DTMF Decoder/Ringer for Multi-party Telephone Lines

Group No: B06

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Abstract

This report discusses the approach, design and implementation of a circuit for managing multi-party telephone lines. For domestic and other purposes, it is uneconomical to use personal telephone exchange for redirecting calls. The report presents a low-cost alternative for such a case. It involves using a DTMF decoder/ringer unit as a parallel attachment to each telephone instrument. Each unit has a distinct number and can be dialed from the instrument keypad. The project involved developing this attachment, using a Dual Tone Multiple Frequency (DTMF) decode chip. The report also discusses the challenges faced in the process and the ways used to overcome them. The circuit has been experimentally tested. Other applications and uses, and further improvements to the circuit are also suggested.

1 Introduction

Multiple telephones on a single telephone line are very common, both in our homes and the offices. The advantages are very well known. But the external call is only meant for one of the many telephones connected to the line. Hence, ringing all the telephones connected is simply unnecessary. Moreover, the telephone loads the telephone line when it rings. So, when multiple telephones ring at the same time, all of these load the telephone line. The telephone exchange does not allow more than two telephones loading their line. Thus, if we wish to connect more than two telephones directly to the telephone line, we should not allow all those to ring simultaneously.

A solution can be the use of a personal branch exchange. But, it is quite uneconomical to go for a complete telephone exchange for such small scale household and office purposes. Further, an exchange requires “star” topology for wiring of the telephone instruments. We can use a multi-drop arrangement in which instruments can be connected in parallel, and each instrument is individually addressable from any of the instruments. This can be achieved by developing a low cost attachment to be connected near each telephone instrument. This device detects the telephone for which the call is meant and rings the respective unit and thus, preventing all the telephones to ring simultaneously.

Now, it remains to identify the unit for which the call is meant. This can be accomplished by assigning a different (unique) identity to each unit and this address is dialled on the telephone in order to activate it. For this, we need to interface the telephone line and analyze the telephone DTMF signals.

Also, in many cases it is advantageous to have an indication of the number of users currently on-the-line. This can also be accomplished in the same unit by observing the telephone line voltages. The circuit designed provides these functionalities.

This unit has good applications in rural areas, where each house (generally farms, far apart) cannot afford a separate telephone line. Hence, a group of houses can use a single telephone connection, with telephones connected in parallel and one such unit attached to each telephone. Each house is assigned a unique address. The external call to any of the house, will be first received at the master phone and then redirected to the desired user using this unit. This turns out to be a cheap and effective solution for such a case.

2 Approach

Figure 1 shows the multi-drop arrangement. The block diagram for the DTMF decoder circuit is shown in Figure 2. We use a DTMF decoder to identify the code dialled and feed it to a micro-controller, which then checks the code for the unit's address and does the required operations. In order to detect the number of users on-the-line, we use a comparator circuit to detect the telephone voltage and thus, get to know the number of telephones off-hook.

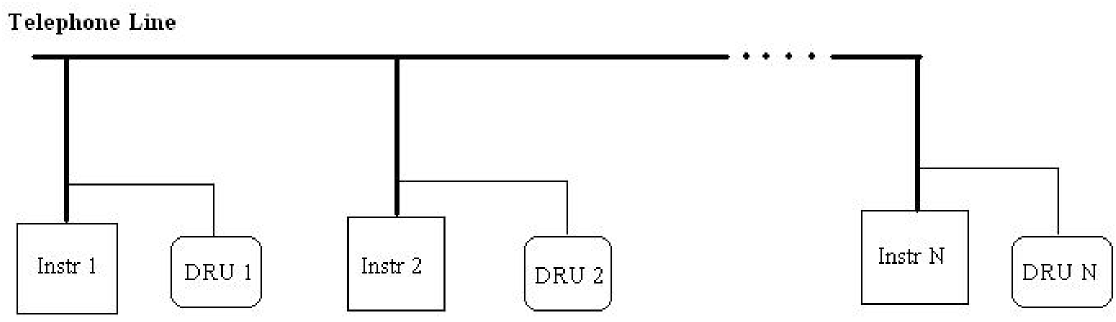


Figure 1: Telephone line with multi-drop arrangement of instruments and DTMF decoder/ringer units

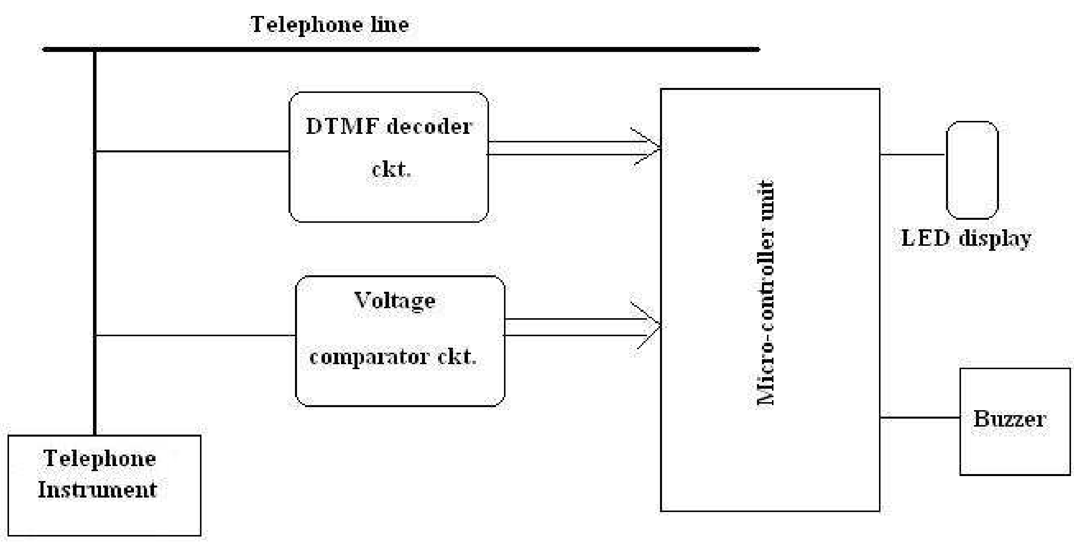


Figure 2: Block diagram of DTMF decoder/ringer

Each unit connected to a telephone will be given an address. We will be giving a single-digit address, ranging from $0-9$ in digital format. The number of digits can be increased for greater number of telephone lines, but in general, single-digit should be sufficient. We choose a telephone unit to be the master phone. Except this telephone, every other telephone has its ringer put off. Thus, when an external call comes, only the master phone rings. The user at the master phone end will find out the person for whom the call is meant and then dials the proper code for the corresponding telephone. The protocol we have used for calling a unit is to dial "$*$" followed by the address assigned to that particular unit. We could have used any other key (say, "#") instead of "$*$", which is just a matter of our choice. When the proper code is dialled, the DTMF decoder in each unit decodes the address dialled and feeds it to the micro-controller. The micro-controller then compares it with the address assigned to it. The actual unit with this address will detect it and activates its ringer. As soon as the user at this end lifts the telephone, the ringer goes off. There is also a provision for deactivating the ringer from the other end, in case the desired user is not responding. This is done by simply dialling "#" at any moment.

We use a voltage comparator circuit to detect the telephone line voltage and indicate the number of telephones off-hook. The telephone line voltage changes depending on the number of phones off-hook. This information is fed to the micro-controller, which uses it to deactivate the ringer (in case it is ringing) when the telephone is lifted and also to provide an indication of the number of on-the-line users. This indication is given through an LED. The circuit we have designed is for two parallel telephones. Thus, a single LED suffices to indicate the number of telephones online. An LED which is off indicates that no telephone is online, while a blinking LED indicates one user is online and a permanently glowing LED indicates two users online. The blinking of the LED also indicates the others users not to pick up the phone. The number of LEDs can be increased for more number of telephones.

3 Design of circuit

DTMF Decoder circuit

The DTMF decoder circuit consists of a DTMF receiver (decoder) chip. We have used CM8870 DTMF decoder chip. The pin lay out is as given in Figure 3. The input to the DTMF decoder is the DTMF signal, which is given to the pins IN+ and IN-. The gain of the signals can be adjusted by varying either the series resistance for the DTMF signal or the feedback resistance from pin3 (GS). The chip needs a crystal of frequency 3.579545 MHz. The decoder will decode the DTMF signal and present the output as four bits on Q1, Q2, Q3, Q4. A logic high on the pin TOE (Three-state output enable) will enable the outputs Q1-Q4. The steering circuit using the pins 18 (ESt) and 19 (St/GT) will control the minimum time for which a DTMF signal should be present on the line for it to be detected. This can be controlled by varying the resistance and capacitance connected to these pins. The ESt pin presents a logic high when a valid pair is detected and any change in the signal causes it go low. The StD pin presents a logic high when a valid tone-pair has been registered and the output is latched. It then returns to logic low when the voltage on the pin St/GT falls below a threshold. When a key is released the signal goes off and hence, ESt will go low and St/GT pin voltage falls to zero. Thus, after a small time StD pin goes low. The output corresponding to each of the keys pressed is given in Table 1.

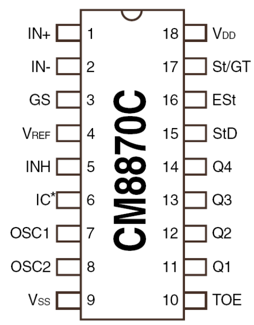


Figure 3: Pin layout of DTMF decoder CM8870

Table 1: Functional decode table of CM8870 [ref. 2]

Digit	TOE	INH	ESt	Q_4	Q_3	Q_2	Q_1
ANY	L	X	H	Z	Z	Z	Z
1	H	X	H	0	0	0	1
2	H	X	H	0	0	1	0
3	H	X	H	0	0	1	1
4	H	X	H	0	1	0	0
5	H	X	H	0	1	0	1
6	H	X	H	0	1	1	0
7	H	X	H	0	1	1	1
8	H	X	H	1	0	0	0
9	H	X	H	1	0	0	1
0	H	X	H	1	0	1	0
*	H	X	H	1	0	1	1
#	H	X	H	1	1	0	0
A	H	L	H	1	1	0	1
B	H	L	H	1	1	1	0
C	H	L	H	1	1	1	1
D	H	L	H	0	0	0	0
A	H	H	L	undetected, the output code will remain the same as the previous detected code			
B	H	H	L				
C	H	H	L				
D	H	H	L				

The maximum voltage on any pin of the DTMF decoder chip is 6 V. Typically the telephone line voltage is 50 V DC in the on-hook state. The line voltage when a ring comes is 90 V (rms) at 15 Hz. Because of this the chip cannot be directly connected to the telephone line. In order to block the DC voltage, we have used two series capacitors of appropriate voltage rating. Thus, only the ac component reaches the DTMF chip. But the ring voltage also being an ac signal simply passes through the capacitors. However, because of its low frequency (15 Hz) it is highly attenuated. In order to ensure that the voltage at the input pins does not overshoot, we have used diodes at these pins. Thus, the DTMF chip is safely interfaced with the telephone line and can respond to the DTMF signals.

The gain of the DTMF signal is so chosen (by adjusting the resistance) that the circuit only detects the local signals, but not the DTMF signals from the exchange (far-off). This is done so as to ensure that the DTMF signals from the other end do not trigger the ringer.

Voltage comparator circuit

To indicate the number of online users as well as to deactivate the buzzer, we need to detect the off-hooking of the telephones. This can be inferred from the telephone. The nominal on-hook voltage of telephone line is 50 V DC. When one phone is off-hook, the line voltage is about 10 V DC. When two phones are off-hook, the line voltage is about 7.5 V DC. This voltage keeps on dropping as more and more phones are off-hook. This DC voltage can be fed to a comparator to know how many of the phones are off-hook. But this DC voltage can be as high as 50V, which can damage any comparator chip if given directly. Thus, in order to limit this voltage we have used a 12 V zener diode between the positive line of the telephone and internally generated ground. By using a voltage divider, half of this voltage is fed to the comparator. Clearly, this voltage now will be in safe limits (<6 V). The observed voltages were : about 6 V in the normal on-hook state; about 2.52 V when one phone is off-hook and about 1.60 V when both the phones are off-hook.

Instead of using n comparators for n telephones, each with a specific reference voltage, it is better to use a single comparator and compare it n times by changing the reference voltage. Since we were working with two telephones, we needed two reference voltages. From the point of view of circuit cost and size minimization, we had chosen the micro-controller AT 89C2051, which has a built-in analog comparator, instead of using any external comparator circuits. This micro-controller has a comparator between pins 12 (P1.0, +ve) and 13 (P1.1, -ve). The output of this comparator is given internally to P3.6, which is not accessible externally. We have connected resistors to two pins of the micro-controller and these two are together connected to VCC through another resistor. These two pins of the micro-controller can be pulled low or high to generate different reference voltage and this reference voltage is given as positive input to the comparator. The voltage from the telephone line after being limited and scaled down (as above) is given to the negative input of the comparator. Initially, the micro-controller pulls both the pins low and generates a reference, which is compared with the voltage from telephone line. Then after a delay, it pulls one of them high, the other still low and generates another reference, which is again compared with the voltage from telephone line. We have properly selected the resistance values in order to get the references of 3 V and 1.75 V. The comparator output is low for both the references if no phone is off-hook; it is high for 3 V reference and low for the other if only one phone is off-hook and it is high for both the references if both the phones are off-hook.

When an external ring comes, the LED also gives an indication of the incoming ring at all other telephones. The LED blinks and goes off periodically, in synchronism with the telephone ring (continuous blinking of LED indicates one phone lifted).

Micro-controller unit

We have used the micro-controller AT 89C2051, keeping in view the number of pins required, its internal comparator functionality and the low cost/size goal of the circuit. The pin-out for 89C2051 is given in Figure 4. It has two 8-bit ports, which can be used as inputs or outputs. A 12 MHz crystal has been used.

We have used the upper nibble of port1 as input for the DTMF decoder outputs Q1-Q4. The pins P1.5 and P1.4 are used to generate the reference voltages. P1.0 and P1.1 are the inputs to internal analog comparator. The address (4-bit) of each unit is set through a DIP switch and is given to the micro-controller port3 (P3.1, P3.3, P3.4, P3.5 from LSB-MSB). The StD output from the DTMF decoder is used to interrupt the micro-controller and is given to P3.2 as $\overline{INT0}$. P3.7 is used to activate/deactivate the buzzer of the unit and P3.0 is used for the LED indication. Thus, the micro-controller

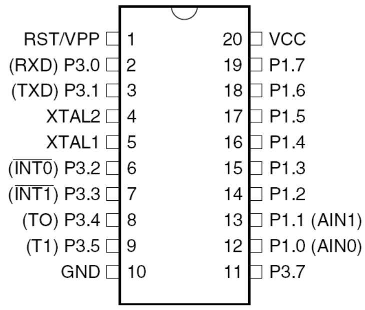


Figure 4: Pin layout of AT 89C2051

is fully utilized with all its 15 input/output pins being used.

In general the polarity of the telephone line may not be known. Hence, we have also used a diode bridge rectifier at the telephone line input in order to identify positive and negative telephone lines. This bridge rectifies the incoming ring ac signal, which does not matter to our circuit. However, the DTMF signal which is also an ac signal remains intact because it rides over a DC signal and so the signal never crosses zero. The complete circuit diagram is given in Figure 7.

Power supply

For the operation of the circuit, we need 5V DC power supply. Our circuit was drawing around 10 mA under normal conditions, when both the phones were on-hook and about 50 mA when both phones were picked up. So, we have used an ac-dc converter which provides 5V DC supply from the AC mains.

We have used a step-down transformer which steps down the 230V (rms) ac to 9V (rms) ac. This is rectified by a diode rectifier bridge and is then filtered by a large capacitor (1 mF), followed by a voltage regulator to give a steady 5V DC output to the circuit. The circuit diagram is shown in Figure 5.

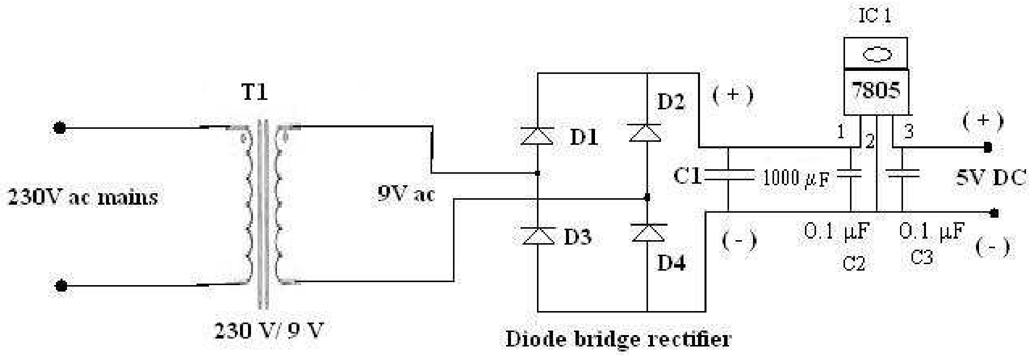
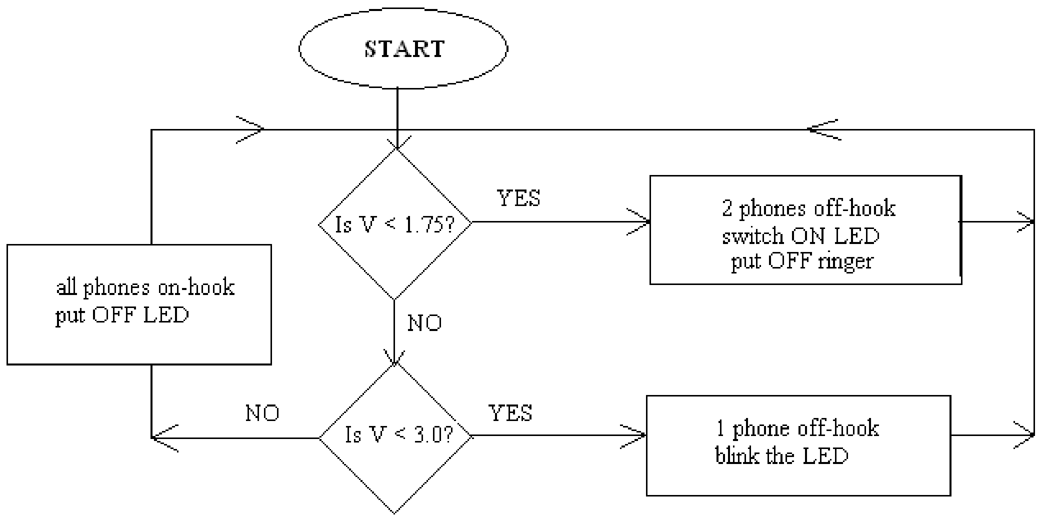


Figure 5: Power supply



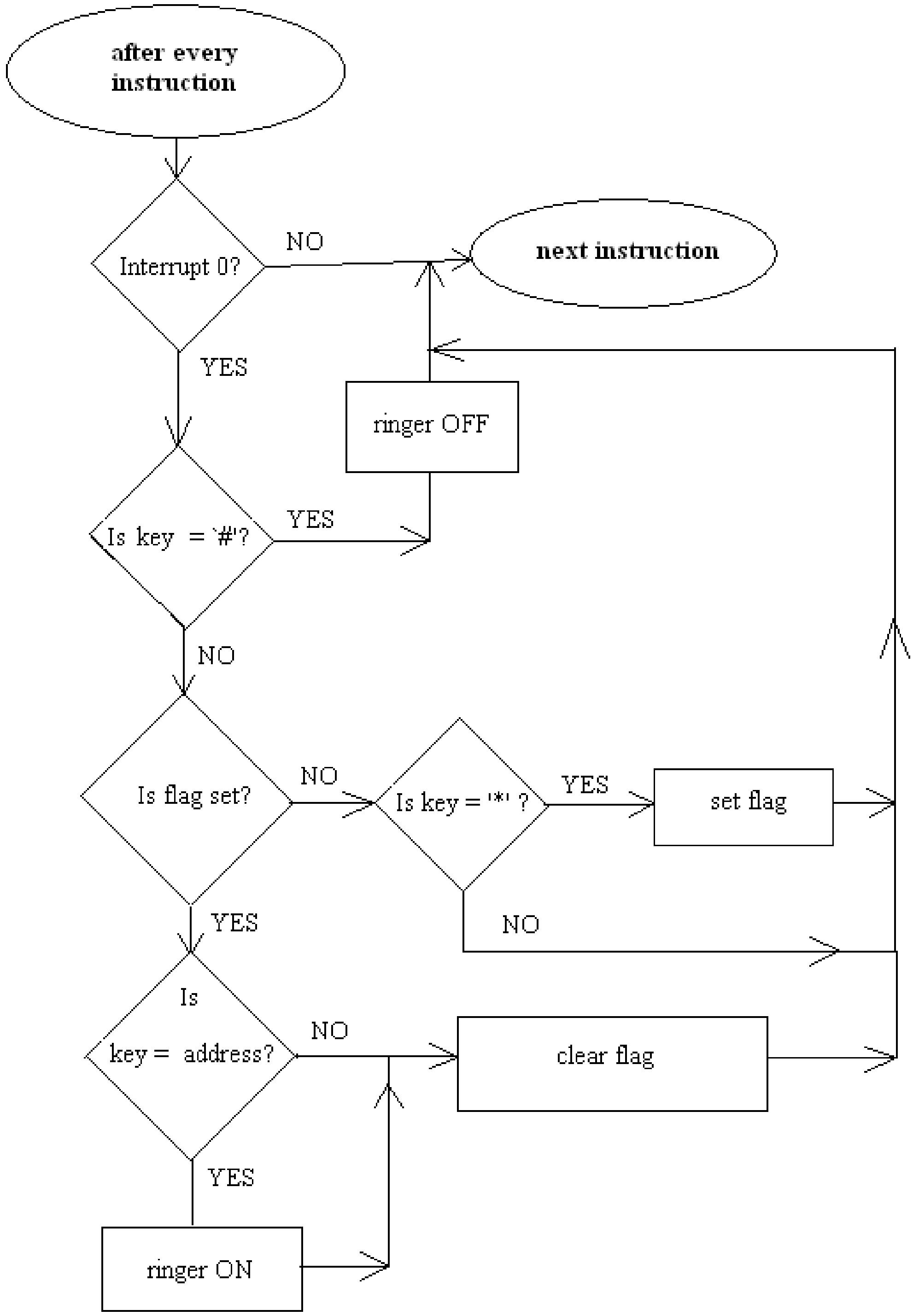


Figure 6: Flow chart

4 Algorithm

The micro-controller has to control both the LED indication as well as buzzer. For this, the micro-controller compares the voltage from the telephone line, twice and determines the number of telephones off-hook. It accordingly sets the state of LED either to be off or blink or to glow permanently. It loops into this process and continues to do this unless it receives an interrupt from the DTMF decoder circuit.

When any key is dialled on a telephone, it interrupts the micro-controller of every unit. The micro-controller then reads in the DTMF decoder output. It first compares it with "#". Incase a match occurs, it puts off the ringer and then returns from the interrupt. For a different key pressed, it then compares with " $*$ " and if a match occurs, it sets a flag to indicate that the first key as per the protocol has been received. For any other key pressed, it first looks at the flag which indicates a match with " $*$ ". In case it is not set, it simply discards this key pressed and returns from the interrupt. If the flag is set, then it compares the DTMF code with the address given to that unit. The micro-controller then activates the ringer, incase of a match, clears the flag and returns from the interrupt. For a mismatch, the key pressed is discarded and it clears the flag and exits from the interrupt.

The micro-controller reads in the address of the unit from the DIP switch, each time it needs to compare it. Thus, the address of the unit can be dynamically changed during the working of the unit.

5 Test procedure

To test the functioning of the circuit, we have used a telephone product tester (BK Precision, Model 1045B). Two telephones were connected in parallel on a single line. A single unit was also connected in parallel. When both the phones were on-hook, the LED was off; when one phone was lifted the LED was blinking and when both phones were lifted the LED was on permanently. Also when we dial $*$ followed by address on one telephone, the ringer starts buzzing. As soon as the other phone is lifted, the ringer goes off. It also goes off when a # is dialled. A $*$ followed by any other key did not trigger the ringer.

The circuit was also tested by connecting to a telephone line from IITB telephone exchange. A ring was given to it externally, and then it was picked

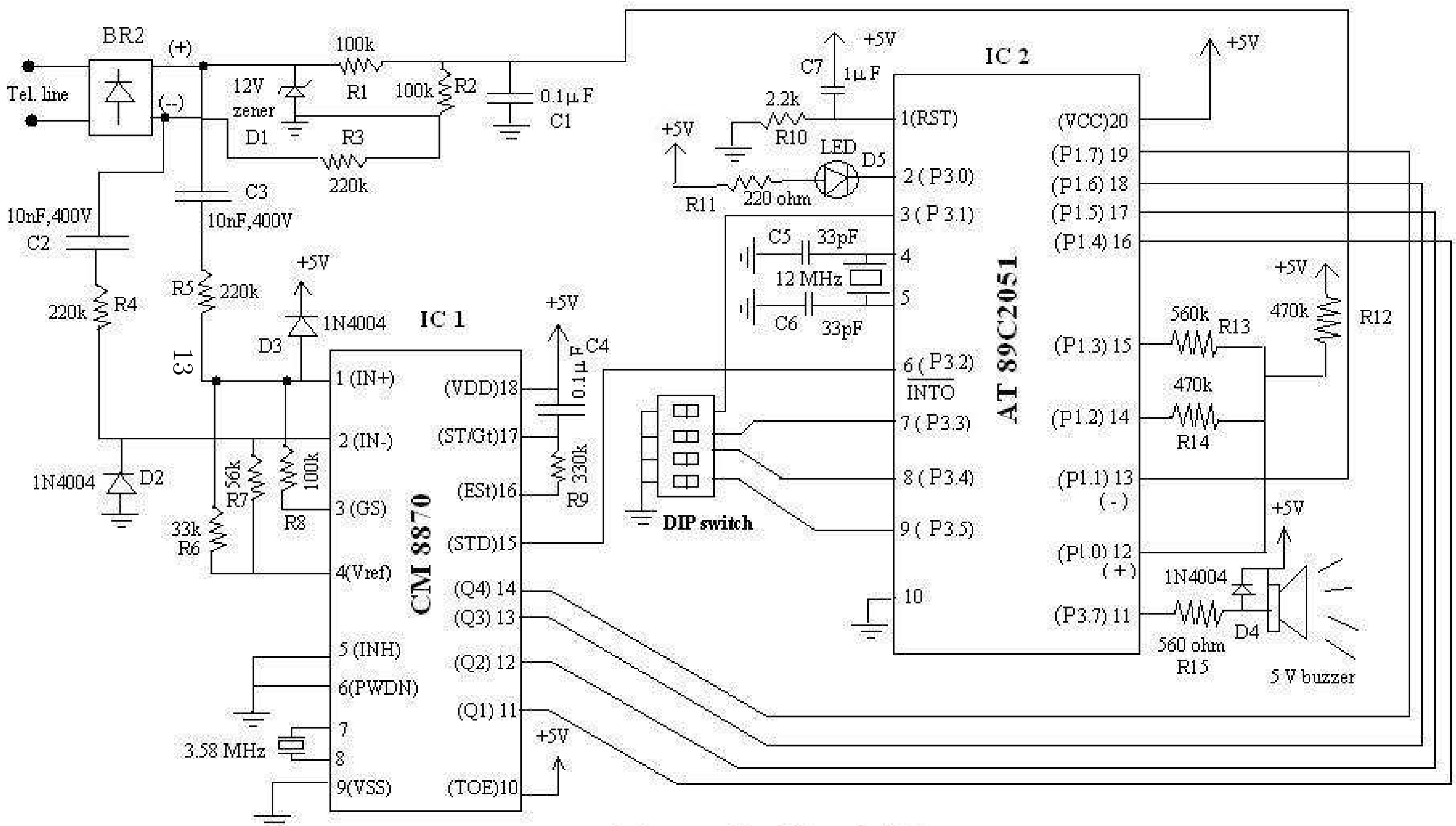


Figure 7 : Circuit Diagram

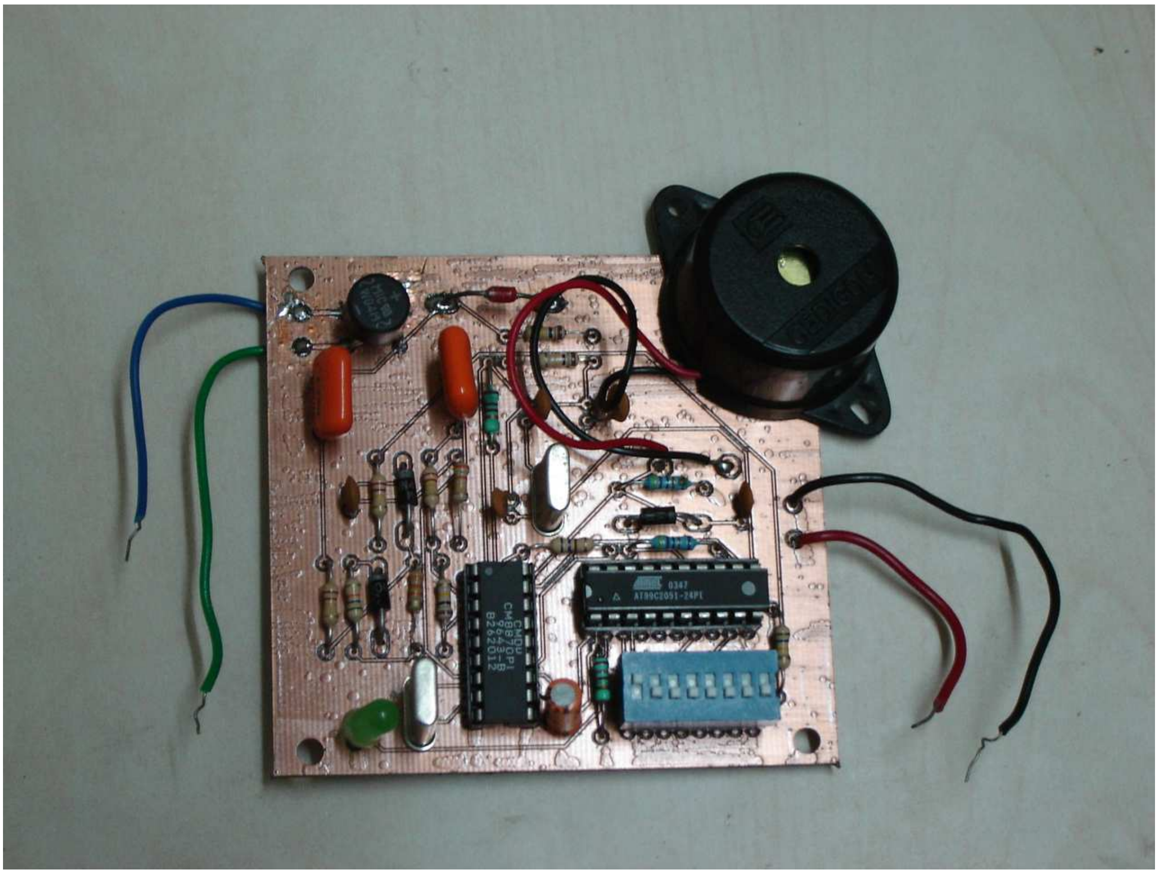


Figure 8: The circuit on PCB

up and when a proper code ($*$ followed by address) was dialled, the ringer of the unit was put on. The above functions were similarly tested. Also, the calling telephone on the other end could not trigger the ringer by dialling the same code. Thus, the full functioning of the circuit was verified.

6 Conclusion

This circuit is an effective low cost implementation of all the minimum features required in a multiple party telephone line. It provides the convenience of intimating a specific party of his call. The circuit uses the already existing telephone line for the communication and thus, does not need any additional wiring. The unit also being a very small one, can be connected parallel to the telephone without any changes.

This circuit can also be extended for more number of telephones on a single line. We can simply increase the digits in the address and increase the number of reference levels for comparison. Everything else remains unchanged. This concept can also be used for other remote applications, like communicating with other devices. For example, we can have such a unit near a unit like a washing machine or a microwave oven or an air-conditioner. By dialling a proper code (as per the protocol), we can control these devices. The unit detects the dialled code and does the operation as commanded (like switching them on or off or other control operations). Thus, the design has a great commercial value.

The circuit can be further improved in power supply aspects. We can provide it with a battery back-up so that it can function even if the mains power is down (like the telephone unit). Also, we can use a rechargeable battery to power the circuit. Most of the time, both the phones are on-hook and hence, in this time we can charge the battery from the telephone line by a very small current. Once any phone is lifted, we can stop the charging process. Also, as the speed is not a major concern, we can decrease the speed of operation of the micro-controller in order to decrease the current it draws. Thus, the circuit can be made even more attractive.

Acknowledgement

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