Multi Drop Telephony Device

Group No. 1
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Problem:

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.

Suggested a priori Solution:

A solution can be the use of a personal branch exchange. But, it is quite uneconomical to go for a complete telephone exchange, especially if the call density is low and for small scale or temporary setups, especially in rural areas. 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, without having a central control unit. Once the call is received at a certain phone, the user can transfer it to the phone for which the call was actually meant through DTMF keyed addressing.

If time permits we could add the functionality of an intercom to the system and also allow SMS over PSTN using LCD screens on the designed units (if time permits).

Goals accomplished:

The primary goal of enabling multi-drop connections and internal call transfer call transfer over a single telephone line has been accomplished.

Also, intercom between the participating internal phones over the line, driven by a separate power supply as well as incoming call warning during ongoing intercom call has been achieved.

Description of Implementation:

For the enabling call transfer, each telephone equipment needs to have a separate 'unit' connected in parallel to the device. This 'unit' essentially comprises of a DTMF decoder, microcontroller, voltage comparator and a buzzer. Each 'unit' will have a configurable address (4 bit). In order to transfer a call, the user must press a special character * followed by the 4 bit address of the 'unit' that in proximity of the telephone to which the call is to be transferred. Upon reception of a DTMF signal propagating on line, the DTMF decoder of the 'unit' will interrupt the u-c and send the decoded 4 bits corresponding to the character dialled. Each such decoded 4 bit set forms one character and thus one bit of the address.
The u-c verifies the 4 bit address received, if it matches with the configured address, and there is no more than 1 telephone off-hook, rings the buzzer. As soon as someone picks up the telephone close to the ringing 'unit' the voltage drops, and the 'unit' stops ringing as the u-c detects this drop.

Functional Diode Table

KEY	TOW	Q_4	Q_3	Q_2	Q_1
1	H	0	0	0	1
2	H	0	0	1	0
3	H	0	0	1	1
4	H	0	1	0	0
5	H	0	1	0	1
6	H	0	1	1	0
7	H	0	1	1	1
8	H	1	0	0	0
9	H	1	0	0	1
0	H	1	0	1	0
*	H	1	0	1	1
#	H	1	1	0	0
A	H	1	1	0	1
B	H	1	1	1	0
C	H	1	1	1	1
D	H	0	0	0	0
ANY	L	Z	Z	Z	Z

L Logic Low, H = Logic, Z = High Impedance

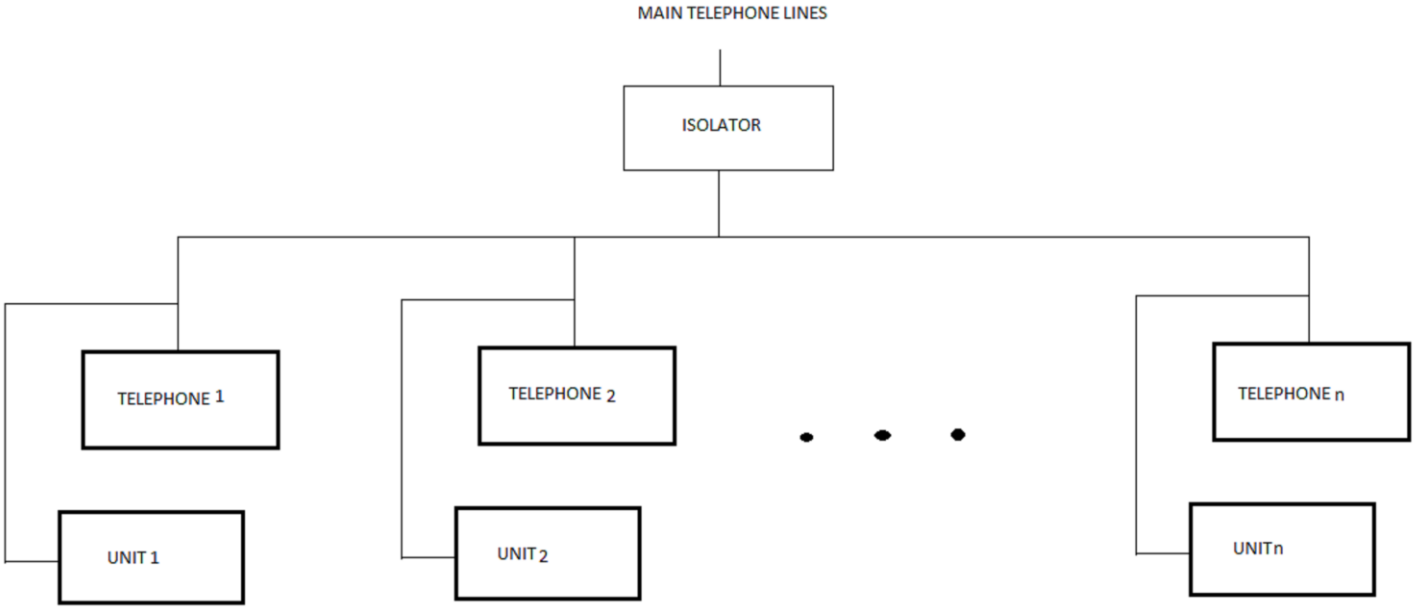
For intercom, 15V supply from the rectified transformer output is used to drive the telephones. The main line is isolated from this internally supplied network by means of a central isolator. This isolator essentially consists of a ring

detector, ring coupler & relay with its driver circuit in addition to the 'unit' circuitry. The main telephone line passes through the isolator unit before connecting to any more devices.

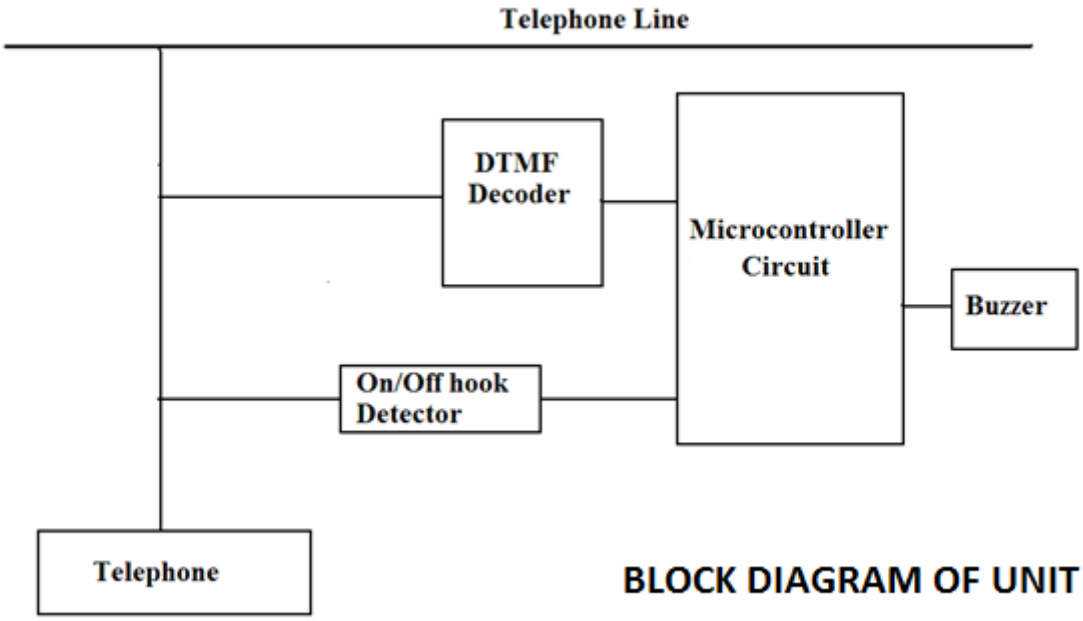
Essentially, one can move between the telephone exchange and intercom modes by pressing the special character '#' key. The isolator recognizes this character and signals the relay driving circuit to flip the relay to the complement mode.

If a call comes in from the exchange during an intercom call, the ring coupler capacitively couples the attenuated incoming ring signal onto the intercom line. Thus the users involved in an intercom conversation will become aware of the incoming external call.

Each 'unit' and the isolator is DC powered through transformed, rectified and regulated AC mains.



Block Diagram of the System(top)



BLOCK DIAGRAM OF UNIT

Problems faced

1. There is an issue with the propagation of DTMF signals causing unnecessary ringing/state switching at the other end i.e. if the callee (receiver) transfers a call, the involved signals might cause an erroneous ringing at the caller's end too.
   a. A simple solution to the above problem would be to use the fact that a signal suffers an overall 6 dB loss from one end of a telephone circuit through the public exchange to the other. This combined with the fact that we can adjust the gain of the DTMF decoder to a threshold such that the signal is just detected at normal signal levels, this would ensure that after being halved the signal would remain undetected at the other end.
   b. However, the above cannot be properly implemented since for the special characters the signals are detected even for theoretically zero gain at the DTMF input (the DTMF chip does not work as an ideal differential amplifier for the two input terminals). The threshold gain for different keys varies and is particularly low for the special keys as described above.

c. The alternative suggested and implemented includes another relay at the isolator. The problem concerned arises because we do not have a clear distinction in the circuit behaviour for the caller and callee (receiver). The only distinction is the fact that only the person who is being called would have received a 90V AC ringing signal. We can thus detect the ring at the isolator and then, if upon getting a call the user wants to transmit, he can press a special key '*' which would cause the extra relay at the isolator to bypass the caller to a simple resistive discharge to ground, and the other relay at the isolator would simultaneously switch the local circuit to intercom/local dc supply, but this would happen only if the isolator had detected a ring priorly i.e. only at the callee's (receiver) end.
d. Thus, once this isolation has been created, the callee (receiver) can now do anything on his intercom nework without affecting the caller's end. Once the transfer of call is done the caller can press '*' again to flip back both relays such that the callee is connected to the caller through the exchange.
e. If the caller has to transfer at his end, he needs to follow the same procedure except that he won't be able to flip back the callee to the original state by himself, the callee would have to do this himself. (Note that when the caller tries to transfer at his end and presses *, the * signal is transmitted to the callee too, and hence, the callee's network also switches to the intercom state, and his incoming line is bypassed to the resistive load. To connect back to his exchange line, which has his call connected, the callee has to press *)
f. Alternatively, we could increase the character/address space at the caller's end and configure it such that if the local system was the caller's i.e. no ring detected then similar things (exchange bypass et. al.) happen for the modified address space.

2. There is however a problem with our solution if we directly use the ring coupler circuit for ring detection purposes by capacitively coupling the ring couplers output to a NOT gate and then output of the not gate to the microcontroller, because any large transitions like that cause due to relay switching or even voice on the line will cause the microcontroller to detect a false ring.

a. This can be avoided by complicated software ring detection which looks for precisely the ring pattern of periodic on offs in a certain frequency range.
b. Or we could use a separate coupler like circuit with higher resistance at the input and more Zener diode pairs (each pair has one diode each in either direction) in the path to nullify the small transitions and also eliminating the transition from the intercom line since this circuit would not be connected to that line but would directly feed the microcontroller through a NOT gate and take input from the exchange line. This was combined with software patch ups to ensure quick resetting for malfunctioned ring detection and also detecting multiple transitions before announcing a 'ringed' state.
c. The software solution finally implemented set a 'ringed' variable if it detected a 'ring count' or more number of transitions and simply put, if the system is 'Ringed' and the a phone is picked up from all on hook state, a transition occurs in another variable 'Sring' to ensure that the desired distinction is created. Once the call is over and all phones are on hook, the 'ringed' signal will reset to zero after around 4 seconds due to absence of any transitions this will cause the 'Sring' variable to go to zero.

3. Also, the large incoming ring causes a problem of malfunctioned detection of no. of off hook phones by the comparator. To solve this we increased the R-C time constant of the ac bypass comparator circuit thus resulting in higher minimum voltage levels during ringing and creating a distinction between one phone off-hook state and when all phones are on hook but the ringing signal is on the line.

Symmetry with respect to the exchange inputs

The only circuit that is un-symmetric with regard to the above is the comparator. It was easily made bidirectional, but however the output when fed to the microcontroller ADC resulted in complete change of voltage levels.

Inserting a full wave diode bridge rectifier caused loading of the line and thus tripping of ring signals.

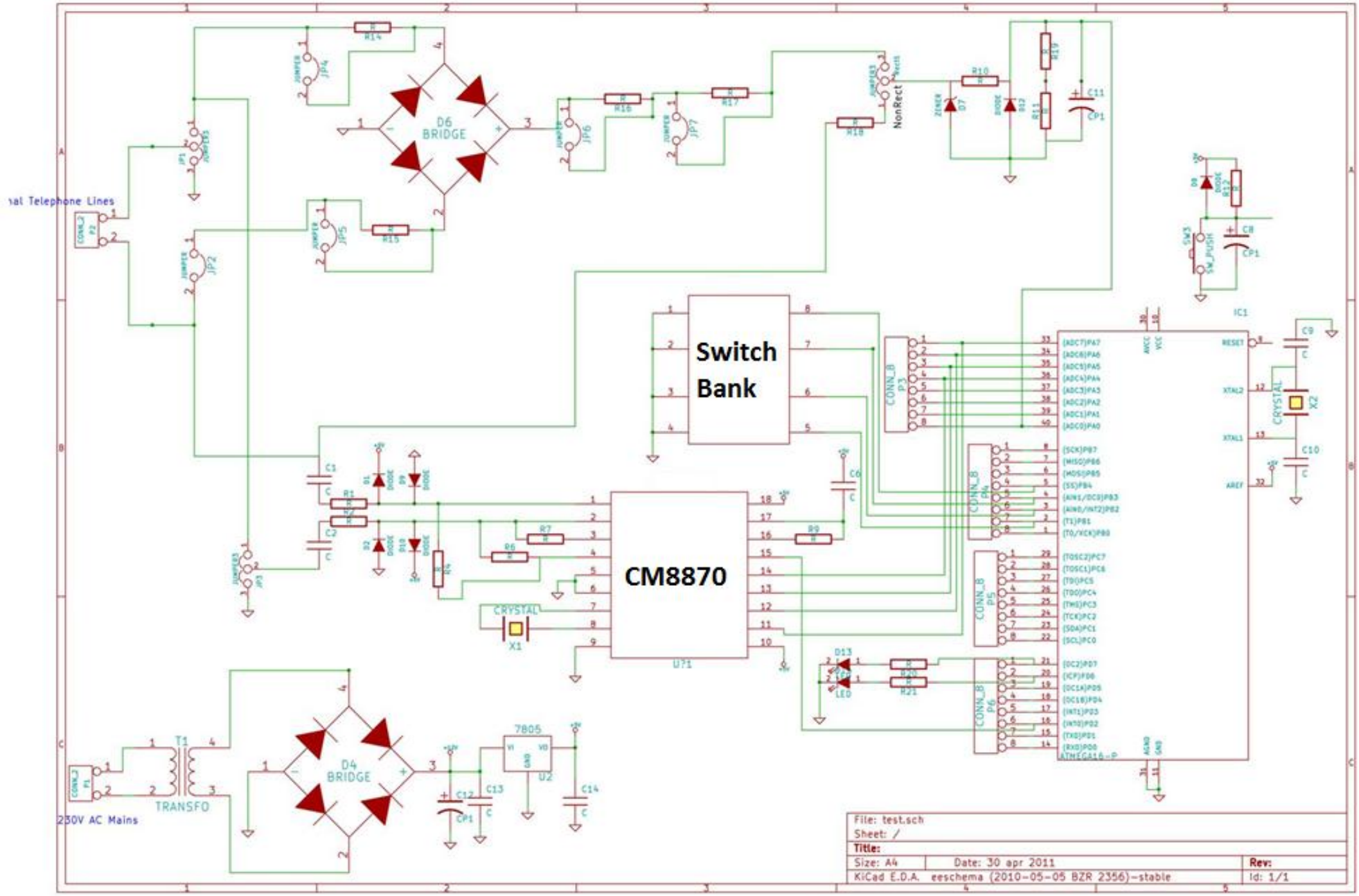
Conclusion:

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 un- changed. This concept can also be used for other remote applications, like communicating with other devices. For example, we can have such a unit
near an equipment 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. 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 power it draws. Thus, the circuit can be made even more attractive.

[1] The datasheets of the ICs ATMEGA !6, CM 8870, 7805 and LM 311.
[2] http://www.epanorama.net/links/telephone.html#how, by Tomi Engdahl.

Schematic for Unit on the next Page. For the isolator schematic we will have two additional relays.


Switch Bank
CM8870
D6 BRIDGE
D4 BRIDGE
TRANSFO
230V AC Mains
7805
CRYSTAL
ATMEGA16-P
NonRect
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