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Wireless modem

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WIRELESS MODEM

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Abstract

The principle of radio modem is presented. The procedure of design and implementation of a real radio modem is described. This modem is consisted of three parts. One part is a single chip modem which use FSK modulation. One part is a single chip Narrow Band FM transmitter. The other part is a single chip FM receiver. The transmitter and receiver chips are widely used in cordless phone. By proper interfacing these three parts, we get a very simple, yet working radio modem.

Chapter 1

Introduction

1.1 Background

The project is a part of the Smart Bridge Monitoring System, a project supported by the NSF sponsored engineering research center on Advanced Technology on Large Structural Systems(ATLSS). By collecting vibration data from a big structure through a small data acquisition and processing unit, the Smart Bridge Monitoring System provides an economically affordable, highly reliable, and remotely accessible continuous monitoring system for large structures, such as highway bridges and railways. The wireless modem is a indispensable component in order to achieve remotely accessibility.

There are many reliable and complicated wireless modems available on the market. As in our application, very limited amount of data will be transmitted over a long period, those powerful and expensive modem would be a waste if used. We only need a small, simple, reliable modem with very basic functions. So, instead of buying an expensive, complicated modem, we build a small simple modem by ourself. This modem have only five IC chips in it, and every chip accomplishs a basic function required by a radio modem.

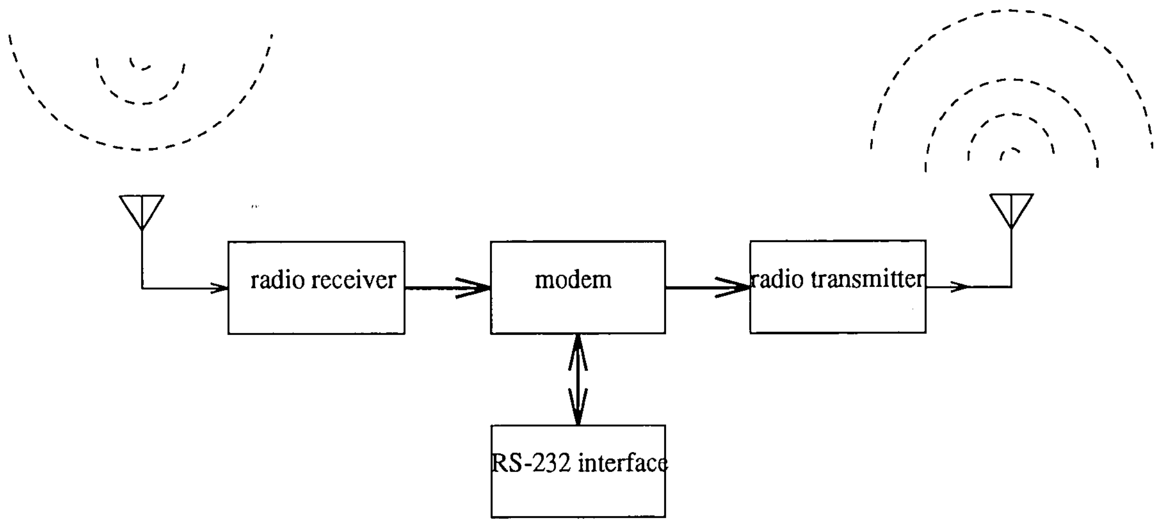

Figure 1.1: Radio Modem Block Diagram

1.2 overview of the modem

1.2.1 Federal regulations, recommended standards.

As we are using wireless communication, we must be concerned with the appropriate federal regulations, and recommended standards. Radios built for certain VHF and UHF bands may qualify under the FCC code of Federal Regulations Title 47, Part 15, for use by unlicensed operators. It is important to know the federal regulations concerning a particular frequency channel or band of channels before a receiver or a transmitter circuit is designed.

1.2.2 structure of the modem

The whole wireless modem can be divided into four parts, one is the radio receiver, one is the radio transmitter, one is modem, and the other is RS-232 interface. Each part is consisted of one specific IC chip. Figure 1.1 is the block diagram. Figure 1.2 is the printed circuit board diagram.

1. The modem

The modem we use is TCM3105. It's a single chip FSK modem. Via the RS-232 interface, the modem exchange data with a central control unit. On transmission, the modem get data from computer, then using FSK modulation send out analog signal to radio transmitter; on receiving, the modem get analog signal from the radio receiver. This analog signal is a FSK modulated signal. After FSK demodulation inside the modem chip, digital data are sent back to computer via the RS-232 interface. The analog signal used by the modem is in the voice band, with frequency around 1kHz.

This modem chip TCM3105 can only support a maximum baud rate 1200bps. However, It's already enough for our application. The advantage the chip offers is the minimum number of other external components. Beside one extra opamp chip used to accomplish signal amplification and impedance matching, it only needs several resistors and capacitors.

2. The transmitter

   For the transmitter, we use a single chip IC, MC2833. This is a FM narrow band transmitter. It receivers analog FSK signal from modem chip, then using FM modulation, add the voice band signal to high frequency carrier. the carrier frequency is around 50MHz.

3. The receiver.

   The radio receiver is composed of MC3362, a FM narrow band receiver chip. This chip can receive radio signal generated by MC2833. They both are widely used in cordless phone. MC3362 converse the received weak high frequency FM signal back to voice band signal, and then input it to modem. Although the key component of the radio modem is the modem chip, as far as the functionality and reliability and calibration are concerned, the receiver is the most important and difficult part for the whole radio modem.

4. RS-232 interface.

   Usually, we use 1488 and 1489 as the RS-232 interface components. Here, in order to reduce the count of chips, a single chip transceiver, MAX232, which combines both line driver and receiver on one chip, is used. This chip also offers another great advantage: it uses single $+5v$ power supply, with no need of $\pm 12v$ dual power supply required by 1488(driver). This relieves us a great burden.

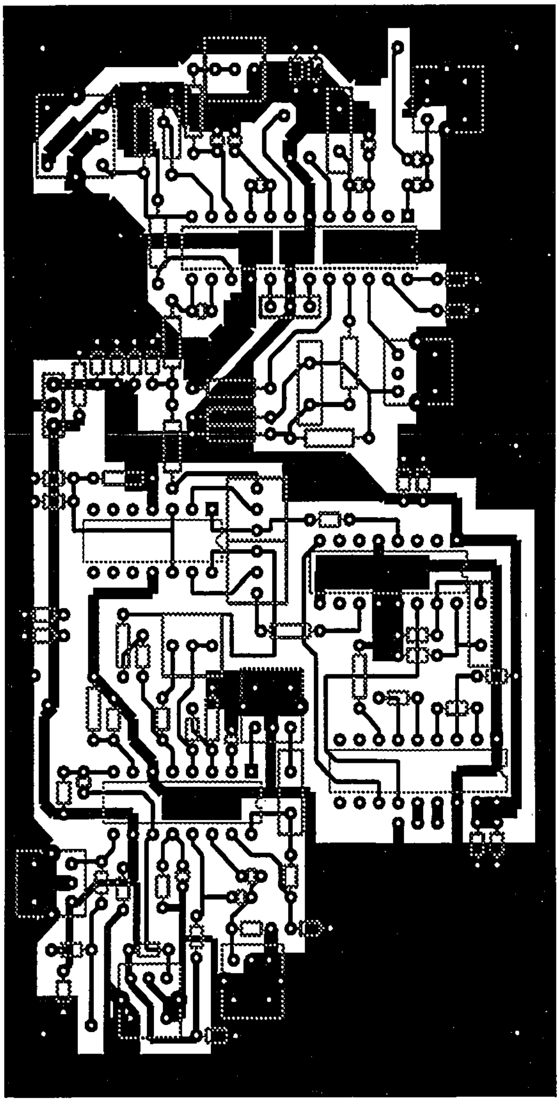

Figure 1.2: Radio Modem Printed Circuit Board

Chapter 2

Modem

2.1 Introduction

The word *modem*[1], is a concatenation of modulator and demodulator,but there is a wide range of opinion as to what constitutes modulation and demodulation, and whether, indeed, a modem should comprise more than just a *mod* and a *dem.* The functions needed for transmission and reception of data are shown in block diagram form in the following figure, with narrow, traditional and broad interpretations of what constitutes a modem.

2.1.1 Modem standards

For any communications, we need to establish a standard for interface. Only with a standardized interface, different manufacturers' communications products can interwork with each other. For modem products, the international standards are established by International Telegraph and Telephone Consultative Committee(CCITT in French). The following table is the CCITT standard for telephone modems.

In U.S., for many years the only important data communication standards operating in the United States were the de facto ones established by the Bell System with their 100 and 200 series; each of these usually came close to but never exactly matched the CCITT recommendations for a modem at the same speed.

Rec.	Date	Speed (bits/s)	HDX/FDX	PSTN/Private	Modulation method
V.21	1964	200	FDX(FDM)	PSTN	FSK
V.22	1980	1200	FDX(FDM)	PSTN	PSK
V.22 bis	1984	2400	FDX(FDM)	PSTN	16QAM
V.23	1964	1200	HDX	PSTN	FSK
V.26	1968	2400	HDX	Private	PSK
V.26 bis	1972	2400	HDX	PSTN	PSK
V.26 ter	1984	2400	FDX(EC)	PSTN	PSK
V.27	1972	4800	HDX	Private	8PSK
V.27 bis	1976	4800	HDX	Private	8PSK
V.27 ter	1976	4800	HDX	PSTN	8PSK
V.29	1976	9600	HDX	Private	16AM/PM
V.32	1984	9600	FDX(EC)	PSTN	32QAM
V.33	1988	14400	HDX	Private	64QAM

Table 2.1: CCITT Recommendations for Telephone Modems

2.1.2 Several Terminology

Three terms are frequently used to describe a modem, or a transmission channel, or a combination of the two, and care must be taken to describe any particular arrangement precisely, Full Duplex modems will not work on halp-duplex channels, and half duplex modems can sometimes work in a full-duplex mode.

- Simplex: capability of passing signals in one direction only.
- Half-Duplex(HDX): capability of passing signals in either direction, but not in both simultaneously.
- Full-Duplex(FDX): capability of passing signals in either direction simultaneously, which requires the ability to separate a receive signal from the reflection of the transmitted signal, if only a two-wire line is used.
- Frequency Divided Multiplex(FDM): the signals in the two directions occupy different frequency bands and are separated by filtering. This is a way achieving FDX.

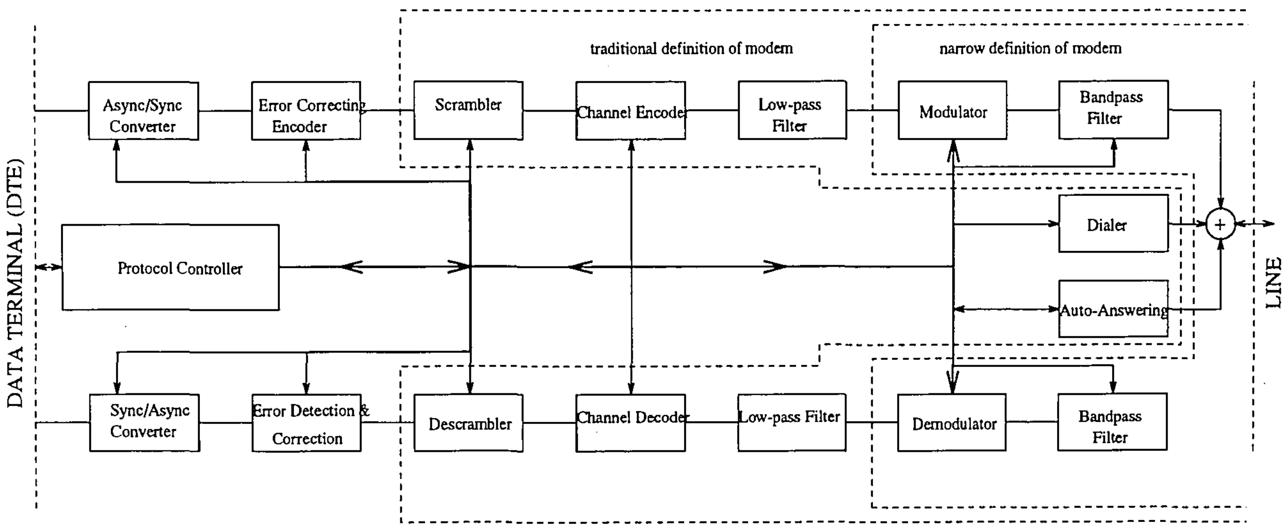

Figure 2.1: Components of a *full*, a *traditional*, and a narrowly defined modem

- Echo Canceling(EC): a locally synthesized replica of the reflected transmitted signal is subtracted from the composite received signal. This is another way of achieving FDX.

- PSTN: public Switched Telephone Network.

- Private line: the leased line. Either a pair(in a simple point-to-point connection) or several(on a multidrop network for a polling or a contention system).

2.2 Principle of Modem

Figure 2.1 is the block diagram for a usual modem. the upper part is the transmitter, the lower part is the receiver. As the function of every block in one part is the complement of that of a block in the other part, and the receiver part is more complicated, so, we will only examine the detail stucture of the receiver,which will still give us a whole picture of a modem.

The main operations that may be needed in the receiver of a private-line modem, in the approximate order in which they will be performed, are as follows:

1. filtering. This may be done in the passband and/or in the baseband after demodulation in Figure 2.1.

2. Compromise Equalization. This may be for amplitude and/or delay distortion.This should be done in the Bandpass filtering stage in Figure 2.1.

3. Automatic Gain Control(AGC).This may be done in the stages before Channel Decoder in the receiver part in Figure 2.1.

4. Demodulation. This is considered here in a much narrower sense than the *demod* that is half of a modem. Here it means only frequency translation from passband to baseband. If the demodulation is to be homodyne or synchrodyne(for coherent detection), there must also be some way of recovering a carrier of the correct frequency and phase.

5. Timing Recovery and Sampling.This is done in the Demodulator.

6. Adaptive Equalization.This is done in the Bandpass Filter.

7. Signal Detection and Decoding.This is done in the Channel Decoder.

If any part of the processing in the receiver is to be done digitally, an Analog-to-Digital Converter(ADC) will also be needed.

Although seven operations are listed above, not all of them will be needed in every receiver, and often two or more are combined in a particular implementation so as to become almost indistinguishable. Some examples of this combination, and also of the interdependence are:

- the compromise equalizer may be included in the bandpass filter.

- The gain control part of the AGC may be performed in the ADC by using a multiplying DAC or a recycling ADC with a controllable reference voltage.

- The timing and carrier recovery may be very interdependent. However, in order to shorten the time needed to train a receiver before data can be sent, considerable effort has been devoted to seeking recovery methods that can proceed independently, concurrently and at approximately the same speed.

- The timing recovery and adaptive equalization can become intertwined if the timing is adjusted so as to minimize some parameter of the signal that is learned by the equalizer.

2.2.1 Filtering

The bandpass filter(BPF) and baseband low-pass filters(LFPs) should together provide the out-of-band attenuation and the in-band spectral shaping. However, the BPF by itself must reject any components of the input signal that might be folded into the signal band by demodulation by any carrier other than a pure sinewave. and only the LPF(s) can deal with any extraneous products of such demodulation.

The combined stop-band attenuation must reduce any out-of-band signals (whether they be from adjacent channels or from noise) so that when they are eventually folded into the band by sampling at the symbol rate, they do not significantly augment the in-band noise. for half-duplex modems this is a simple task; 30dB of attenuatioin would be more than enough. On the other hand, the problems of filtering in duplex modems are very complicated and difficult.

2.2.2 Compromise Equalizers

If a channel is significantly distorted, but an adaptive equalizer is not used, the distortion of a signal delivered to the threshold detector can be reduced by using a fixed equalizer that would counteract the distortion of some average channel. The attenucation and delay responsed of this channel can be defined as the simple averages of the extremes(back-to-back and worst-case)or as weighed averages that consider the probabilities of each amount of distortion.

2.2.3 Automatic gain control

1.AGCs for Signals without amplitude modulation

These signals can be detected by using zero-level thresholds or, in the case of multiphase signals, by comparing the ratio of two signals to a nonzero threshold. In either case the amplitude of the signal is not important. Nevertheless,a crude AGC is usually desirable because:

- The bandwidth and transient response of the carrier recovery loop will depend on the amplitude of the input signal. Conservative design of the loop can usually ensure that a variation in level of about $2dB$ can be tolerated; the AGC need adjust the signal only within this degree of precision.
- A d.c. offset in the baseband may seriously impair the detection of low-level signals; an AGC in the passband before demodulation avoids this.

2.AGCs for signals with amplitude modulation

For a multilevel QAM signal, the AGC must perform two functions:

- It must crudely control the level of the input signals to the timing-recovery, carrier-recovery, and tap-adjustment loops so that their transient responses are acceptable and their stabilities are ensured;
- It must control the relationship between the signal and threshold levels so that the error in the gain contributes an acceptably small amount to the total MSE.

2.2.4 Demodulation

Demodulation, the process of shifting the frequency band of the received signal back down to baseband, may , for the sake of convenience, be performed in several stages. However, we need not be concerned with any intermediate stages; it is the overall demodulation that is important. This can be one of three types:(1)coherent preferably described as either homodyne or synchrodyne-demodulation; (2) noncoherent, or free-running demodulation; or (3) differential demodulation.

2.2.5 Sampling

In an elementary receiver an analog signal is processed(filtered, etc.), demodulated down to baseband, and input to a threshold detector. The continuous output of the detector is then sampled digitally at the learned symbol rate, and the result is passed to a decoder. This is the basic sampling process.

2.2.6 Detection and Decoding

Unless convolutional coding is used, detection and decoding are simple processes. The baseband signals are quantized to their nearest nominal levels by using (1)threshold slicing, (2)table look-up, (3)Viterbi decoding, or (4) error detection and correction, and then decoded to yield the original input data.

2.3 Modem Chip (TCM3105)

Just as being said above, the seven operations described may or may not be present in every modem. The modem chip we used, TCM3105, is an old, simple and reliable component. It only meets CCITT V23 specifications, which was finalized far way back to 1964. It doesn't have adaptive equalization, decoding and sampling functions.

2.3.1 Chip Description

The TCM 3105 has the following features:

- single-chip Frequency shift keying(FSK) Modem
- meets both Bell 202 and CCITT V23 specifications
- transmit modulation at 75, 150, 600, and 1200 Baud
- receive demodulation at 5, 75, 150, 600, and 1200 Baud
- Half-Duplex operation up to 1200 Baud transmit and 150 Baud receive
- on-chip group delay equalization and transmit/receive filtering
- carrier-detect-level adjustment and carrier fail output

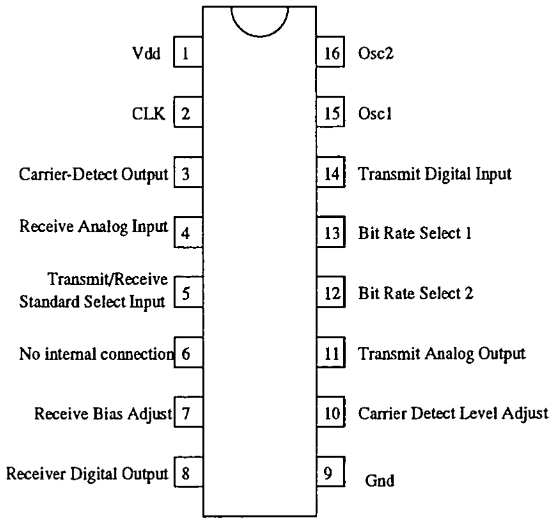

Figure 2.2: Pin description for TCM3105

- single 5-V power supply .
- low power consumption
- reliable CMOS silicon gate technology

2.3.2 Structure of TCM3105

the TCM3105 FSK modem is made up of four functional circuits. The circuits are the transmitter, the receiver, a carrier detector, and control and timing.

1. **transmitter**

   The transmitter comprises a phase coherent FSK modulator, a transmit filter, and a transmit amplifier. The modulator is a programmable frequency synthesizer that drives the output frequencies by variable divison of the oscillator frequency (4.4336Mhz). The division ratio is set by the states of three input pins: transmit/receive standard input(TRS), the bit rate select inputs(TXR1 and TXR2) , and the digital data input(TXD).

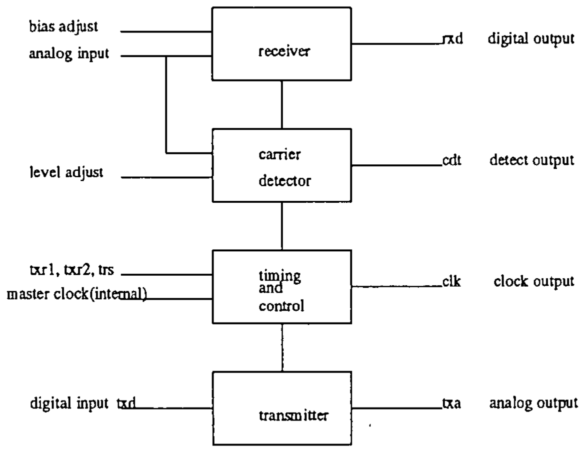

figure 1. TCM 3105 system partitioning

Figure 2.3: block diagram for TCM3105

A switched-capacitor low-pass filter limits the harmonics and noise outside the transmit band and the characteristics of this filter are set by the frequency select inputs as previously described. The harmonics introduced by the transmit filter clock are removed by a continuous low-pass filter.

2. **receiver**

A continuous low-pass anti-aliasing filter is followed by the receive amplifier, which automatically controls the gain to give a constant output level from the receive filter. The receive filter limits the bandwidth of the signal presented to the demodulator, reducing out-of-band interference, and has very high rejection of the transmit channel frequencies. These are typically present at much higher levels than the received signal.

The group delay equalizer is a switched-capacitor network that compensates the delay introduced by the receive filter and the network. The output from the equalizer is then limited to give an FSK modulated squarewave that is presented to the demodulator.

The demodulator is an edge-triggered multivibrator that triggers off positive and negative going edges. The output of the demodulator is, therefore, a stream of constant-length pusles at a frequency that is double the frequency of the limited input signal. The dc component of this signal is proportional to the received frequency and is extracted by a switched-capacitor, low-pass, post-demodulator filter. The variation of dc level with received frequency is presented to a comparator that slices at a level externally fixed by the RXB bias adjustment pin. This voltage depends on received bit rate and internal offsets. The comparator output is then the received data at the RXD output.

3. **Carrier detect**

The carrier detect circuits comprise an energy detector and digital delay. The energy detector compares the total signal level at the output of the receive filter to an externally set threshold level on the CDL input. The comparator has a 2.5-dB hysteresis and a delay to allow for momentary signal loss and to prevent oscillation. The output of the detector is available on the CDT pin where a high level indicates that a carrier is present. The data output is clamped to MARK condition when the carrier detect output swithces off at the end of transmitssion.

4. **control and timing**

An on-chip oscillator runs from an external 4.4336Mhz crystal connected between the OSC1 and OSC2 pins or an external signal driving OSC1. A clock signal equal to 16 times the highest selected bit rate (transmit or receive) is available on the CLK output. The single-supply rail means that all analog functions are referenced to an internally generated reference. All analog inputs and output must be ac coupled.

5. **transmit and receive modes**

The various modes of operation of ther TCM3105 are determined by TRS, TXR1, and TXR2 3 pins.

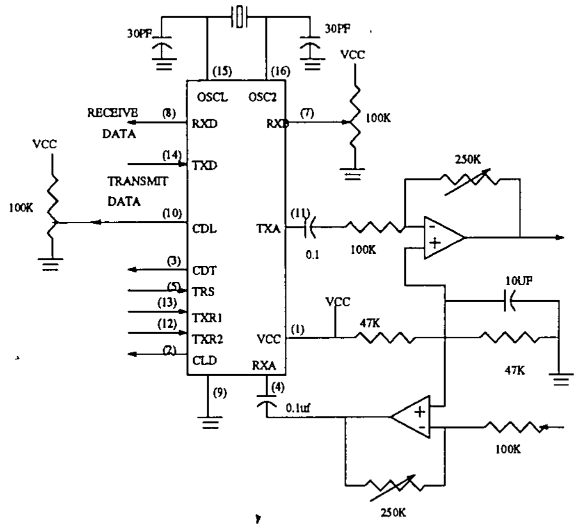

Figure 2.4: Application Circuit for TCM3105

2.4 Application Circuit and Calibration

As this modem chip works at low frequency, the calibation is not a difficult one. The key point is, when interfacing the radio transmitter and receiver, there must be a opamp in between to adjust the ananlog input and output, and performs AC coupling.

pin		
No.	name	description
1	VDD	positive supply voltage
2	CLK	output for a continuous clock signal at 16 times the highest selected (transmit or receive) bit rate
3	CDT	carrier-detect output. A low-level output indicates carrier failure
4	RXA	receive analog input to which the received line signal must
		be ac coupled
5	TRS	transmit/receive standard select input, which, with TXR1 and TXR2, sets the standard bit rates and mark/space frequencies
6	NC	no internal connection
7	RXB	receive bias adjust for external adjustment of the decision threshold of the final comparator to minimize bias distortion
8	RXD	receiver digital output for the demodulated received data in positive logic. The logic level is a mark and the low logic level is a space.
9	VSS	most negative supply voltage; connected to substrate
10	CDL	Carrier Detect Level Adjust for external adjustment of carrier detect threshold
11	TXA	Transmit Analog Output for the modulated signal, which must be ac coupled
12	TXR2	Bit Rate Select 2 input, which, along with TXR1 and TRS, sets the bit rates and mark/space frequencies
13	TXR2	bit Rate select 1 input, which, alogn with TXR2 and TRS, sets the bit rates and mark/space frequencies
14	TXD	Transmit Digital Input for input data to teh transmitter in positive logic. The high logic level is a mark and the low logic level is a space. The data can be accepted at any speed from zero to the selected speed and may be totally asychronous.
15 16	OSC1 OSC2	Oscillator connections. The crystal(typically 4.4336 MHz) is connected to these pins.If an external clock is used , OSC2 is left open and the clock is connected to OSC1.

Table 2.2: Pin function description

Chapter 3

Radio Transmitter

3.1 Principle of FM

For this radio modem, we are using two chips which use FM modulation. FM has the following merits over AM.

- constant amplitude of FM makes it less susceptible to nonlinearities.
- The constant amplitude of FM gives it a kind of immunity against rapid fading. The effect of amplitude variations caused by rapid fading can be eliminated by using automatic gain control and bandpass limiting.
- Angle modulation is also less vulnerable than AM to small signal interference from adjacent channels.
- FM is capable of exchanging SNR for the transmission bandwidth.

3.1.1 theory background

FM modulation [2] is clearly expressed by the following equations:
input signal:

$$\varphi(t) = A\cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)d\alpha\right]$$

the instantaneous frequency:

$$\omega_i(t) = \frac{d\theta}{dt} = \frac{d}{dt}\left(\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)d\alpha\right) = \omega_c + k_f m(t)$$

We want to find out the bandwidth of FM signals:

$$a(t) = \int_{-\infty}^{t} m(\alpha)d\alpha$$

$$\hat{\varphi}_{FM} = A\exp\left[j(\omega_c t + k_f a(t))\right]$$

$$\varphi_{FM} = Re[\hat{\varphi}_{FM}]$$

$$\hat{\varphi}_{FM} = A\left[1 + jk_f a(t) - \frac{k_f^2}{2!}a^2(t) + \cdots + j^n \frac{k_f^n}{n!}a^n(t) + \cdots\right] e^{j\omega_c t}$$

$$\varphi_{FM} = Re[\hat{\varphi}_{FM}] = A\left[\cos\omega_c t - k_f a(t)\sin\omega_c t - \frac{k_f^2}{2!}a^2(t)\cos\omega_c t + \frac{k_f^3}{3!}a^3(t)\sin\omega_c t + \cdots\right]$$

If, k_f is very small(that is, if $|k_f a(t)| \ll 1$), then all but the first two terms in above equation are negligible, and we have

$$\varphi_{FM} \simeq A[\cos\omega_c t - k_f a(t)\sin\omega_c t]$$

This is a linear modulation. This expression is similar to that of the AM wave. Because the bandwidth of $a(t)$ is B, the bandwidth of φ_{FM} is only 2B. For this reason, the case $|k_f a(t)| \ll 1$ is called narrowband FM (NBFM). It's interesting to compare the above equation with AM modulation equation:

$$\varphi_{AM} = A\cos\omega_c t + m(t)\cos\omega_c t = [A + m(t)]\cos\omega_f t$$

This two equations looks similiar. Only the second terms in two equation differ in phase by $\frac{\pi}{2}$. However, the AM and FM signals have very different waveforms. In an AM signal, the frequency is constant and the amplitude varies with time, whereas in an FM signal the amplitude is constant and the frequency varies with time.

If the deviation in the carrier frequency is large enough(i.e. if the constant k_f is chosen large enough so that the condition $|k_f a(t)| \ll 1$ is not satisfied), the analysis of FM signals becomes very involved for a general modulation signal $m(t)$. This case is called wideband FM(WBFM). The bandwidth can be approximated by :

$$B_{FM} \simeq 2\Delta f$$

where

$$\Delta f = \frac{k_f}{2\pi} m_p, m_p = |m(t)_{min}| = m(t)_{max}$$

Wideband FM is widely used in space and satellite communication systems. The large bandwidth expansion reduces the required SNR and thus reduces the transmitter power requirement, which is very important because of weight considerations in space. Wideband FM is also used for high-fidelity radio transmission over rather limited areas. In our radio modem, we use a narrow band FM transmitter.

3.1.2 Generation of FM waves

Basically, there are two ways of generating FM waves:indirect generation and direct generation. The chip we are using in the radio modem uses direct generation. This method varies one of the reactive parameters (capacitor, in our chip) of the resonant circuit of an oscillator. As our oscillator uses a crystal, the frequency change is very small (k_f is very small), and it is a narrowband FM. Crystal gives us a very stable frequency. As the crystal frequency is not high enough, the modulated signal is multiplied several times before it is sent out.

The frequency multiplier is a nonlinear device. A simple square-law device, for example, can multiply the frequency by a factor of 2. Suppose input $e_i(t)$ and the output $e_o(t)$ are related by

$$e_o(t) = [e_i^2(t)]$$

If

$$e_i(t) = \varphi(t) = \cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha) d\alpha\right]$$

then

$$e_o(t) = \cos^2\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha) d\alpha\right] = \frac{1}{2} + \frac{1}{2}\cos\left[2\omega_c t + 2k_f \int_{-\infty}^{t} m(\alpha) d\alpha\right]$$

The DC term is filtered out to give the output, whose carrier frequency as well as frequency deviation are multiplied by two. Any nonlinear device, such as a diode or a transistor, can be used for this purpose. These devices have the following characteristic:

$$e_o(t) = a_0 + a_1 e_i(t) + a_2 e_i^2(t) + \cdots + a_n e_i^n(t)$$

In our transmitter chip, transistors are used to act as frequency multiplier as well as an amplifier.

3.2 Radio Transmitter Chip(MC2833)

MC2833 is a one chip narrow band FM transmitter subsystem designed for cordless telephone and FM communication equipment. It includes a microphone amplifier, voltage controlled oscillator and two auxiliary transistor.

The MC2833 has following features:

- wide range of operating supply voltage(2.8-9.0v)
- low drain current (Icc=2.9mA typ).
- low number of external parts required.
- -30dBm power output to 60MHz using Direct RF output
- +10dBm Power Output attainable using on-chip transistor amplifiers.

Figure 3.1 is the pin assignments.

3.3 Application Circuit and Calibration

As this is a RF circuit, the design of a printed circuit board becomes a critical issue for achieving optimal performance. This means(typically) a one- or two-sided copper clad board with adequate ground plane connected to Vee potential. It is also important that all Vcc interconnections are made using copper traces on the board. *Free floating* point to point wiring for the Vcc interconnections can be disastous.In general, keep all lead lengths as short as possible, with an emphasis on minimizing the highest frequency path lengths. Decoupling capacitors should be placed close to the IC.

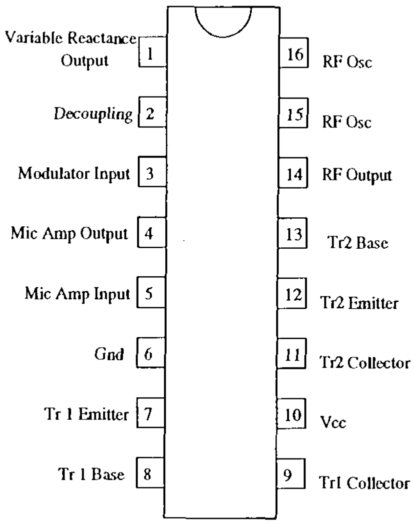

Figure 3.1: MC2833

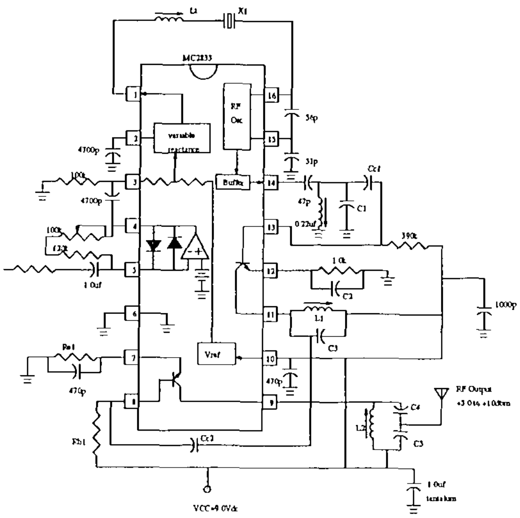

Figure 3.2: Application Circuit for MC2833

Chapter 4

Radio Receiver

4.1 Principle of Demodulation

In an FM wave, the information resides in the instantaneous frequency $\omega_i = \omega_c + k_f m(t)$. Hence, a frequency-slelective network with a transfer function of the form $|H(\omega)| = a\omega + b$ over the FM band would yield an output proportional to the instantaneous frequency. The simplest among them is an ideal differentiator with the transfer function $j\omega$.

If we apply $\varphi_{FM}(t)$ to an ideal differentiator , the output is

$$\dot{\varphi}_{FM}(t) = \frac{d}{dt}\left\{A\cos\left[\omega_c t + k_f\int_{-\infty}^{t} m(\alpha)d\alpha\right]\right\} = A[\omega_c + k_f m(t)]\sin\left[\omega_c t + k_f\int_{-\infty}^{t} m(\alpha)d\alpha\right]$$

The signal $\dot{\varphi}_{FM}(t)$ is both amplitude and frequency modulated , the envelop being $A[\omega_c + k_f m(t)]$. Because $\Delta\omega = k_f m_p \ll \omega$, $\omega_c + k_f m(t) \gg 0$ for all t, and $m(t)$ can be obained by envelope detection of $\dot{\varphi}_{FM}(t)$.

4.2 MC3362

MC3362 is a complete FM narrowband receiver from antenna input to audio preamp output. The low voltage dual conversion design yields low power drain, excellent sensitivity and good image rejection in narrowband voice and data link applications.

MC3362 has the following features:

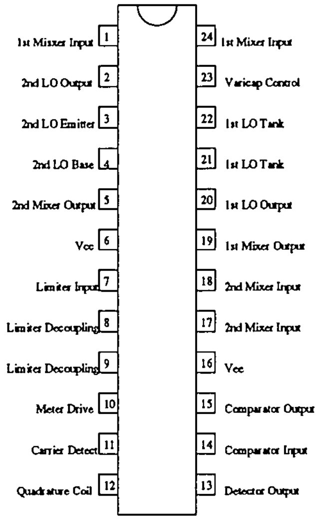

Figure 4.1: Pin description for MC3362

- complete dual conversion circuitry
- low voltage: Vcc=2.0 to 6.0 Vdc
- low drain current (3.6 mA(Typ) @ Vcc=3.0Vdc)
- Excellent sensitivity: Input limiting voltage- (-3.0db)=0.7uv(Typ)
- Externally adjustable carrier detect function
- low number of external parts required
- manufactured in Motorola's MOSAIC Process technology

4.3 Principle of Operation

By using two accurate local crystal oscillators, the input RF signal is translated from RF frequency first down to 10.7MHz(the first IF) , and then down to 455KHz(the second IF).Both mixers also amplify the signal. After external bandpass filtering, the low IF is fed into the limiting amplifier and detection circuitry. The audio is

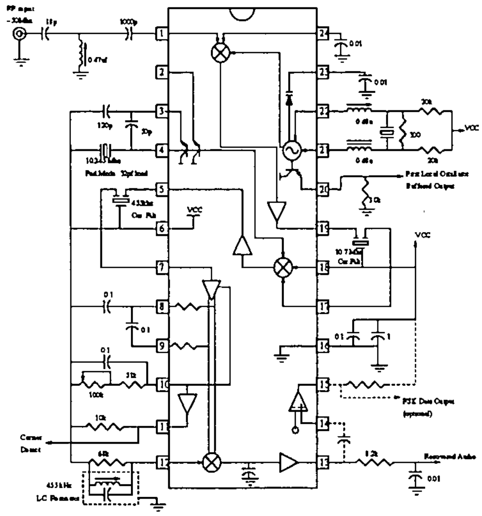

Figure 4.2: Applicaton circuit for MC3362

recovered using a conventional quadrature detector. Twice-IF filtering is provided internally.

The input signal level is monitored by meter drive circuitry which detects the amount of limiting in the limiting amplifier. The voltage at the meter drive pin determines the state of the carrier detect output, which is active low.

4.4 Application Circuit and Calibration

Figure 4.2is the application circuit.

The calibration of this circuit is very much like that of MC2833. As they are all RF circuit, great attention should be paid to the layout design.

Bibliography

[1] John A.C.Bingham. *The Theory and Practice of Modem Design.* John Wiley & Sons, Inc., 1988.

[2] B.P.Lathi. *Modern Digital and Analog Communication.* Holt, Rinehart and Winston, Inc., second edition, 1989.

Appendix A

Biography

Personal

Born August 18, 1969 in Anhui Province, P.R.China

Education

Tsinghua University

Beijing, P.R.China

PERIOD: Fall, 1987 - Fall, 1992

DEGREE: B.S. 1992

MAJOR: Electronics Engineering

Lehigh University

Bethlehem, Pennsylvania

PERIOD: Fall, 1993 - NOW

DEGREE: Master Degree

MAJOR: Electrical Engineering

END

OF

TITLE