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Local Area Paging Network

Group No: B10

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Supervisor (s) –Self Proposed Topic

Abstract

The objective of this project is to develop a Local Area Paging Network system. The system consists of a main Central Control System which will transmit the carrier wave at the required frequency to all paging units in the vicinity. The frequency of transmission will be 433.92 MHz. The pager for which the message was meant will give an indication in the form of a flashing LED and a small beep. We have chosen the Micrel ICs and MICRF010 (as a Low-Power UHF Receiver) MICRF102 (as UHF Transmitter).Also the Atmel Microcontroller IC AT89C51 is being used for the keypad interfacing and generating the serial output. The same IC AT89C51 is being used at the receiver unit for the user interfacing as to give the indication to the user only if the message sent at the central control system is meant for him.

1. **Introduction**

In Local areas as Hostels, the existing system of announcing/ informing students i.e. The P.A [Public Address] System is neither efficient nor elegant.

- Most of the times when there is an external call for the student; he can either not hear it or it is not intelligible.
- It disturbs the tranquility of the rest of the hostel

Our system offers a very cost-effective, elegant solution for this purpose.

2. Design Approach

The Central Control System will consist of the following units

- There will be Keypad in which the watchman will type the required room number to which the message has to be transmitted
- There will be a 3 Seven segment LED display for the purpose of knowing to whom the message is being transmitted
- There will be a microcontroller which will encode the data in a suitable format

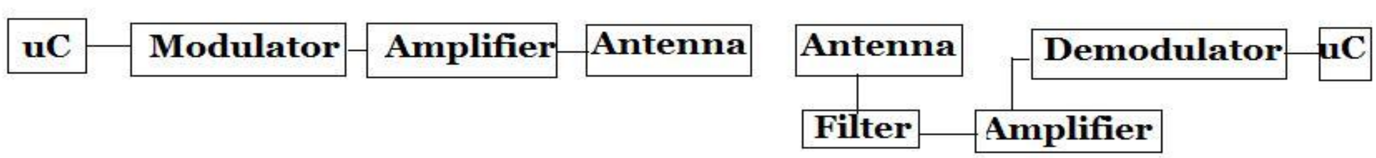


Figure 2.1: Basic Block Diagram

Then UHF Transceiver devices are used for further processing of the serial data pulse for transmitting it at 433.92 MHz which has been generated at the transmitted section. The UHF Transceivers ICs serves as the compounded unit corresponding to modulation, demodulation, amplification, filtering of the waveform. Thus the corresponding encoded wave by the transceiver is transmitted using the antenna.

The corresponding wave is received from the antenna at the receiver side and then the original sent message is received using the transceiver IC as receiver which does the demodulation, amplification, filtering of the input waveform.

Then using the microcontroller after detecting the original message the user gets an indication only if the message sent at the central control system is meant for him.

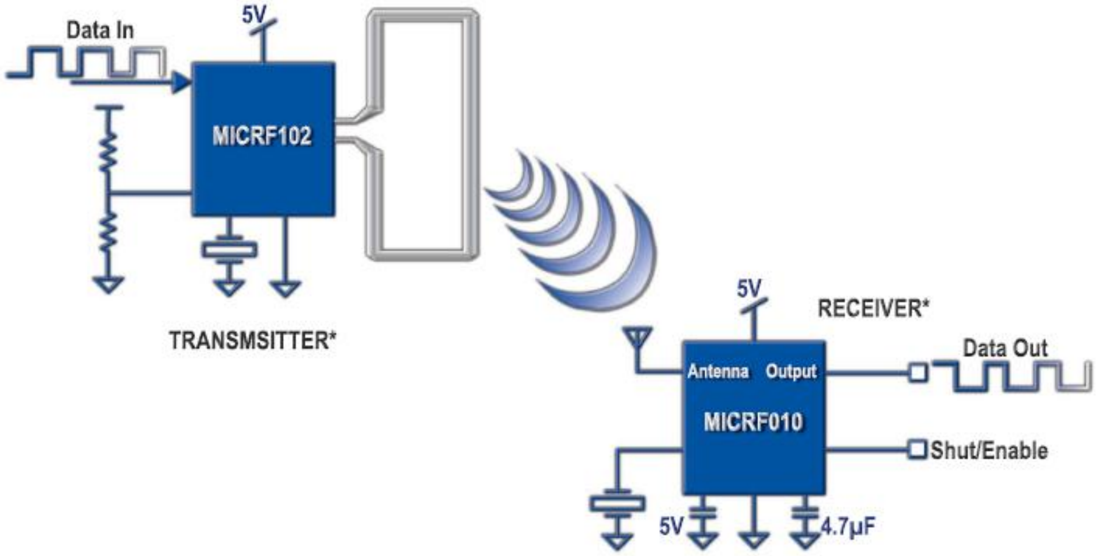


Figure 2.2: Transceiver part at Transmitter and Receiver Units

3. Design Details

3.1 Keypad Interfacing at Transmitter:

At the Central control station at the transmitter part we are using 4x4 keypad interfacing using the microcontroller AT89C51 and displaying the input value at the keypad through LEDs. The microcontroller AT89C51 is most suitable for our project as it is having 4 ports (32 programmable I/O lines), 4K Bytes of in-system programmable flash memory. So using this microcontroller we can further reprogram it for higher number of receiver units because of having 4 ports available. And because of having sufficient large memory we can even program it for multiple options as for sending different messages to corresponding receivers.

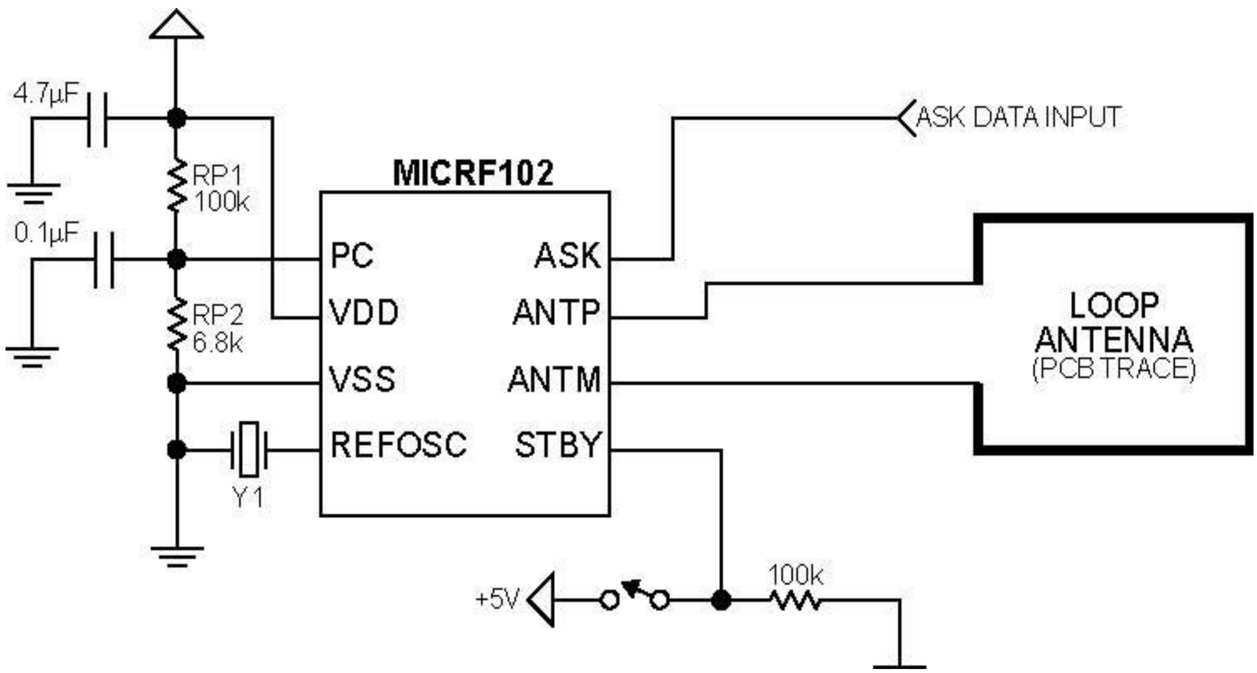
In our project we are first doing our project for a maximum of 15 receivers units by using the two ports of AT89C51. The microcontroller is programmed for 4x4 keypad interfacing and serial data communication. The input of the keypad is taken at Port 1 (P1.0-P1.7) and displaying the corresponding output at 4 I/O lines of port 3 (P3.2 – P3.5). Then using the serial data communication the corresponding serial data pulse is available at Tx pin (P3.1) which is the fed to the transceiver IC MICRF102 for further processing of the data pulse. The circuit of the keypad interfacing part at transmitter section is given below (Figure 1.3).

3.2 UHF Transmitter

The choice for the UHF Transmitter is the Micrel IC MICRF102.The MICRF102 is a single chip Transmitter IC for remote wireless applications. This device is a true “data-in, antenna-out” monolithic device. All antenna tuning is accomplished automatically within the IC which eliminates manual tuning, and reduces production costs. The result is a highly reliable yet extremely low cost solution for high volume wireless applications. Because the MICRF102 is a true single-chip radio transmitter, it is easy to apply, minimizing design and production costs.

The MICRF102 uses an architecture where the external loop antenna is tuned to the internal UHF synthesizer. This transmitter is designed to comply worldwide UHF unlicensed band intentional radiator regulations. The IC is compatible with virtually all ASK/OOK (Amplitude Shift Keying/On-Off Keyed) UHF receiver types. It is hence quite compatible with our goal of transmitting at 433.92 MHz frequency.

The automatic tuning in conjunction with the external resistor insures that the transmitter output power stays constant for the life of the battery. The transmitter is designed to work with transmitter data rates from 100 to 20k bits per second.



<u>Figure 3.1</u>: Transmitter Circuitry kept at the Central Control System End

A Step by Step Approach for determining the various parameters in Transmitter Design

The transmitter design process is as follows:

1). Set the transmit frequency by providing the correct reference oscillator frequency .Transmit frequency in our case = 433.92 MHz Hence we need a crystal corresponding to this frequency.

2). Ensure antenna resonance at the transmit frequency by:

$$L_{ANT} = 0.2 \times Length \times \ln(Length/d - 1.6) \times 10^{-9} \times k \qquad \ldots\ldots(1)$$

Where: Length is the total antenna length in mm. d is the trace width in mm. k is a frequency correction factor.

L_{ANT} is the approximate antenna inductance in Henries.

3) Calculate the total capacitance using the following equation.

$$C_T = \frac{1}{\left(4 \times \pi^2 \times f^2 \times L_{ANT}\right)} \qquad \ldots..(2)$$

Where: $C_{T=}$ total capacitance in farads.

$\pi = 3.1416$.

f = carrier frequency in hertz.

$L_{ANT\,=}$ inductance of the antenna in henries.

4). Calculate the parallel and series capacitors, which will resonate the antenna.

4.1)Ideally the series and parallel capacitors should have the same value or as close as possible.

$$C_S = \frac{1}{\left(\frac{1}{C_T} - \frac{1}{(C_{VAR} + C_P)}\right)} \qquad \ldots(3)$$

4.2). Start with a parallel capacitor value and plug in the following equation.

Where:

C_{VAR} is the center varactor capacitance (5pF for the MICRF102) in farads.

C_P is the parallel capacitor in farads.

C_S is the series capacitor in farads.

Repeat this calculation until C_S and C_P are very close.

5.) Set PC pin to the desired transmit power.

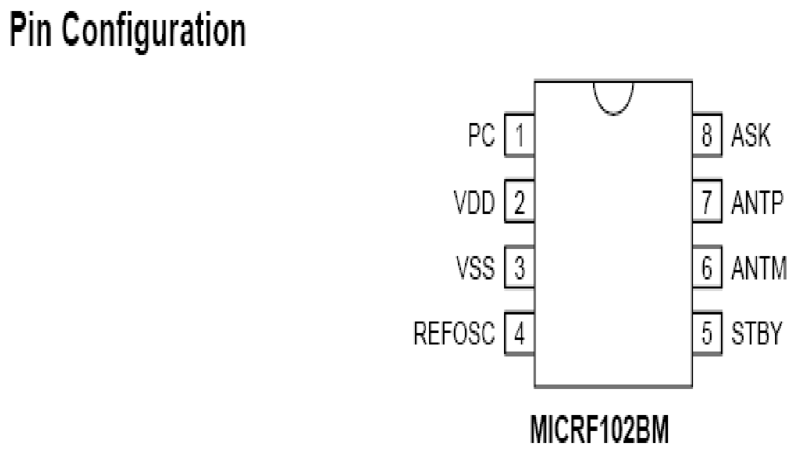


Figure 3.2: Pin configuration of MICRF102BM

Reference Oscillator Selection

An external reference oscillator is required to set the transmit frequency. The transmit frequency will be 32 times the reference oscillator frequency.

$f_{TX} = 32 \times f_{REFOSC}$ …..(4)

Crystals or a signal generator can be used. Correct reference oscillator selection is critical to ensure operation. Crystals must be selected with an ESR of 20 Ohms or less. If a signal generator is used, the input amplitude must be greater than 200 mV_{P-P} and less than 500 mV_{P-P}.

Antenna Considerations

The MICRF102 is designed specifically to drive a loop antenna. It has a differential output designed to drive an inductive load. The output stage of the MICRF102 includes a varactor that is automatically tuned to the inductance of the antenna to ensure resonance at the transmit frequency.

A high-Q loop antenna should be accurately designed to set the center frequency of the resonant circuit at the desired transmit frequency. Any deviation from the desired frequency will reduce the transmitted power. The loop itself is an inductive element. The inductance of a typical PCB-trace antenna is determined by the size of the loop, the width of the antenna traces, PCB thickness and location of the ground plane. The tolerance of the inductance is set by the manufacturing tolerances and will vary depending how the PCB is manufactured.

The MICRF102 features automatic tuning. It automatically tunes itself to the antenna, eradicating the need for manual tuning in production. It also dynamically adapts to changes in impedance in operation and compensates for the hand-effect.

Automatic Antenna Tuning

The output stage of the MICRF102 consists of a variable capacitor (varactor) with a nominal value of 5.0pF tunable over a range from 3pF to 7pF. The MICRF102 monitors the phase of the signal on the output of the power amplifier and automatically tunes the resonant circuit by setting the varactor value at the correct capacitance to achieve resonance.

In the simplest implementation, the inductance of the loop antenna should be chosen such that the nominal value is resonant at 5pF, the nominal mid-range value of the MICRF102 output stage varactor.

Using the equation:

$$L = \frac{1}{4\pi^2 f^2 C} \qquad \ldots\ldots(5)$$

If the inductance of the antenna cannot be set at the nominal value determined by the above equation, a capacitor can be added in parallel or series with the antenna. In this case, the varactor internal to the MICRF102 acts to trim the total capacitance value.

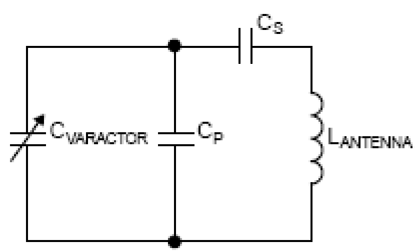


Figure 3.3: The output stage of the MICRF102

Antenna Characteristics

The desired loop inductance value s for this particular frequency are given on next page

Freq. (MHz)	R (ohms)	XL (ohms)	Ind (nH)	Q (XL/R)	K
315	2.34	89.3	45.1	39.65	0.85

Loop antennas are often considered highly directional. In fact small loop antennas can achieve transmit patterns close in performance to a Dipole antenna. The radiation pattern below is the theoretical radiation pattern for the antenna shown

Supply Bypassing

Correct supply bypassing is essential. The IC is susceptible to supply-line ripple, if supply regulation is poor or bypassing is inadequate, spurs will be evident in the transmit spectrum.

MICRF102 Series Capacitor Calculation

$$f = 433.92 \times 10^{6}$$
$$L = 52 \times 10^{-9}$$
$$C_{VAR} = 5 \times 10^{-12}$$
$$C_{P} = 2.7 \times 10^{-12}$$

$$C_{T} = \frac{1}{4 \times \pi^{2} \times f^{2} \times L}$$
$$C_{T} = 2.587 \times 10^{-12}$$

$$C_{SERIES} = \frac{1}{\frac{1}{C_{T}} - \frac{1}{C_{VAR} + C_{P}}}$$
$$C_{SERIES} = 3.9 \times 10^{-12}$$

$$L1 = 52 \times 10^{-9}$$
$$f1 = 433.92 ¥ 10^{6}$$

$$C_{T1} = \frac{1}{4 \times \pi^{2} \times f^{2} \times L1}$$
$$C_{T1} = 2.587 \times 10^{-12}$$

3.3 UHF Receiver

The MICRF010 is a single chip, ASK/OOK (ON-OFF Keyed) RF receiver IC. It achieves low power operation, a very high level of integration, and it is particularly easy to use.

All post-detection data filtering is provided on the MICRF010, so no external baseband filters are required. In fact, the entire receiver circuit is made of very few external components and with the 8-pin SOIC package makes it ideal for small printed circuit board area applications.

The data rate is up to 2.0kbps (Manchester encoding).

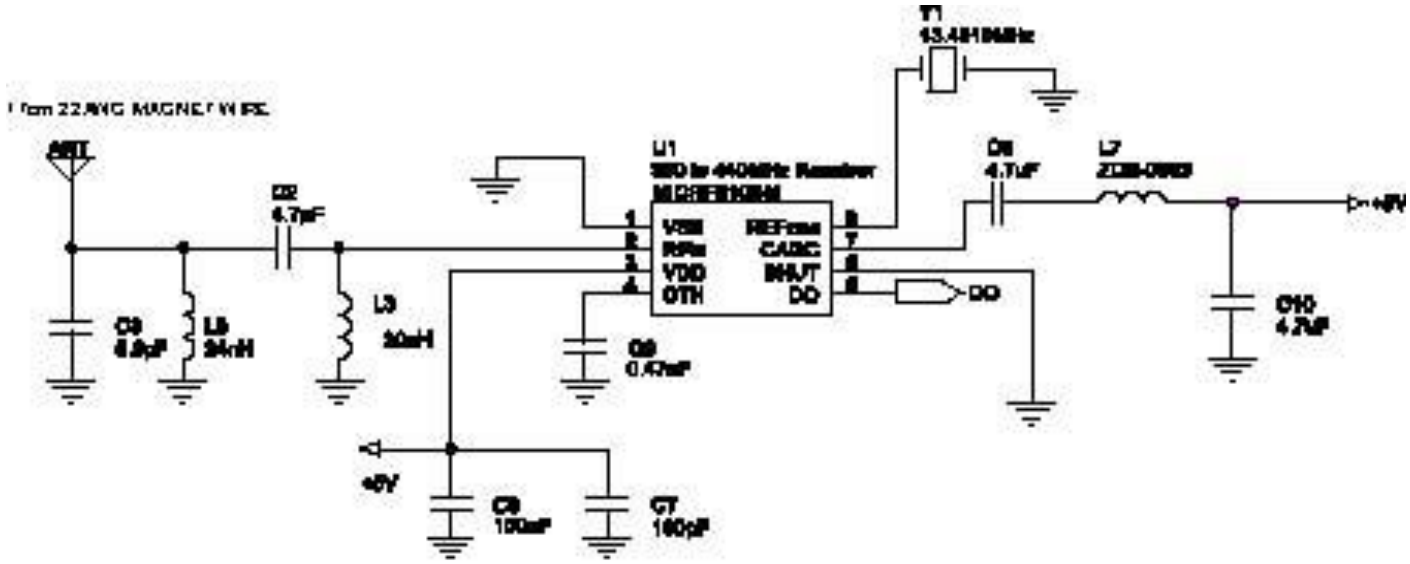


Figure 3.4: 433.92 MHz 1000 bps On-Off Keyed Receiver

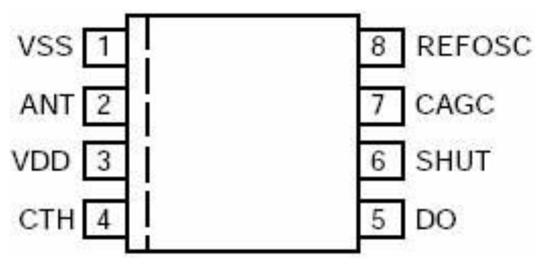


Figure 3.5: UHF Receiver IC

Selecting the Reference Oscillator

Timing and tuning is controlled through the REFOSC pin in one of three ways:

1. Connect a crystal.
2. Drive this pin with an external timing signal.

The specific reference frequency required is related to the system transmit frequency.

Selecting Reference Oscillator Frequency fT

The difference between the internal LO (local oscillator) frequency fLO and the incoming transmit frequency fTX, should equal the IF center frequency.

$$f_{LO} = f_{TX} \pm \left(0.86 \frac{f_{TX}}{315}\right) \qquad \ldots\ldots(6)$$

Frequencies fTX and fLO are in MHz. Note that two values of fLO exist for any given fTX, distinguished as "high-side mixing" and "low-side mixing." High-side mixing results in an image frequency above the frequency of interest and low-side mixing results in a frequency below. There is generally no preference of one over the other.

After choosing one of the two acceptable values of fLO, compute the reference oscillator frequency fT:

$$f_T = 2 \times \frac{f_{LO}}{64.5} \quad \text{……..(7)}$$

Frequency fT is in MHz. Connect a crystal of frequency fT to REFOSC on the MICRF010. Four-decimal-place accuracy on the frequency is generally adequate. The following table identifies fT for some common transmit frequencies.

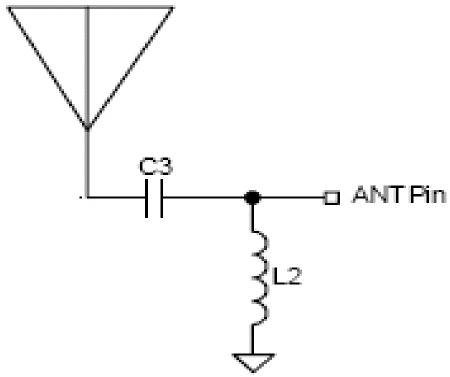
Transmit Frequency (fTX)	**Reference Oscillator Frequency (fT)**
433.92 MHz	13.4916 MHz

Antenna Impedance Matching

It is recommended that the antenna impedance is matched to the input of the IC. The Antenna pin can be matched to 50Ω with a high pass circuit shown on the next page.. That is, a shunt inductor from the ANT Pin to ground and a series capacitor from ANT Pin to the antenna.

Frequency (Mhz)	S11 Mag, angle	Z11, ohms	C3, pF	L2, nH
435	0.911, -49.925	12.94-j106	1.8	27

From Micrel Datasheet



<u>Figure 3.6:</u> Antenna at the receiver unit

3.4 Interfacing of the receiving unit with the user:

At the receiver unit we are using the same microcontroller AT89C51 for user interfacing. We have programmed the AT89C51 for serial data communication and the logic whether that user should get any indication of sent message or not. The serial data pulse is received at the Rx pin of port 3 (P3.0) from the UHF transceiver (as receiver). The depending on the message corresponding to the input data pulse, the user gets the indication at the port 2 pins using the LEDs and piezoelectric buzzer only if that message was being sent at the central control station for him only. The circuit for the receiver unit for user interfacing is shown below (Figure 2.0).

3.5 PCB Layout

Basically the PCB we have made is half duplex i.e. it can either act as a transmitter or as a receiver at any given time. On a single PCB we can fabricate either the Transmitter unit [MICRF102] or the Receiver unit [MICRF010].The PCB layouts are as given on the next page (Figure 2.1 and 2.2):

Conclusion:

Thus the given project can be used as good substitute for the current existing Public Address System currently existing hostels, local areas etc. The given project is for a limited number of receiver units – 16 units. So for further improvement the number of receivers can be increased more than 100s of such units by slight modification in the programming of microcontroller. Also the current system is meant only for giving a single indication for any reason of messaging. So, it can also be modified in giving different indications for different messages sent at the central control station.

What we have achieved so far is that the transmitter side modulator and receiver side de-modulator are working.Also we have made the PCBs for the transmitter and receiver unit,but have yet to test them.

References

[1] Data sheet of transceiver MICRF010

Source: http://www.micrel.com/product-info/products/micrf010.shtml

[2] Data sheet of transceiver MICRF102

Source: http://www.micrel.com/product-info/products/micrf102.shtml

[3] Data sheet of transceiver MICRF102

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[4] Kenneth J.Ayala, The 8051 Microcontroller, Architecture, Programming and Applications. Second edition, Thomas Delmar Learning, 1997.

[4] Sedra & Smith, Microelectronic circuits, Fifth Edition