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DTMF decoder ringer for multiple party line telephone

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Abstract: This report is deals with the approach, design and implementation of a circuit for managing a multiple party telephone line by using a Dual Tone Multiple Frequency (DTMF) decoder chip to ring a particular telephone for which the call is meant. The report also explains all the issues faced during the implementation of the circuit and the ways adopted to overcome them. Further improvements which can be made to the circuit have also been suggested.

Introduction:

Multiple telephones on a single telephone line are very common. When a call is made to a particular line all the telephones connected to it will ring. But the call is meant for only one of the many telephones connected to the line. Thus ringing all the telephones connected to the line is totally unnecessary. Moreover ringing all the telephones simultaneously would require a lot of current to be supplied by the exchange. Typically the exchange can supply current to ring not more than two telephones on the same telephone line. Hence it is simply not possible to connect more than two telephone lines directly to the telephone line.

Thus if we want to connect more than two telephones to the same telephone line, we cannot allow all the telephones to ring simultaneously. We have already made an observation that any call made to a telephone line will be meant only for one of the many telephones connected to it. Thus the idea is to identify the particular telephone for which the call is meant and ring only that particular telephone instead of ringing all the telephones.

In order to accomplish this task there should be a way to distinguish the different telephones connected to the line. This is achieved by providing a unique address to each of the telephones. An interface is required between the telephone line and the telephone which determines if the call is meant for it or not. The circuit we designed provides the necessary interface.

Approach:

First and foremost we decided upon the protocol for assigning addresses to the telephones. We decided upon a four digit code which starts with a '# (hash)'. The address could have been restricted to only two digits. But a two digit code limits the operation of the circuit. For example, both the calling and receiving parties might have multiple telephones and the same two digit code protocol used on both the sides will cause confusion as to which telephone was addressed. This can be overcome by assigning different first two digits for both the parties. A four digit address also makes it easier to extend the circuit. As will be seen later this same concept can be used to connect not only telephones, but also other devices like microwave ovens, washing machines and other programmable devices which can be controlled remotely by the calling party. In such a case the first two digits can be used to identify the class of the particular device. Thus a four digit address provides a lot of flexibility. The '#' is used in order to indicate the starting of a valid address. This way all the devices connected to the telephone line are assigned an address.

Except for one telephone, the ringers of all the telephones connected to the line are switched off so that when a call comes only one telephone will ring. This telephone which rings will be called 'the operator telephone'. The call is answered at this operator telephone and the address corresponding to the telephone to which the call has to be directed is dialed. The dialed numbers are encoded into DTMF codes and are sent on the line. A DTMF decoder chip is available at each telephone which decodes the signal and stores the number in a microcontroller. The microcontroller verifies if the address dialed matches the address assigned to the particular telephone and then rings a buzzer if the address matches. There is an on/off hook detector which detects whether the phone is on/hook. The output of this detector is used to stop the buzzer the moment the receiver is lifted. The address of each telephone can be set using four switches provided. Thus there can be a maximum of sixteen telephones which can be connected to a telephone line. The buzzer also stops ringing if "#' is pressed. This enables the operator to direct the call to another telephone in case there is no response from the telephone to which it has been originally directed.

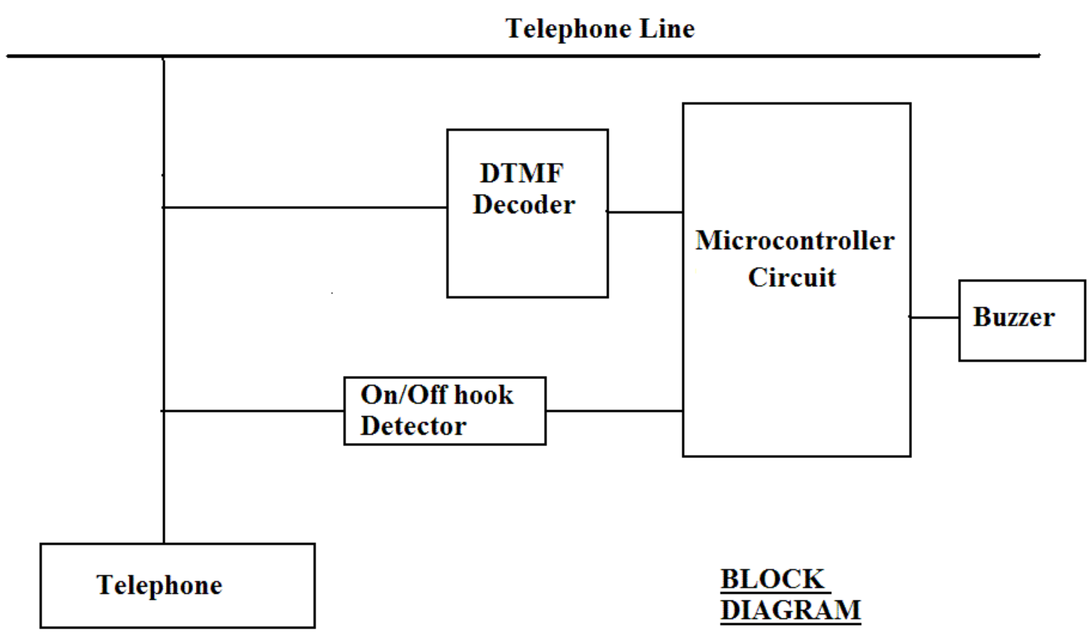

Figure 1: Block Diagram

Description:

DTMF Decoder:

The DTMF decoder is used to decode the DTMF signals sent on the line. We have used the CM8870 DTMF decoder chip.

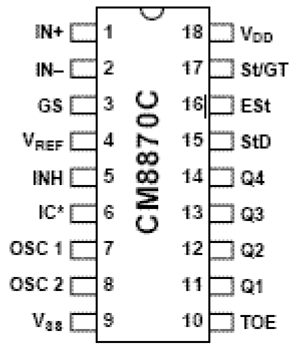

Figure 2: Pin Out of CM8870

The input to the DTMF decoder is the DTMF signal. This input is connected to the pins IN+ and IN-. The DTMF code is then decoded and the output is obtained on the pins Q1, Q2, Q3, Q4. The StD pin presents a logic high when a received tone pair has been registered and the output is latched. This pin remains at logic high as long as the digit is pressed. The chip uses a crystal of 3.579545MHz. A logic high at the TOE (Three State Output Enable) pin will enable the outputs Q1-Q4. The output corresponding to each of the keys pressed is as shown in Table 1.

Table 1: Functional Decode Table

KEY	Q1	Q2	Q3	Q4
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

The maximum voltage on any pin is 6V. But the voltages on the telephone line are very high. Typical on hook DC voltage on the telephone line is -60V and the off hook DC voltage is -8V. Thus the DTMF decoder chip cannot be directly connected to the telephone line. This problem is overcome by connecting the telephone line to the input pins of the DTMF decoder through two capacitors as shown in Figure 3. These capacitors act as DC blocks and filter out the DC component and only the DTMF signals reach the chip. This protects the decoder chip from damage.

Problems Faced:

The use of capacitors overcame the problem of the DC voltages. But the ring signal generated when the phone is on hook does not get filtered. The ring signal is a 15Hz wave with a voltage of 90V rms. This signal will damage the chip if not blocked.

The strategy we first came up with to overcome this problem was to use a Ring Detector Chip IC 1240A. Using this chip along with a rectifier circuit and a voltage a regulator we managed to obtain a digital signal to indicate the presence of the ring signal. The telephone would remain disconnected from the line and the signal indicating the presence of ring signal on the line would connect the telephone to the telephone line using a relay. Although we had considered using an analog switch, we eventually chose not to because it was not able to handle the high voltages present on the line. Using a relay didn't turn out to be feasible because a 17V control signal was required for the it. Generating such a signal on the board will turn out be very difficult because we were planning to use a fixed power supply of 5V.

We then came up with another alternative. Instead of using the relay, we used two diodes, one at each line (as shown in Figure 3), to clip the ring signal so that it wouldn't exceed 5V. The telephone line to which diode D2 is connected cannot have a voltage more than 5V and the line connected to D1 cannot have a voltage of less than 0V. This helped in protecting the DTMF decoder chip from very high ring voltages.

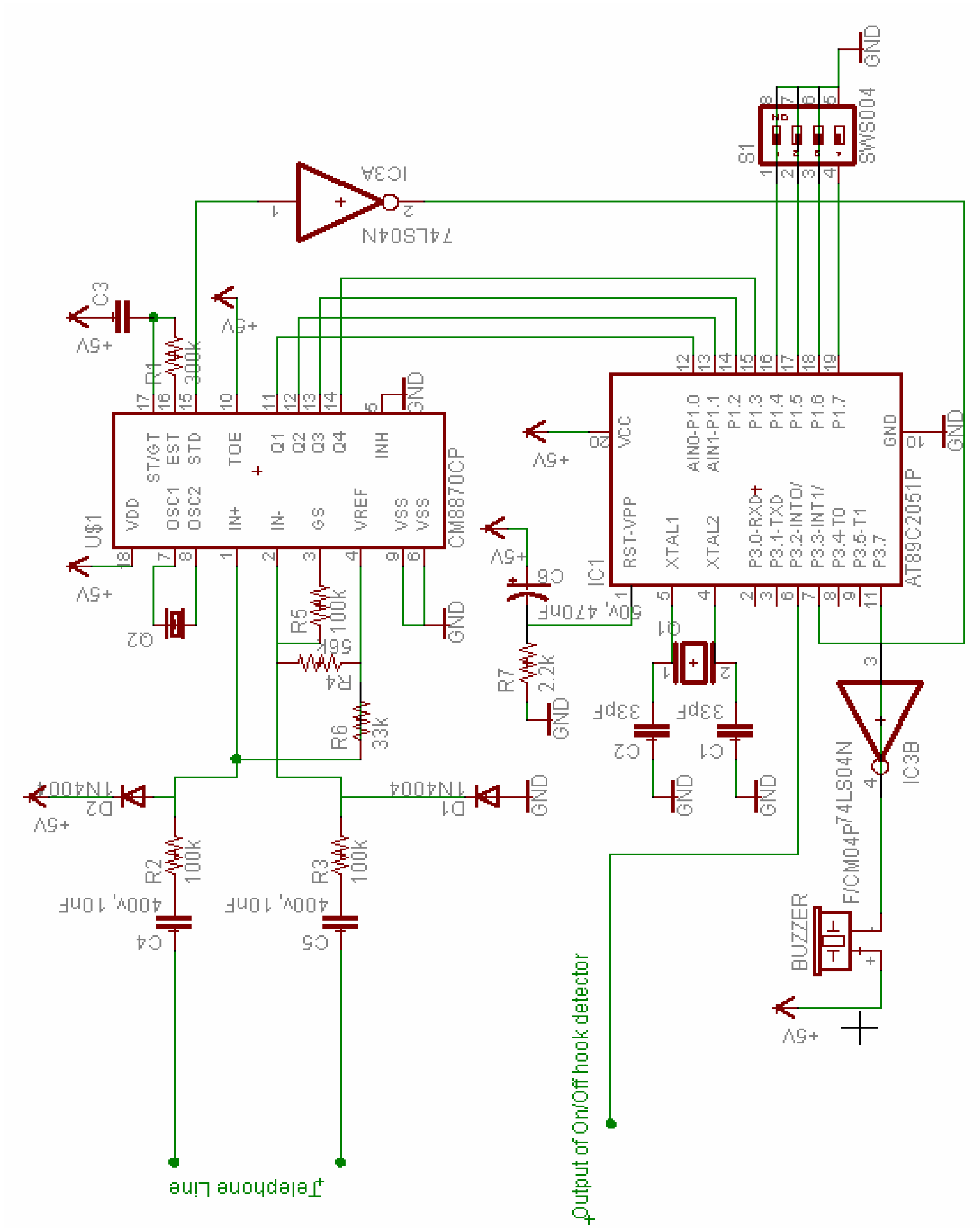

Figure 3: DTMF decoder

Microcontroller:

We are using the AT 89C2051 microcontroller. The pin out is as follows:

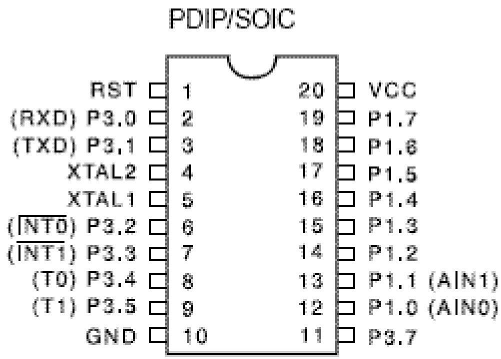

Figure 4: Pin Out of AT89C2051

This is a two port microcontroller. It has two input/output ports. It uses a crystal of 12MHz. The strategy used is to connect the outputs Q1, Q2, Q3, Q4 to the lower nibble of the port 1 which is being used as an input port and the StD pin as interrupt 1. The moment a new code arrives the StD pin generates an interrupt and the microcontroller reads the lower nibble of port 1. It then checks if the digit matches the corresponding digit in the address assigned. The upper nibble of port 1 is used to set the address of the telephone. The base address is taken as 1000. To this base address the upper nibble of port 1 is added to obtain the address of the telephone. The value of the addition factor can be adjusted using the DIP switch provided (see Figure 3). Thus there can be a maximum of 16 telephones which can be connected to a single telephone line.

The program determines the address of the telephone by reading the upper nibble of port 1. This address is stored in the memory. The moment a digit is pressed, the StD pin goes high and generates interrupt 1. The lower nibble of port 1 is read and is compared with the corresponding digit of the address stored in the memory. The variable, number of matches (N) stores the number of consecutive matches with the address stored starting from the highest significant digit. Thus every digit is compared with the $(N+1)^{th}$ digit of the address stored. If the digit matches then the microcontroller waits for the next digit in the sequence. If the digit does not match then it returns to the initial state of zero number of matches. If the number of matches reaches 5, it makes it zero and starts ringing the buzzer. Here we are not ringing the telephone and ringing a buzzer instead. Ringing a telephone would require a lot of power and generating that power on the board will always be difficult. The moment the receiver is lifted the on/off hook detector generates the interrupt 0. Immediately it stops ringing the buzzer and returns to the state of zero number of matches. If interrupt 1 is generated then it checks if the dialed digit is '#'. If the dialed digit is not '#' then it is simply ignored and the buzzer will continue to ring. If the dialed digit is "#' then the buzzer is stopped and it reaches the state of one match.

Algorithm:
The Flowchart of the algorithm is as follows:

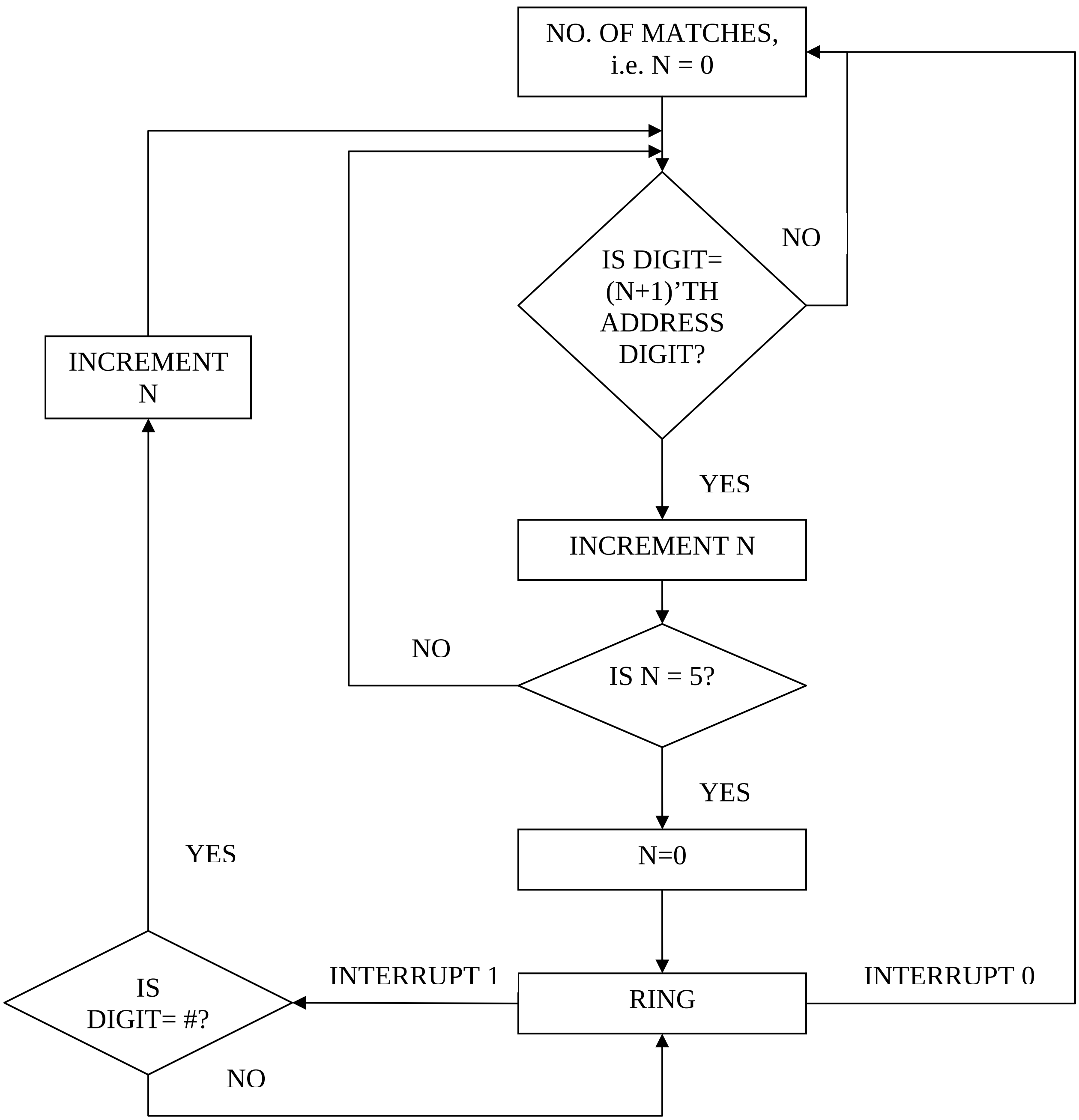

Figure 4: Flow chart

Power Supply:

There were three options available for powering the circuit. One was to get the power directly from the exchange. This is not such an attractive option because the exchange cannot provide the current required by all the circuits connected to the telephone line. The other option is to get the power from the AC mains. This is the method we have used in our circuit as shown in Figure 5.

We have used a transformer which converts the 230V AC to 9V AC. Then a diode bridge is used as a rectifier followed by a capacitor and a voltage regulator to give a steady voltage of 5V.

The third option which is available is to use a battery. The battery can use the power from the exchange to charge. But its implementation will turn out to be very complicated and expensive. Thus we have the chosen the option of connecting to the AC mains.

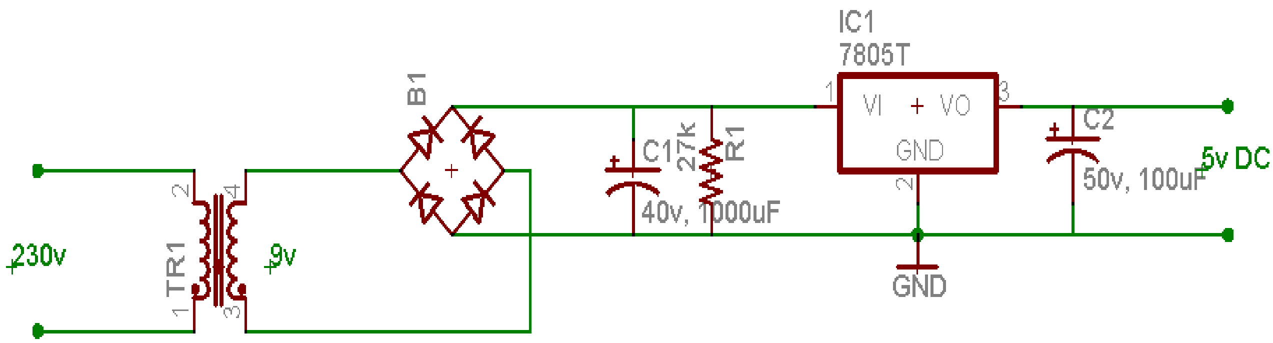

Figure 5: Power Supply

On/Off Hook Detector:

The voltages on the telephone line are different when the telephone is on hook and off hook. The voltage is around -60V when it is on hook and around -8V when it is off hook. This fact can be used to determine if the telephone is on hook or off hook. But these voltages are too high for any voltage comparator. Hence we have used a 12 volt zener diode across the telephone line with a very high resistance in series. Then a voltage divider is used across the zener diode to further reduce the voltage. This voltage can be used as an input to a voltage comparator to determine whether the telephone is on/off hook.

But here it should be realized that the operator telephone is already off hook, when we want to determine if a particular telephone is on/off hook. Thus we don't have the luxury of using the voltage difference of on the telephone line for on/hook cases. But we have noticed that there is a small voltage difference when both the telephones are off hook or when only one is off hook. We planned to use this to detect the on/off hook condition. We had observed that the output of the potential divider connected across the zener diode is around 2.92V when both the telephones are off hook and around 4.2V when one of them is on hook and the other is off hook. This we have used as one of the inputs to the voltage comparator LM311. The other input was fixed at 3.5V. The output of this voltage comparator worked as an on/off hook detector. The pin out of the IC is shown in the Figure 7.

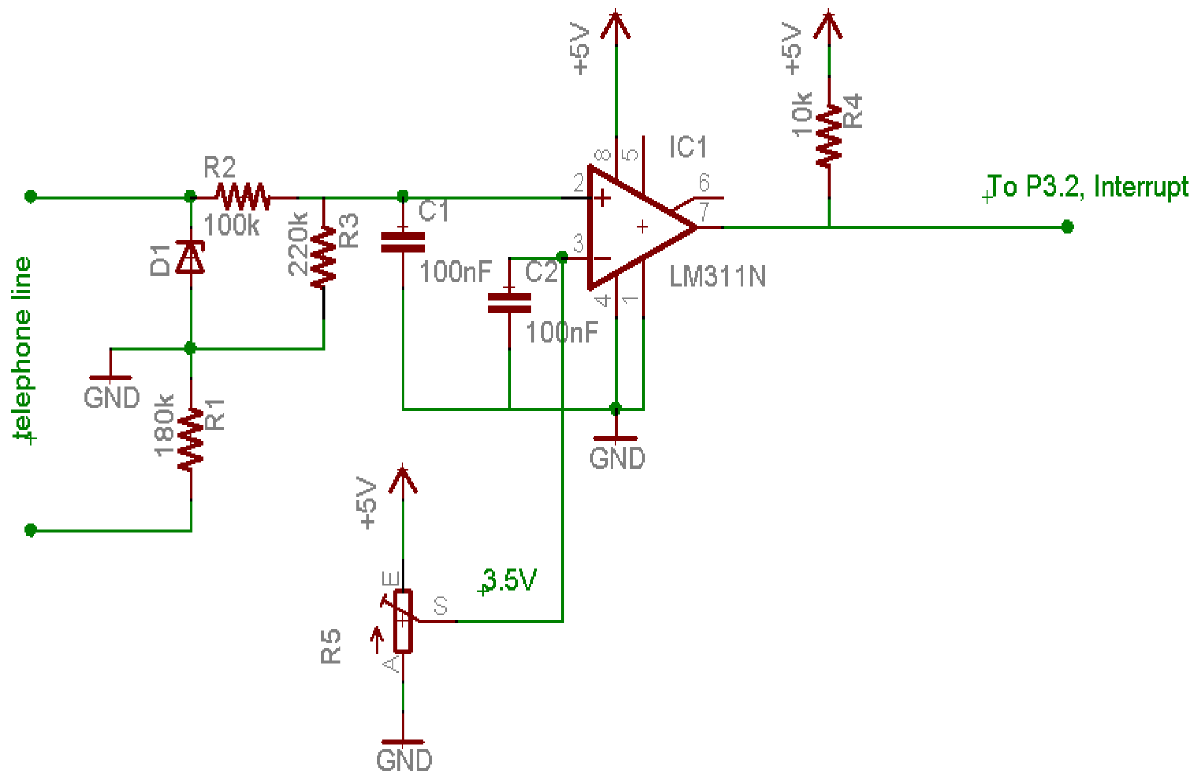

Figure 6: On/Off hook detector

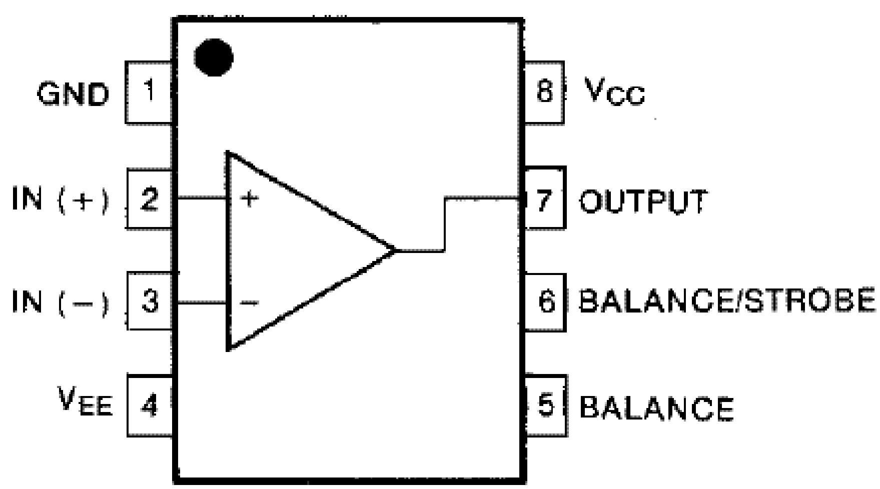

Figure 7: Pin Out of LM311

We have used a voltage comparator instead of simply using an LM324 because the range of voltages is very small and this resulted in a difficulty ion choosing the reference voltage of the comparator. The mid point voltage was not sufficient because the voltage drops with in the IC were more than the differences in the voltage. The circuit diagram is as given above.

Conclusion and Scope:

The circuit is a very effective low cost implementation of all the minimum features required in a multiple party telephone line. It provides the convenience of intimating a remotely located party of their call. The circuit uses the telephone line itself for communicating and does not require any changes in the established infrastructure. A circuit has to be just connected locally to each of the multiple telephones on the telephone line. Thus the lines already need not be disturbed.

This concept can be easily extended for remotely communicating with devices connected to a line. Here the DTMF codes being decoded by the circuit, act as the addresses of the telephones. Instead we can connect any device which can be controlled by a microcontroller to the circuit. Then we assign a code in such a fashion that the first two digits identify the device and the last two specify the task to be carried out. For example, say a microwave oven is connected to the circuit. Suppose we identify it with an address '20'. Now suppose we want to set the timer to 10 min. and switch on the oven. Let's say the code for performing this task is '01'. Then we simply dial '#2001'. The microcontroller can be programmed to identify this and perform the required action. Thus a variety of devices can be connected and can be controlled from any where. This leads to the concept of 'Smart Homes'. All the devices at home like lights, fans, A/C, ovens, geysers, etc. can be connected. These can be controlled from outside using a cell phone. Thus before reaching home, the geyser can be switched on to warm the water or the oven switched on to cook the food, by just dialing a few digits on the cell phone.

Hence this design has a great commercial value.

Acknowledgment:

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