• Distance - It is also desired that the user have the ability to determine if they are directly approaching the sign. Without such information, the user would not know if they were walking in the wrong direction until the signal ceased being received.

• Multiple Sign Add-on Devices - It is important that such a system has the ability to function with more than one sign add-on device, whether these are next to each other, or a few metres away from each other.

7.2 MIRSIGS Prototype

The designed prototype was implemented. The images of the prototype are shown in Figures 7.2 and 7.1. The prototype was tested for the above performance measures.

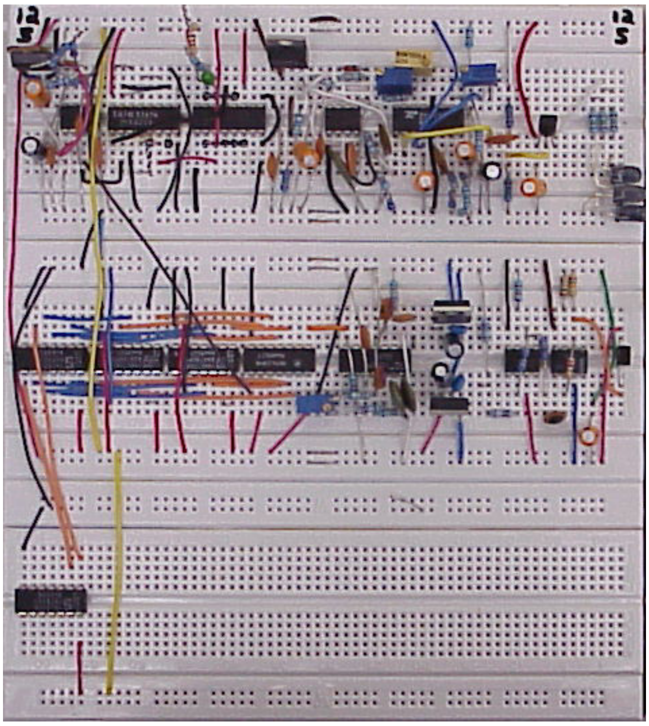

Figure 7.1: Prototype Sign Add-on Device

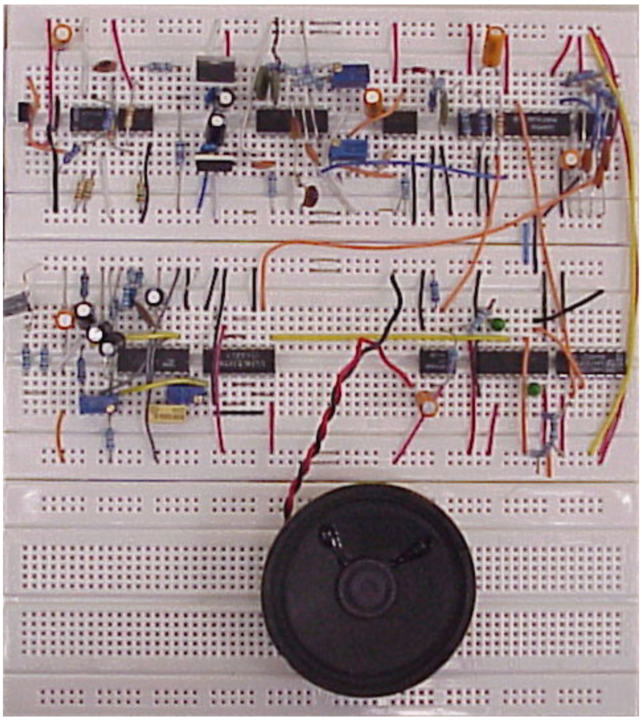

Figure 7.2: Prototype Hand Held Device

7.3 MIRSIGS Performance

The prototype MIRSIGS performed successfully according to the first three performance measures, and has the ability to fulfill the fourth. The 8-bit identity code word was successfully generated, modulated, transmitted, received, demodulated and stored without errors. Both the sign add-on device, sending its 8-bit identity code word, and hand held device, sending the 8-bit 'Request' code word, successfully generated, modulated and transmitted. The sign add-on device successfully received, demodulated and recognised the 'Request' code word (when sent by hand held devices), using this as a control line to send its own 8-bit identity code word. The hand held device also received and demodulated the 8-bit identity code word sent by the sign add-on device successfully without errors.

The guidance tone, transmitted from the sign add-on device to the hand held device was successfully implemented. A 1kHz guidance tone was continuously generated, modulated and transmitted by the sign add-on device. The hand held device successfully received, demodulated and played this guidance tone back to the user through a speaker (earphone). The characteristic of (IR transmissions) receiving differing signal magnitudes for different distances and orientations was successfully harnessed in guiding the user to the sign. The user was able to determine both the direction in which the sign was located, and if they were directly approaching the sign. The conical dispersion pattern was measured for different points within the cone. Table 7.3 tabulates these results in such a way that the conical pattern can be observed with little effort.

Consider the transmitter laying on a flat surface, transmitting horizontal to this surface. Each line on this table represents a vertical cross section of the propagation cone. The labelling of the rows of this table represent the distance of the vertical cross section from the transmitter. Note that these distances are perpendicular to the transmitter face. The columns of this table represent the radial distance out from the perpendicular distances mentioned. The table also provides measurements for one half of the horizontal cross section. For the entire vertical cross section, this data would have a mirror image

	0cm	2cm	4cm	6cm	8cm	10cm	12cm
5cm	6800	900	504	368	330	250	240
15cm	1380	880	408	312	292	264	260
25cm	800	720	460	296	268	276	264
35cm	544	536	428	308	248	256	252
45cm	472	456	372	304	260	248	248
55cm	388	372	336	300	252	244	248
65cm	360	344	308	280	248	236	236
75cm	292	282	276	262	256	252	232
85cm	300	264	244	242	220	208	200
95cm	268	240	244	210	196	184	172

Table 7.1: Measured IR Conical Irradiance Pattern

of equal data, about the axis perpendicular to the transmitter face. For the entire three-dimensional cone of propagation, this data would have to be rotated around this perpendicular axis a full 360 degrees. Along with the detailed measurements tabulated here, amplitude measurements were taken at points on both sides of this perpendicular axis on the horizontal plane, and at other points within the cross section of the cone. These measurements agreed with what was expected, in that for any specified radius from the centre of the cone (perpendicular axis), and at a set distance from the transmitter, the strength (amplitude) of the received signal is constant, irrespective of the angle from which the measurement is taken, and the horizontal plane.

In Table 7.3 it can be seen that as distance from the transmitter increased, the received amplitude decreased. The shape of propagation can be seen to be cone shaped upon close examination of the table. The received amplitude decreases as the radius from the centre of the cone increases for each cross-sectional distance away from the transmitter. Also, at set distances away from the centre of the cross section, the received amplitude level decreases as the distance from the transmitter is increased.

7.4 MIRSIGS Parts and Price List

Description	Quantity	Cost (ea)	Total
Semiconductors			
1N4148 Silicon Signal Diode	5	$0.10	$0.50
555 Timer	4	$0.53	$1.06
74HC7266 Quad 4-input XNOR gate	2	$0.93	$1.86
74LS08 Quad 2-input AND gate	1	$1.20	$1.20
74LS164 8-bit Serial-Parallel Shift Register	1	$1.25	$1.25
74LS165 8-bit Parallel-Serial Shift Register	2	$1.10	$2.20
74LS21 Dual 4-input +ve AND gate	2	$0.75	$1.50
74LS221 Dual Monostable Multivibrator	2	$1.13	$2.26
7805 +5V Voltage Regulator	2	$1.00	$2.00
7905 -5V Voltage Regulator	2	$1.00	$2.00
8-bit DIP Switches	1	$2.15	$2.15
LF351 JFET Op Amp	2	$0.70	$1.40
LM741 Bi-polar Op Amp	4	$1.25	$5.00
LTE4208 Infra Red Transmitting Diode	4	$1.10	$4.40
LTR53A Infra Red Receiving Diode	2	$2.66	$5.32
MAX274 Active BPF	2	$33.15	$66.30
MPSA14 NPN Darlington Transistor	2	$0.80	$1.60
XR-2206 Monolithic Function Generator	2	$10.16	$20.32
XR-2211 FSK Demodulator	2	$4.36	$8.72
Sub-total			**$131.04**

Description	Quantity	Cost (ea)	Total
Resistors			
(0.25W 1% Metal Film Resistors, E24Series)	94	\$0.05	\$4.70
33Ω x 2, 47Ω x 2, 62Ω x 2, 75Ω x 4,			
240Ω x 2, 1.1kΩ x 2, 1.3kΩ x 2, 1.8kΩ x 2,			
5.1kΩ x 6, 10kΩ x 4, 18kΩ x 2, 20kΩ x 7,			
24kΩ x 2, 33kΩ x 2, 36kΩ x 6, 39kΩ x 8,			
43kΩ x 8, 47kΩ x 4, 51kΩ x 2, 55kΩ x 2,			
78kΩ x 4, 82kΩ, 91kΩ x 2, 110kΩ x 2,			
220kΩ x 2, 270kΩ x 2, 620kΩ x 2,			
1.36MΩ x 2, 1.5MΩ x 6			
Potentiometers	10	\$1.80	\$18.00
20kΩ x 2, 25kΩ x 2, 50kΩ x 2, 100kΩ x 2,			
500kΩ x 2			
Capacitors			
(Electrolytic)			
1uF	15	\$0.17	\$2.55
3.3u	2	\$0.24	\$0.48
10uF	2	\$0.22	\$0.44
(Ceramic)			
1.9pF	2	\$0.30	\$0.60
13.7pF	2	\$0.30	\$0.60
0.01uF	6	\$0.20	\$1.20
0.022uF	2	\$0.20	\$0.40
0.04uF	1	\$0.42	\$0.42
0.047uF	2	\$0.35	\$0.70
0.1uF	11	\$0.25	\$2.75
0.74nF	2	\$0.42	\$0.84
Total			**\$164.72**

Table 7.2: Component List and Prices

7.5 MIRSIGS Specifications

MIRSIGS comprises of two devices. The sign add-on device and the hand held device. The sign add-on devices transmit signals carrying two types of information. Identity information is transmitted using BFSK, with frequencies of 40kHz and 50kHz used to represent binary '0's and '1's respectively. When no identity information is being transmitted, a constant 40kHz signal is transmitted. This signal is constructed by connecting the 8-bit identity code word (in serial, digital form) to the XR-2206 modulation IC. The BFSK signal is then amplitude modulated (also performed by the XR-2206) by a 1kHz guidance tone which carries directional information to the user. The hand held device demodulates both types of information and plays back both the guidance tone and the sign identity to the user through the use of an earphone.

Each type of sign has its own unique 8-bit identity code word, which is yet to be defined. This code word is used to directly address a location on a voice recorder IC which contains a description of the sign.

However, hand held devices however only transmit one type of information. This is the 8-bit 'Request' code word, requesting that the signs identify themselves. The sign add-on devices demodulate the received code words, identify 'Request' code words transmitted by the hand held device, and respond appropriately.

Digital serial code words are generated using parallel-input, serial-output shift registers, with the parallel inputs being HIGH or LOW. This is set by using an 8-bit DIP switch (all connected to HIGH on one side)for the sign add-on device (so the devices are not restricted to being used on one type of sign). The guidance tone is generated using a 555 timer to generate a 1kHz square wave with a 50% duty cycle. This signal is then adjusted and utilised by the XR-2206 BFSK modulation IC to amplitude modulate the BFSK signal.

After receiving a transmission, both the sign add-on device and the hand held device filter the received signal using an active eighth order Butterworth filter to remove unnecessary noise. A special purpose FSK demodulation IC (the XR-2211) is then used to convert the BFSK signal back to a digital voltage waveform. Guidance tone extraction is completed using an envelope detector before being amplified and played to the user.

Infra red transmission is used due to its characteristics such as line of sight, and strength of signal with respect to distance and orientation. An operational distance of approximately 15 metres will be required in the final system. However, this was not covered within the scope of the prototype, although the design permits.

8.0 CONCLUSIONS & FUTURE WORK

8.1 What Was Achieved

A prototype MIRSIGS was designed, implemented and tested. Design was performed in such a way that the complete system can be extended from this design, as the final system was the main focus of this prototype. This prototype has successfully shown that the proposed solution (MIRSIGS) is feasible. The prototype involved tests of the primary system functions. These were that the received amplitude of IR transmission is proportional to the distance from the transmitter, and the orientation of the receiver, with respect to the transmitter. This characteristic of IR was successfully harnessed and used to transmit the guidance tone. A binary IR communication link was also designed and successfully implemented, using BFSK.

8.2 Future Work and Design

8.2.1 Queueing of Multiple Signs

Simple queueing and logic circuitry needs to be designed for the hand held device so that it can receive 8-bit identity code words from multiple signs, and play them back to the user in a controlled fashion (user interface). This would require FIFO (first-in first-out) shift registers such as the 74HC7030, or simpler logic components. This logic circuitry will need to deal with code words in such a way that after the user has listened to the description of the sign, they can select to be guided towards it by pressing with a user interface button. This is carried out by the hand held device transmitting the signs 8-bit identity code word, indicating for that sign to transmit its guidance tone. Also, if the user presses that same button again without first sending another 'Request' code word, the hand held device shall again transmit that signs 8-bit identity code word.

8.2.2 Delay Circuitry

To support multiple signs the circuitry must be designed to provide the delay before a sign add-on device transmits its 8-bit identity code word, the delay being defined by the code word itself (since these are unique). This could be done by using a one-shot and logic gates.

8.2.3 List of Signs

A complete list of signs and their corresponding code words, needs to be developed using the appropriate ISO standards as a guide. It may be decided that these code words will be larger than 8-bits in length. The prototype system built in this project is readily expandable. When the list of signs has been developed, updates to the list will also require hand held units to be updated.

8.2.4 Developing a Vocabulary

Instead of recording and storing multiple words to describe each (some) sign, it may be feasible to develop a vocabulary of words on the ChipCorder$^{(R)}$ and send multiple code words in succession. This would require control bits, such as an 'end of stream marker'. These multiple code words should then be interpreted as being the description of one sign and played in succession. This idea needs further exploration upon defining a list of signs.

8.2.5 Updating the Voice IC

Circuitry needs to be developed to enable hand held units to be updated. This is required as the list of signs included in the system will be updated occasionally. This can be done by including a jack located on the hand held device to which a sound source can be attached. With the assistance of a few control buttons the ChipCorder$^{(R)}$ IC should be extended to include any new signs added to the system. This does not pose a problem as the ISD ChipCorder$^{(R)}$ IC's can be re-recorded on up to an estimated 100,000 times and have an expected life time of 100 years. For the final system a ChipCorder$^{(R)}$ with a reasonably large storage space should be chosen so that its time length will not limit the system. Currently ISD ChipCorder$^{(R)}$'s are available with storage time of up to 16 minutes (960 seconds). This should be sufficient as sign descriptions are in the order of only a few seconds each.

8.2.6 Distance

Since operational distance was outside the scope of this project, a choice needs to be made on how to achieve practical and reasonable distances of approximately 15 metres. This could be done by expanding the number of LED's using the current design, or by researching another model of IR LED that has a larger range ability. IR LED 'spot lights' could be purchased and integrated into the design. However, these would have to be specifically suited due to power requirements and distance requirements (including the need for very low power reflections).

8.2.7 Power Management

The power dissipation of devices was considered when selecting components for this prototype. However, the prototype streams continuously, which is not a feature of the final MIRSIGS. Now that it has been established how the guidance tone and 8-bit identity code words can be successfully transmitted, received and utilised, the design needs to be altered to the final operational mode. Sign add-on devices should remain idle, in a low power mode (still receiving), until either a 'Request' code word, or its own 8-bit identity code word has been detected. Upon detecting the 'Request' code word, a sign add-on device powers up and transmits its own 8-bit identity code word, then returns to the low power state. Upon detecting its own 8-bit identity code word a sign also powers up and transmits the guidance tone for an amount of time yet to be defined, before again returning to its low power consumption state. If the user still wishes to hear this guidance tone then they should press the sign selection button again to continue hearing the guidance tone of the same sign.

8.2.8 Dispersion of More Information

MIRSIGS could possibly be extended to disperse more information than the identity of signs, objects and locations. Currently, since the voice signal is pre-recorded and stored within the hand held device, such information would have to be defined before production.

8.3 Conclusions

Due to the amount of design and development needed to produce the final MIRSIGS, the results presented in this thesis are limited and by no means conclusive. Nevertheless, they do indicate that MIRSIGS does provide a useful system to solve the problem of multilingual sign identification and guidance for the vision impaired. The prototype constructed provided a greater understanding of the successful design and operation of the system and hence, is a major step towards developing a universally adaptable multilingual sign identity and guidance system for the vision impaired.

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Appendix A

SCREEN CAPTURES OF THE SOFTWARE USED TO DESIGN THE BPF

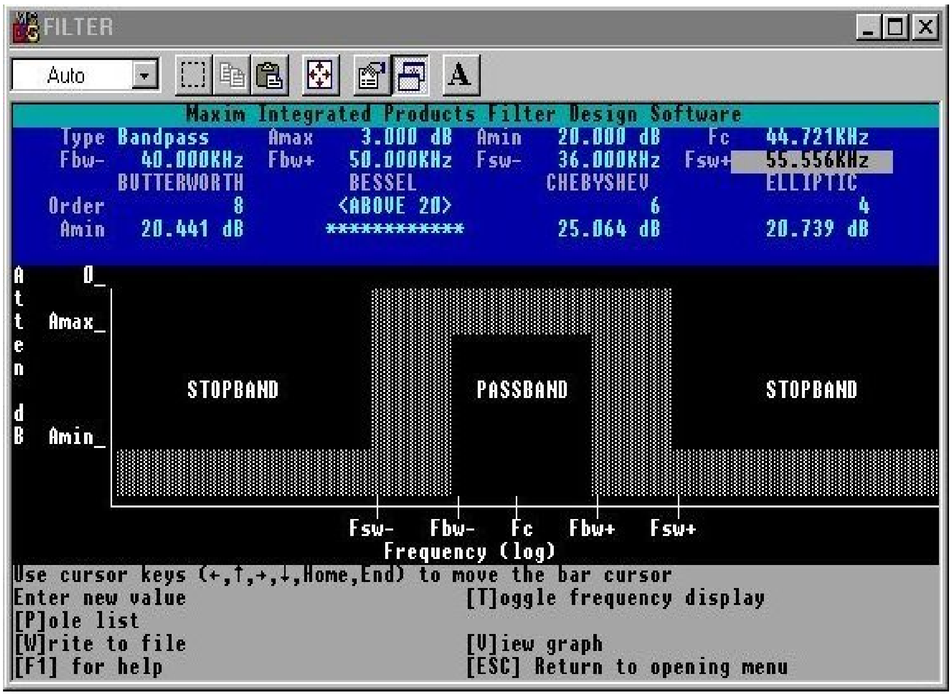

Figure A.1: Defining Filter Parameter Values

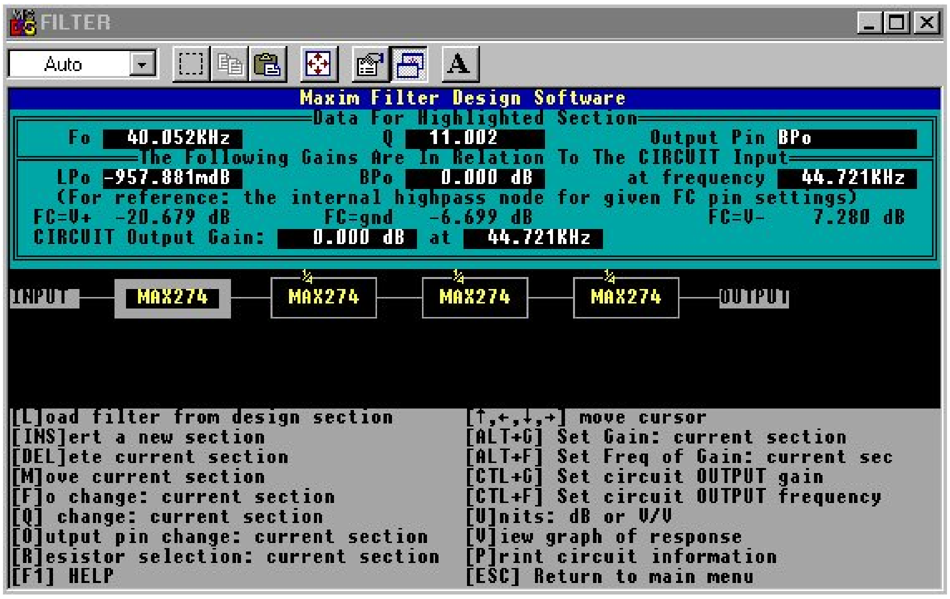

Figure A.2: Implementing Design

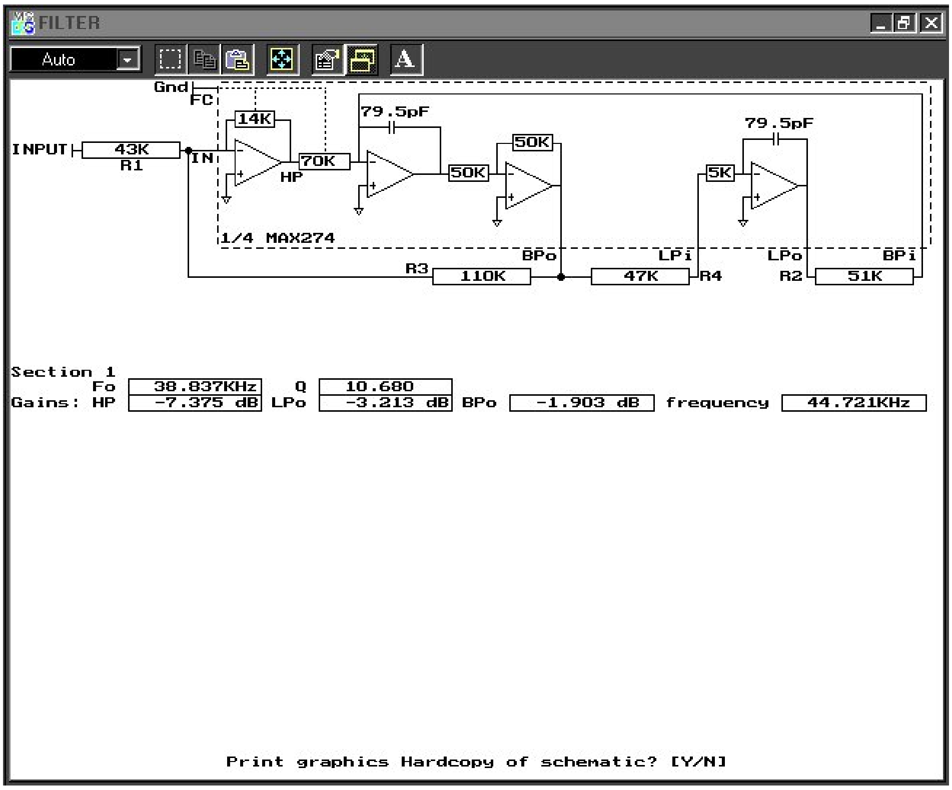

Figure A.3: Resistor Selection for Section 1

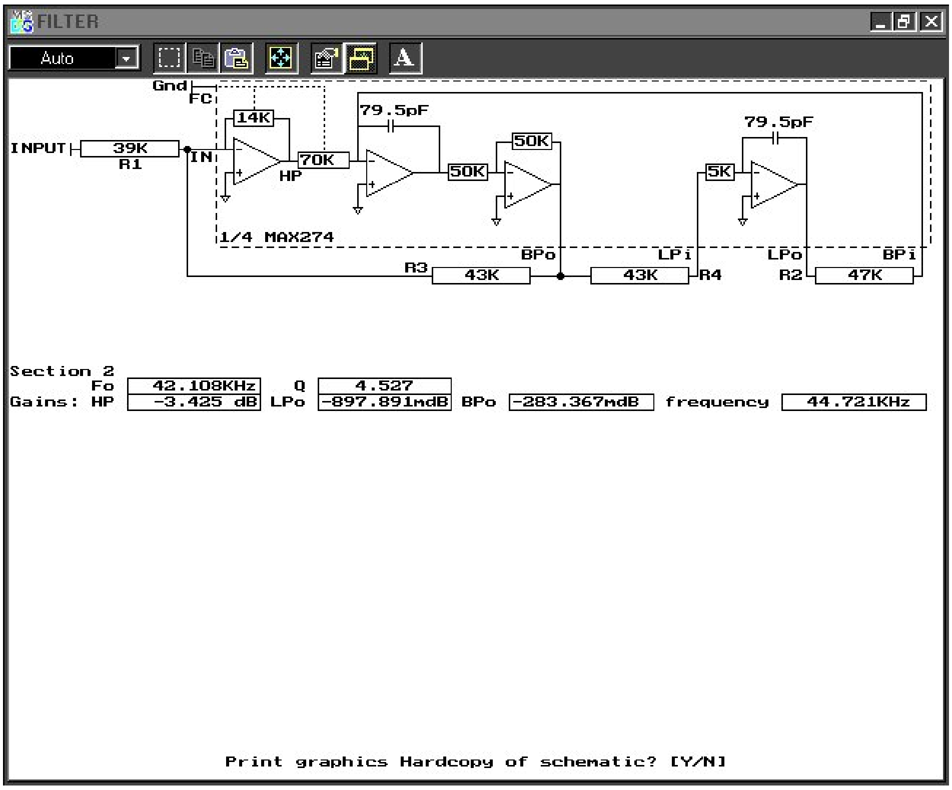

Figure A.4: Resistor Selection for Section 2

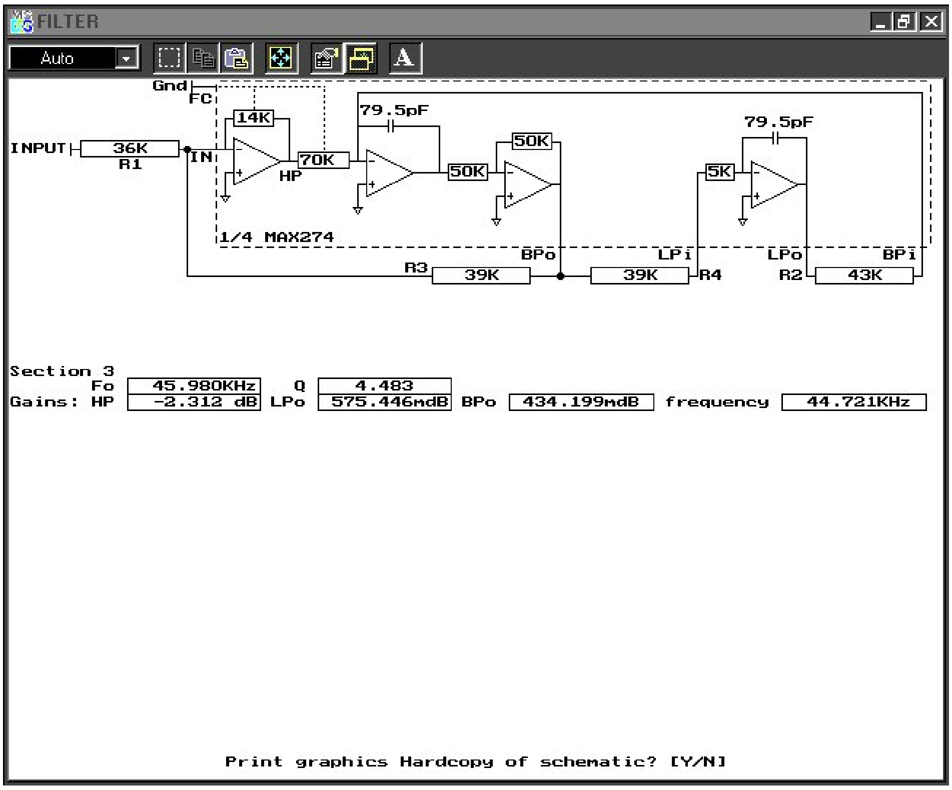

Figure A.5: Resistor Selection for Section 3

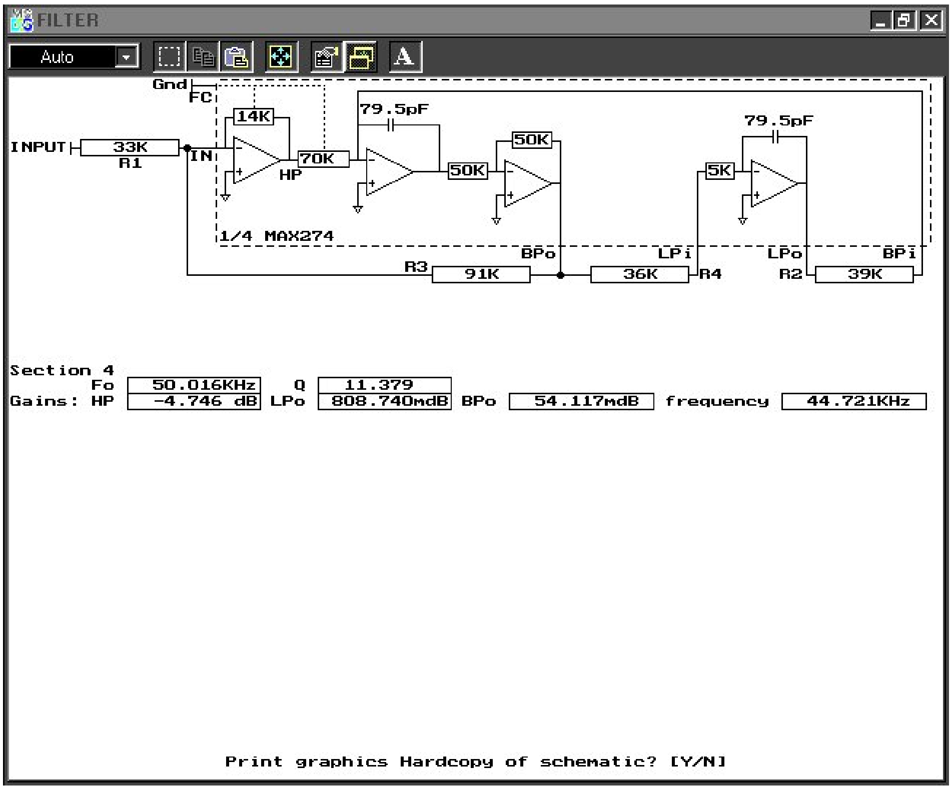

Figure A.6: Resistor Selection for Section 4

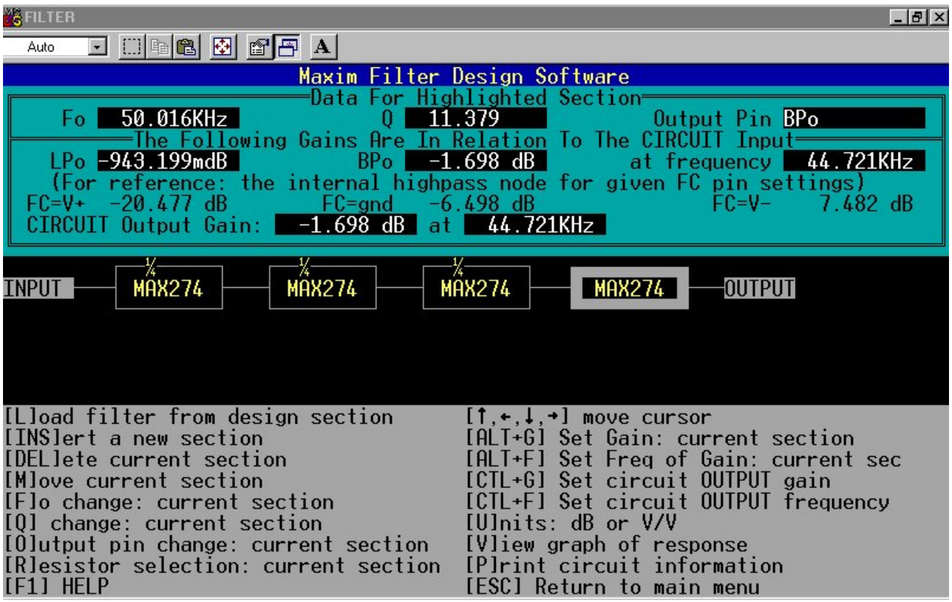

Figure A.7: Implementing Design

Appendix B

CALCULATIONS OF EXTERNAL COMPONENT VALUES FOR THE XR2211

Following are the design instructions from the data sheet;

Step 1

The value of f_O is found using Equation B.1, where F_1 is the BFSK frequency of a binary '1', and F_2 is the BFSK frequency of a binary '2'. f_O was found to be 44.72kΩ, using the chosen BFSK frequencies of 40kHz and 50kHz.

$$f_O = 1/\sqrt{F_1.F_2} \tag{B.1}$$

Step 2

The value of R_0 was chosen to be 20kΩ, as was the potentiometer R_X. R_T was then calculated using Equation B.2 and found to be 30KΩ.

$$R_T = R_0 + R_X/2 \tag{B.2}$$

Step 3

C_0 was calculated to be 74.5pF using Equation B.3.

$$C_0 = 1/(R_T.f_O) \tag{B.3}$$

Step 4

The tracking bandwidth was chosen to be 20kHz, with $f_1 = 40kHz$ and $f_2 = 50kHz$, using these values, R_1 was calculated to be $\cong$ 270kΩ using Equation B.4.

$$R_1 = 2.R_T.f_O/(f_2 - f_1) \tag{B.4}$$

Step 5

C_1 was calculated to be 13.88pF using Equation B.5, using the recommended value of $\xi = 0.5$.

$$C_1 = 1250.C_0/(R_2.\xi^2) \tag{B.5}$$

Step 6

A value of $R_F = 1.36M\Omega$ was chosen such that $R_F \geq 5R_1$.

Step 7

Similarly, a value of $R_B = 6.8M\Omega$ was chosen such that $R_B \geq 5R_F$.

Step 8

A value of $R_{SUM} = 1.315M\Omega$ was calculated using Equation B.6.

$$R_{SUM} = (R_F + R_1).R_B/(R_F + R_1 + R_B) \tag{B.6}$$

Step 9

C_F was calculated to be 1.657nF using Equation B.7.

$$C_F = 0.25/(R_{SUM}.BaudRate) \tag{B.7}$$

Appendix C

COMPLETE SCHEMATIC DIAGRAMS