Caller-ID Unit Using Micro-controller

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The facility of knowing your caller's telephone number before answering the call, which has been available to cellular phone users only in India so far, has now been extended to the normal telephone users also in Delhi, Mumbai and some other cities of India through MTNL and DoT since 1st January.

MTNL/DoT telephone exchanges transmit the telephone number of calling party just before the first ring while in systems used in USA and China, the data relating to the calling number is sent between first and the second rings. The number of calling party in India is transmitted by MTNL/DoT exchanges in DTMF codes.

Two documents containing standards and specifications issued by DoT's Telecommunications Engineering Centre (TEC) in the form of 'Generic requirements' and 'Interface requirements' for 'Subscriber service unit for calling line identification presentation (SSU for CLIP)' are available from TEC, Khursheed Lal Bhawan, Janpath,

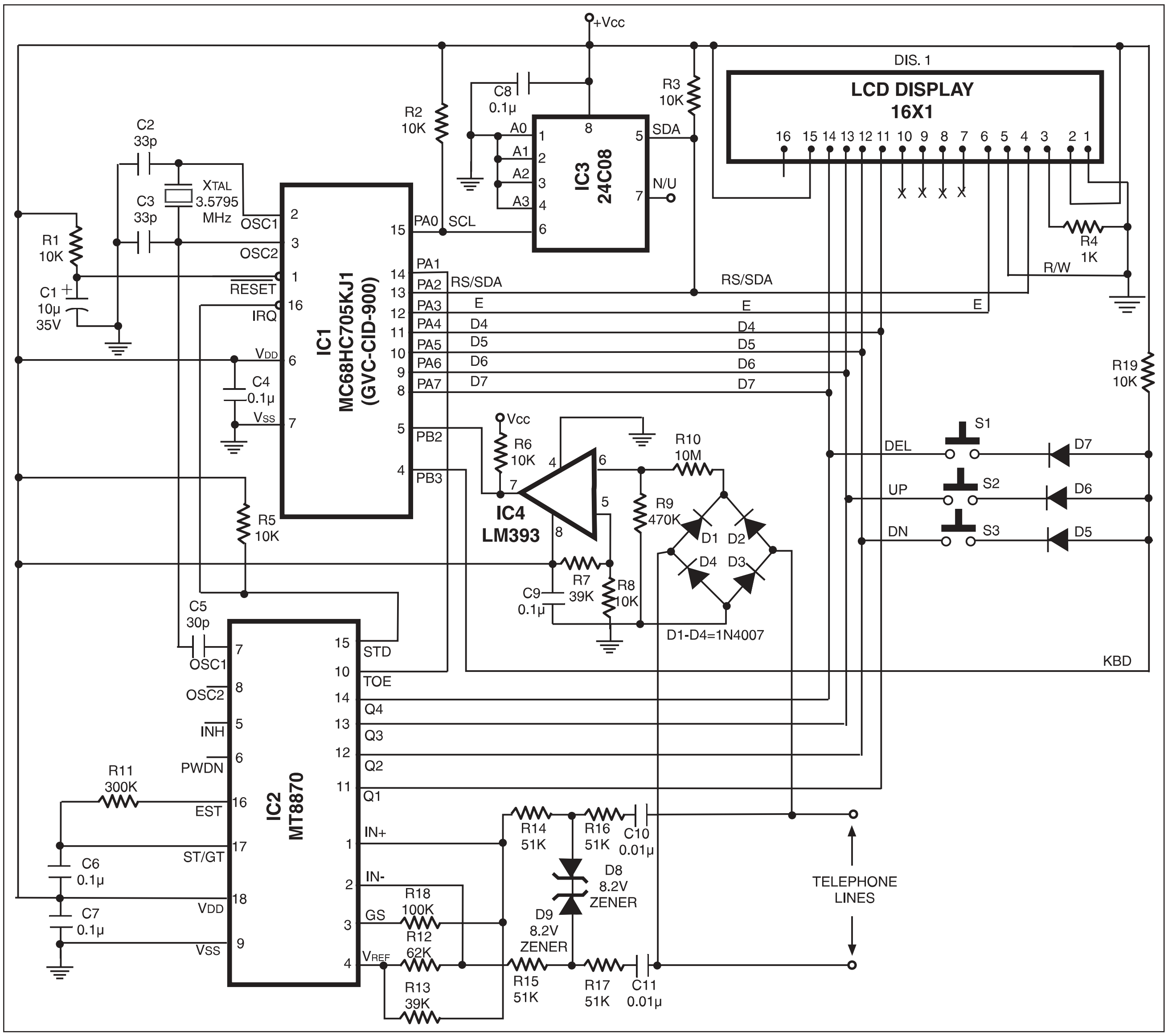

Fig. 1: Complete circuit diagram of caller-ID unit

TABLE 1			
	Column 1 1209 Hz	Column 2 1336 Hz	Column 3 1447 Hz
Row 1 697 Hz	1	2	3
Row 2 770 Hz	4	5	6
Row 3 852 Hz	7	8	9
Row 4 941 Hz	*	0	#

New Delhi against payment of Rs 250 each.

In older versions of telephones using rotory dials, whenever a digit was dialled, telephone line was disconnected and reconnected for short durations. These were referred to as pulses and the system was called pulse dialing system. The number of connections and disconnections equaled the dialled digit. For example, if number 7 was dialled, the line was disconnected 7 times for short durations. For number 0, the number of connections and disconnections equalled 10.

In later versions of telephones using push buttons and integrated circuits, the same protocols are used to maintain compatibility with older phones and exchanges.

DTMF (dual tone multi frequency) system is replacing the pulse dialling system in modern telephones and exchanges. In DTMF telephones (and exchanges), the numbers are transmitted using different tone frequency pairs and not by making or breaking connections.

A normal telephone instrument has 12 buttons (keys) arranged in three columns and four rows. Each row in the key-pad matrix activates a specific frequency tone. Similarly, each column also controls a specific frequency tone. So when a key is pressed, two different tones corresponding to the row and column combination of the key are generated.

Table I shows the tone frequencies associated with each row and column of the telephone key-pad. Thus pressing 8 will generate a combination consisting of row and column frequencies of 852 Hz and 1336 Hz respectively. Similarly, pressing 4 will generate 770 Hz and 1209 Hz combination. The same tone frequency combinations are used for transmitting calling party's number from exchange to the called party's telephone instrument.

Caller-ID circuit presented here has the following features:

- Displays dialled numbers (in tone mode only).
- Displays incoming numbers and stores them in memory.
- Only last 99 numbers are stored in memory. (Older numbers are automatically deleted and new numbers are stored when the stored numbers exceeds 99—on first-in-first-out basis.)
- View incoming numbers and selectively delete stored numbers.

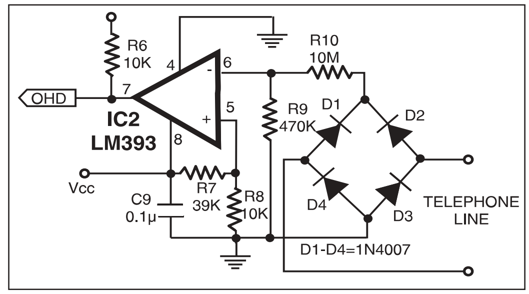

Fig. 3: Off-hook detector

Description

This caller-ID unit has seven main functional blocks: power supply, off-hook detector, DTMF decoder, LCD display unit, micro-controller, memory and keyboard. The key electronic components are shown in Table II.

TABLE II		
Micro-controller	MC68HC705KJ1	IC1
DTMF decoder	MT8870	IC2
Memory	24C08	IC3
Comparator	LM393	IC4
Alphanumeric LCD	16 characters x 1 Line	DIS.1

MC68HC705KJ1 is the latest low-cost micro-controller from Motorola. Other parts like ICs MT 8870, 24C08, LM393 and LCD module are standard parts and are available from more than one source.

Power supply (Fig. 2): The power

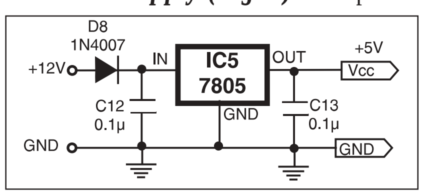

Fig. 2: Power supply

supply unit is used to provide a constant 5V supply to different ICs. This is a standard circuit using external 12V DC adopter and fixed 3-pin voltage regulator. Diode is added in series to avoid damage to the unit if reverse voltage is applied by mistake.

Off-hook detector (Fig. 3): The telephone line voltage is around 48V when unit is on-hook. This voltage falls to around 10 V when telephone handset is lifted from the cradle, and it remains the same during dialling or conversation. This voltage may vary by ± 20 per cent due to battery voltage variations at exchange and line voltage drop, depending upon the distance between exchange and the telephone instrument.

Off-hook detector circuit uses a bridge rectifier to take care of polarity reversal of telephone lines. Resistor divider comprising R9 and R10 divides the line voltage by 20 for comparison against a fixed voltage (approximately 1 volt), which is derived from +5V supply voltage using voltage divider comprising resistors R7 and R8. Output of comparator IC4 at pin 7 is logic low (0V) when unit is on-hook and logic high (+5V) when unit is off-hook. The output level from the comparator is suitable for direct interfacing to micro-controller IC1.

LCD display unit (Fig. 4): LCD display is a single-line, 16-character unit. This is a standard unit available in local market. Interface with micro-controller is accomplished via four data lines D7-D4 and two control lines RS and E. Using these six lines, micro-controller displays all messages and telephone numbers. The signal names used here are the same as used by the LCD module/driver manufacturers. Pin configuration for a typical 16-character x 1 line module is shown in Table III.

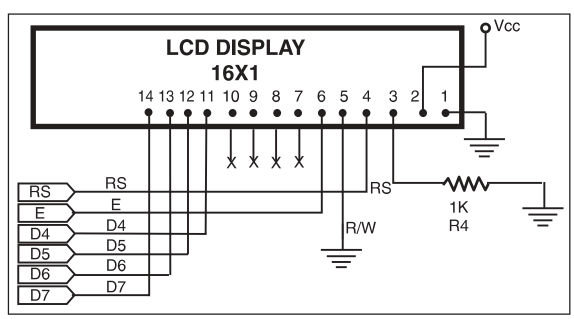

Fig.4: LCD display unit

TABLE III

Pin No	Signal	Remarks
1	Ground	Vss
2	+ 5 V	Vcc
3	Contrast	Ground for maximum contrast
4	RS	H = Data L = Command
5	R/W	H = Read L = Write
6	E	H = Enable L = disable
7 - 10	D0 - D3	Data lines (Lower nibble) *
11 - 14	D4 - D7	Data lines (Higher nibble) *

*Note : For 8-bit (byte) data interfacing all the eight data lines (Pins 7 through 14) are used whereas for 4-bit (nibble) data operation, data lines for D4-D7 (pin 11 through 14 only have to be used.)

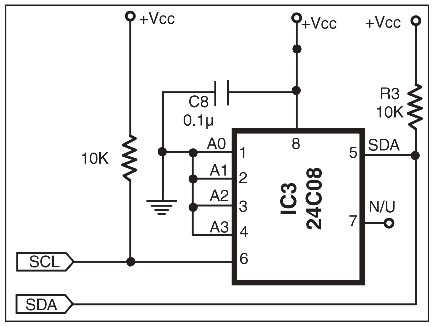

Fig. 5: Non-volatile memory

Some LCD modules come with additional one or two pins. These extra pins are used for back-lighting. There is no fixed standard for the additional pins. However, in case of Lampex, Oriole and Crystalonics (popular brands available in India), connections for pins-15 and 16 are shown in Table IV.

TABLE IV

Pin/Manufacturer	Lampex	Oriole	Crystalonics
15	+5 V	Ground	Ground
16	Gnd.	X	X

LCD controller is a flexible controller and can be used with 8-bit or 4-bit micro-controller. In 4-bit mode, only D4-D7 are used, leaving D0-D3 open.

In our circuit, we have connected R/W pin to ground as we are using it for write operation only. Reading back of the module's status, which is required to see if LCD module is busy, is not possible.

To avoid problems, extra delays in software are provided after every write command so that before writing another command/data, LCD module should be ready (not busy). Further, only four data lines (D4-D7) have been used while the other four data lines (D0-D3) are left disconnected. Thus even though we are using an 8-bit micro-controller, the LCD module has been interfaced for 4-bit mode. Again, to save pin count, RS line is shared with SDA (serial data) line for memory (IC3) since at any given moment micro-controller will either interface with the LCD module or the memory, and this does not affect the system operation.

Non-volatile memory (Fig. 5): 2-wire serial CMOS EEPROM 24C08 is used in this circuit to retain last 99 incoming numbers. Numbers stored remain in memory even after power failure. 24C08 is an 8k (1024x8) bits non-volatile memory. 8k bits are internally organised as 1024 x 8 bits or 1k bytes. As each byte can store two digits of a number, a total of 8 bytes are reserved for each number (for maximum of 16-digit length). So while this unit can store 128 such numbers, the software used is configured only for 99 numbers, so that only 2 digits are required on display for call counter. This IC is interfaced with micro-controller using two control lines SCL (serial clock) and SDA (serial data). This 2-wire interface is popularly known as I²C bus interface.

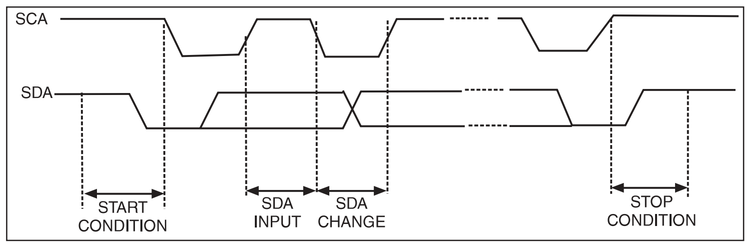

Fig. 6: Wave form showing conditions existing in I²C bus transfer

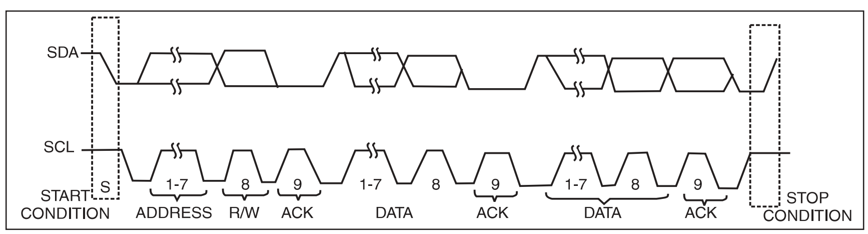

Fig. 7: Sample of I²C bus message

Overview of I²C bus : I²C stands for inter-integrated circuit. This was designed by Philips but now a number of semiconductor device manufacturers are making devices compatible with I²C bus.

This I²C bus is used mainly with single-chip micro-controller based systems that require general-purpose circuits like EEPROM, RAM, real-time clock, LCD controller and audio/video tuning circuits. A key advantage of this is that only two lines can connect multiple devices. All devices have built-in addresses. For example, 24C08 used in this design has a device address of A0 (hex).

In circuit with multiple devices, one device (usually the micro-controller) takes the role of master. Another device (only one of the multiple devices at any one time) acts as a slave device. Master device takes control of SCL, i.e. SCL is set low or high under the control of master (usually the micro-controller). Slave device accepts the data from micro-controller (e.g. writing into memory) or sends the data to micro-controller (reading from memory) under the control of master device.

Four different conditions exist in I²C bus transfers. These are start, stop, bit transfer (read/write) and acknowledge. All these conditions are explained below with reference to waveforms shown in Figs 6 and 7.

1. Normal data bit write/read. During transfer of data from master (micro-controller) to slave device (e.g. EEPROM), SDA is set to logic 0 or 1 only when SCL is low. After small delay, SCL is pulsed high to clock in data. During read operation, SDA is an input line and its logic state is clocked in with SCL going high. Master (micro-controller) can then read the level of SDA.

2. Start condition. Start is a special condition where SDA changes its state from high to low when SCL is high. Both SCL and SDA are controlled by master (micro-controller).

3. Stop condition. Stop is also a special condition where SDA goes from low to high when SCL is high. Both SCL and SDA are controlled by master (micro-controller).

4. Acknowledge. After-transmitting eight data bits from micro controller to the device (e.g. EEPROM), direction of SDA line is reversed. One more clock pulse is given by micro-controller. During this period, the slave device sets SDA to low. This indicates the acceptance of data by receiving device (e.g. EEPROM). When data is read from slave device (e.g. EEPROM), after reading eight bits, direction of SDA is reversed. SDA is set low (to send acknowledge) or high (to send no-acknowledge) and then SCL is pulsed.

How to write a byte in EEPROM

A sample I²C bus message is shown in Fig. 7 while a typical example of writing into memory (device address A0 hex) location 58 (hex) with data byte 30 (hex) is given below:

S 1 0 1 0 0 0 0 0 A 0 1 0 1 1 0 0 0 A 0 0 1 1 0 0 0 0 A P

Where S indicates start, P indicates stop and A indicates acknowledge conditions, while 1 and 0 are data bits.

Description of the above sequence is as follows:

- Action is started with start condition generated by master (micro-controller).
- 1010 0000 (A0H) is transmitted as address for EEPROM.
- EEPROM responds with acknowledge during next clock pulse.
- 0101 1000 (58H) is transmitted as byte address with EEPROM.
- Again EEPROM responds with acknowledge during next clock pulse.
- Finally, data byte 0011 0000 (30H) is transmitted.
- EEPROM acknowledges during next clock pulse.
- At the end, master (micro-controller) generates stop condition.

Keyboard (Fig. 8): Three keys (tactile switches) are used to view stored numbers and to delete selected numbers. Keyboard is used in a scanning mode.

Each data line is set to low level sequentially while keeping other lines at high level. Then level of KBD signal is checked. If it is low, it indicates that key connected to the data line which is low is pressed, else it is not pressed. Due to high speed of micro-controller, all three keys can be checked for their positions quickly.

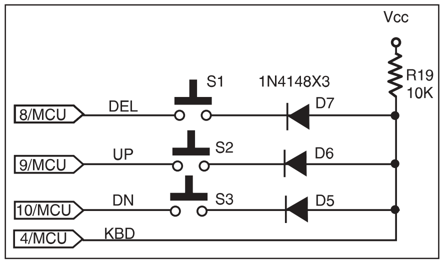

Fig.8: Keyboard using three tactile switches

DTMF decoder (Fig. 9): DTMF decoder IC2 MT8870 is AC coupled to telephone lines and keeps on sensing tone frequencies. As soon as a valid DTMF digit is detected, it sets STD signal (pin 15) high and interrupts the micro-controller. DTMF decoder also requires a 3.58MHz crystal. For cost saving, the output of micro-controller oscillator is connected to 8870 oscillator input pin 7 through a capacitor. Micro-controller then reads the digital number on four data lines (D4-D7) by making TOE (output enable pin 10 of IC2) high.

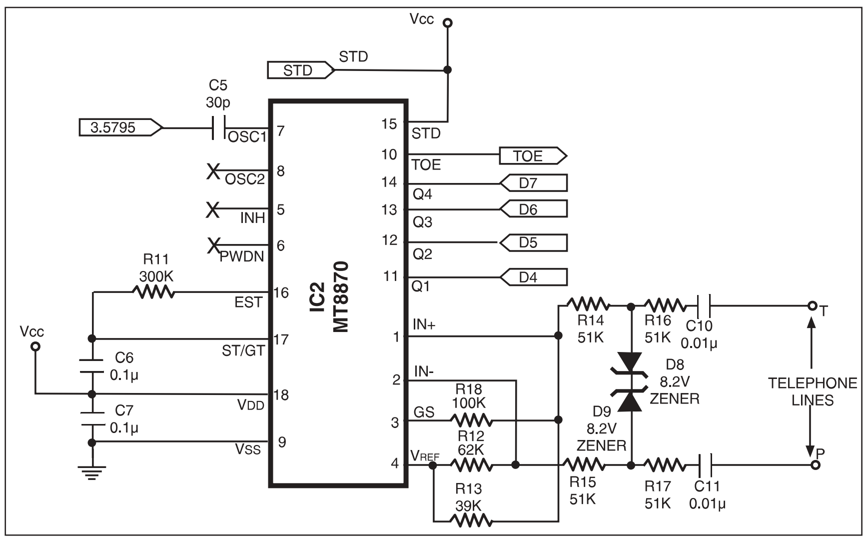

Fig. 9: DTMF decoder circuit.

Micro-controller (Fig. 10): Micro-controller used is MC68HC705KJ1 from Motorola which features:

- 11 I/O pins
- 1240 bytes of program memory
- 64 bytes of user RAM
- 15 stage multiple function timer.

Out of 11 I/O pins, four pins are used for data bus connection to LCD module, DTMF decoder and keyboard (tactile switches). Two pins are used to interface DTMF decoder (TOE and STD). Two pins are used for LCD controller (E and RS) interfacing. One pin is used for EEPROM clock signal (SCL). The pin required for EEPROM data sig-

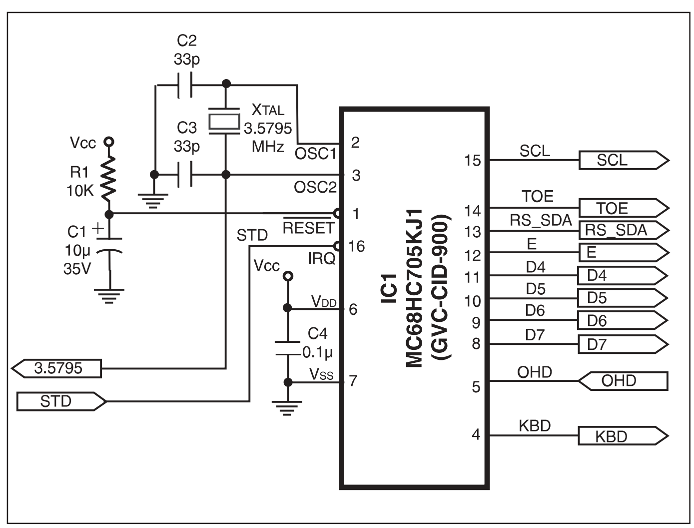

Fig. 10: Micro-controller circuit

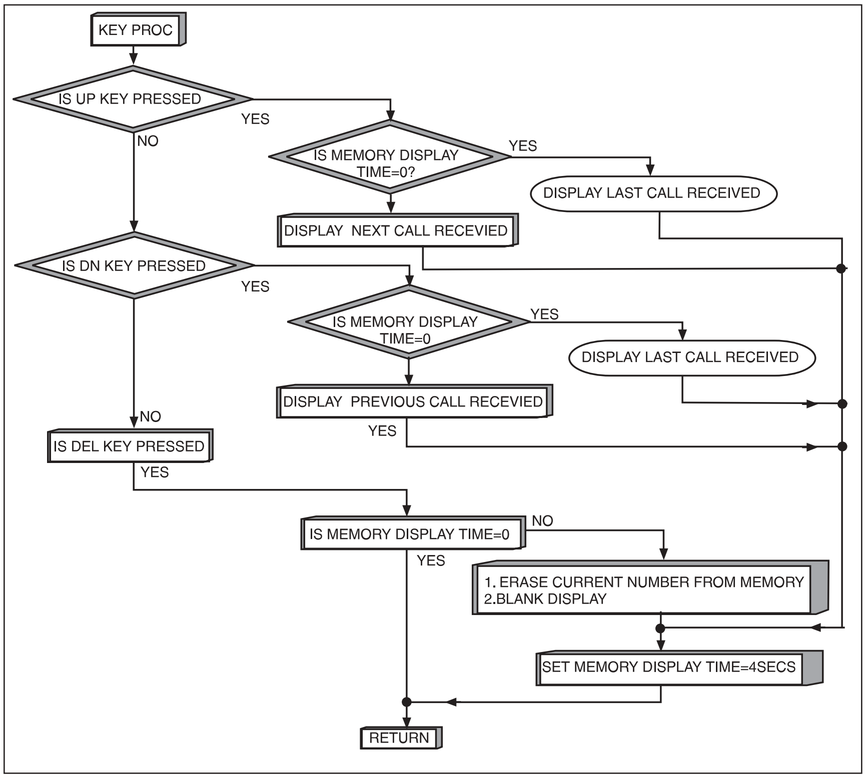

Fig. 16(a): Flow chart of key procedure

nal (SDA) is multiplexed with LCD module signal (RS). One pin scans keyboard. One pin scans off-hook/on-hook status of the hand-set.

A complete schematic diagram of the caller-ID unit is given in Fig. 1. Actual-size, single-sided PCB layout for the circuit in Fig. 1, with the exception of keyboard, is given in Fig. 11 while PCB layout for the keyboard is given in Fig. 13. The component layouts for the above-mentioned PCBs are given in Figs 12 and 14 respectively.

Software: Software code installed in ROM of the micro-controller for proper operation of the caller-ID unit is intellectual property of the author, and the same can not be published at this stage for commercial/other reasons. However, software flow chart for the main program and subroutines is shown in Figs 15 and 16(a) through 16(c).

Assembly and Testing

Assembly of this unit is simple. Mount all parts as per the component/PCB layout. For mounting ICs (except 5-volt regulator) use sockets. No special soldering/assembly precautions are necessary. However, before mounting the ICs, proceed as follows:

Raw DC at 7805 input	+12 V (+8 to + 15 V)
Regulated DC at 7805 output	+5V

1. Do not connect telephone line.

Voltage	On-hook	Off-hook
O/P of bridge	35 to 50 V	8 to 10 V
Pin 5/LM393	1.0 V	1.0 V
Pin 6/LM393	Above 1.8 V	Below 0.7 V
Pin 7/LM393	0 V	5 V

Power on the unit and check:

2. Mount LM393. Connect telephone lines. Check for following:

3. Install micro-controller, LCD module and memory IC. At power on "Have a nice day" message should appear on LCD screen.

4. Install DTMF decoder IC. Keep telephone line connected. Pick up the handset and press any key on your telephone (make sure that telephone is in tone mode) and keep it pressed. Check voltage at STD pin 15 of IC MT8870. It will be logic high as long as telephone key is pressed.

The number pressed on telephone instrument will also appear on LCD display. Press more keys and numbers will

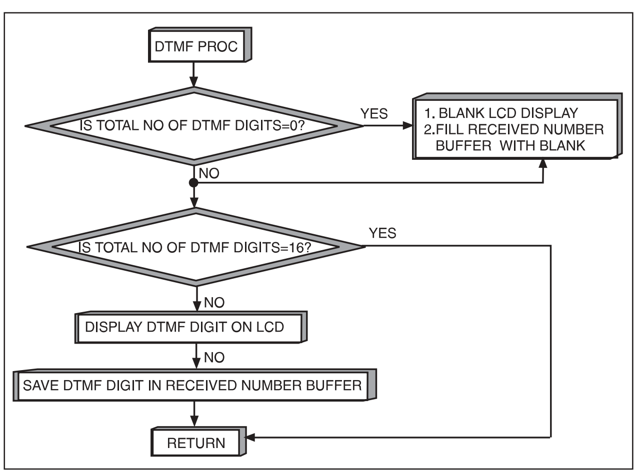

Fig. 16(b): Flow chart of DTMF procedure

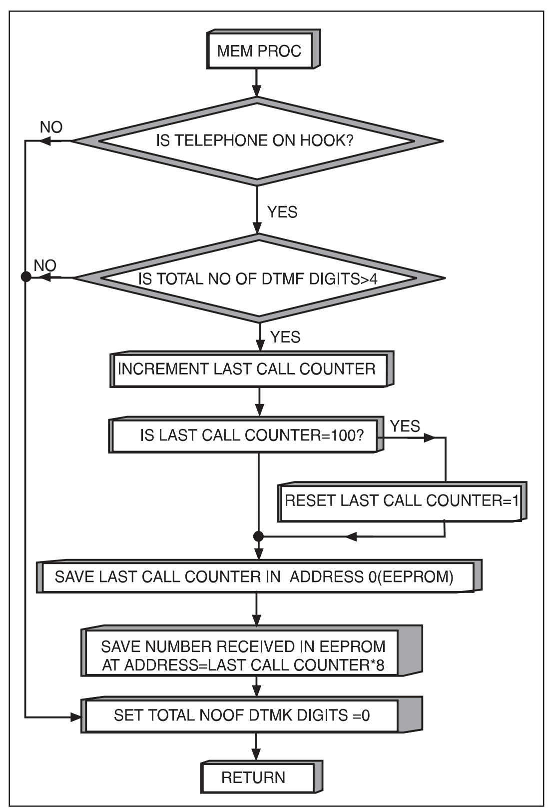

Fig 16 (c): Flow chart of memory procedure

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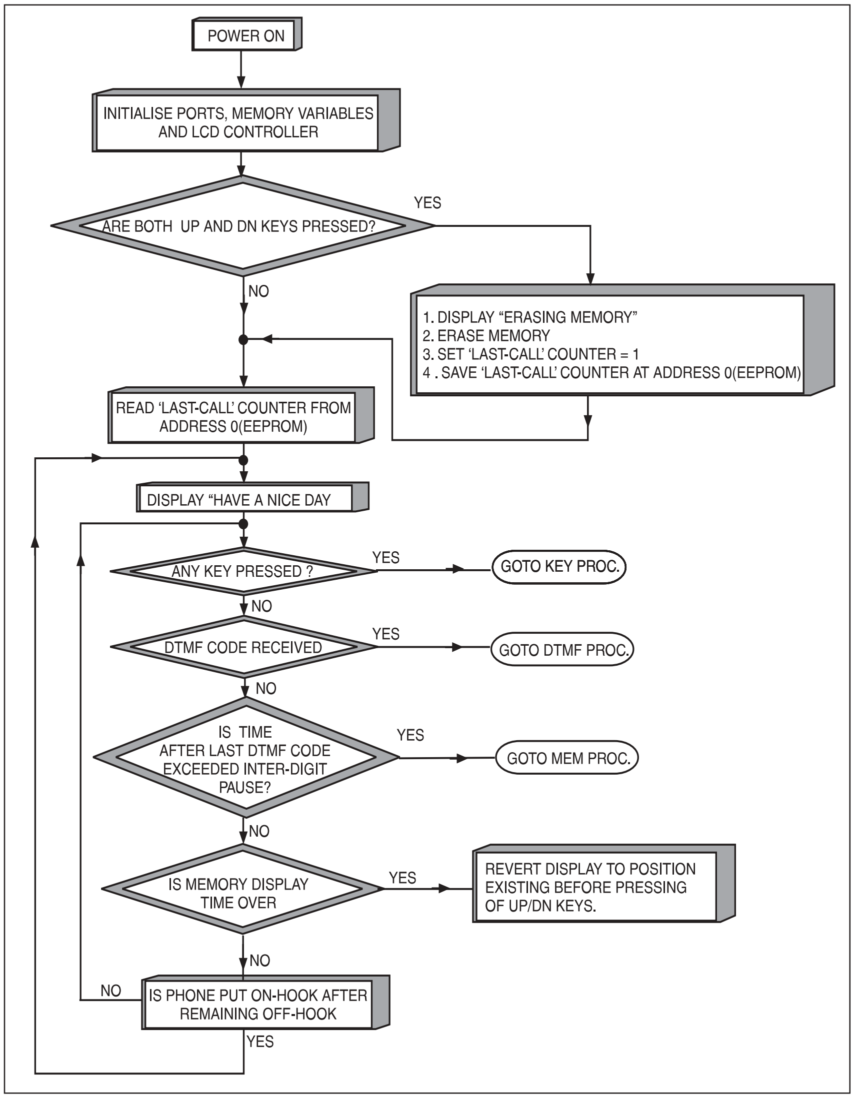

Fig. 15: Software flow-chart of main program

continue to be displayed one after another. The number dialled will remain there as long as phone is off-hook. Once you replace the handset, the standard message "Have a nice day" will appear again.

5. Short pin 7 of comparator LM393 to ground. Press some digits quickly or use redial switch to dial out the last number. This condition simulates the incoming number from telephone exchange. Micro-controller thinks that unit is on-hook (as pin 7 is forced to ground) and accepts DTMF tones generated by telephone handset as originating from exchange. After receiving full number it stores it in memory. Repeat this procedure with a few more numbers. All these numbers will be stored in memory as incoming numbers.

Remove the short. Unit is now in normal condition. Last number displayed will remain on display till handset is picked and replaced.

6. Press UP or DOWN key on keyboard. The last number received will appear on screen. Press DOWN again and second last number will appear on screen. Press UP or DOWN to scroll through list of received calls.

If no key is pressed for five seconds, the display reverts back to normal state, i.e. "Have a nice day" message or last received number is displayed. Pressing UP and DOWN key again shows the last number received.

7. To delete any specific number, press UP or DOWN key to view the number to be deleted. Press DEL key when the number is on display. Display will blank out and the number will be erased from memory.

PARTS LIST

Semiconductors:		
IC1	-	MC68HC705KJ1, micro-controller
IC2	-	MT8870, DTMF decoder
IC3	-	24C08, serial CMOS EEPROM
IC4	-	LM393, dual comparator
IC5	-	7805, voltage regulator
D1-D4, D8	-	1N4007, rectifier diode
D5-D7	-	1N4148, switching diode
D9, D10	-	Zener, 8.2 volt
Resistors:		
(all ±5%, ¼W carbon-film unless stated otherwise):		
R1-R3, R5-R6 R8, R19	-	10 kilo-ohm
R4	-	1 kilo-ohm
R7, R13	-	39 kilo-ohm
R9	-	470 kilo-ohm
R10	-	10 mega-ohm
R11	-	300 kilo-ohm
R12	-	62 kilo-ohm
R14-R17	-	51 kilo-ohm
R18	-	100 kilo-ohm
Capacitors:		
C1	-	10µF, 35V electrolytic
C2, C3	-	33 pF ceramic disc
C4,C6-C9,C12,C13	-	0.1µF ceramic disc
C5	-	30 pF ceramic disc
C10, C11	-	0.01µF ceramic disc
Miscellaneous:		
XTAL	-	3.5795 MHz crystal
S1-S3	-	Tactile switches (push-to-on)
DIS.1	-	16x1 LCD display module
	-	RG11 connectors
	-	Tel. cable with connector
	-	Body with knobs

Pressing UP /DOWN keys will show previous or next numbers but the deleted number will not be shown.

8. To delete all stored numbers, switch off the unit, press UP and DOWN keys simultaneously. Switch on the unit while keeping both switches pressed. Display will show "Erasing Memory" message for a few seconds and then "Have a nice day" message will be displayed. Now all numbers stored in the memory are erased permanently.

Your unit is ready. Celebrate and have fun !

What Next ?

Additional functions like storing outgoing calls, missed calls, adding a new call indicator (blinking led), black listing specified calls, date and time recording on all types of calls etc are also feasible. However, that requires more program memory in micro-controller. The present micro-controller version used has only 1240 bytes of program

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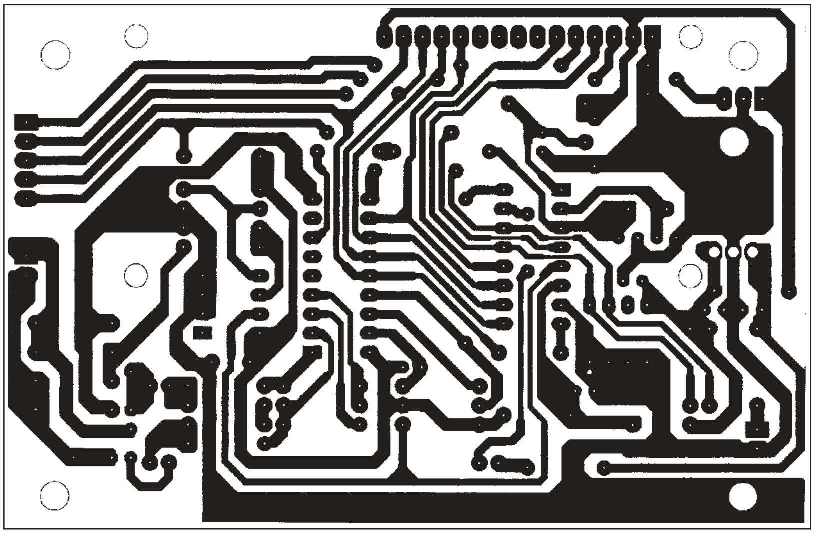

Fig .11: Actual-size, single-sided PCB layout for circuit in Fig. 10 except key-pad

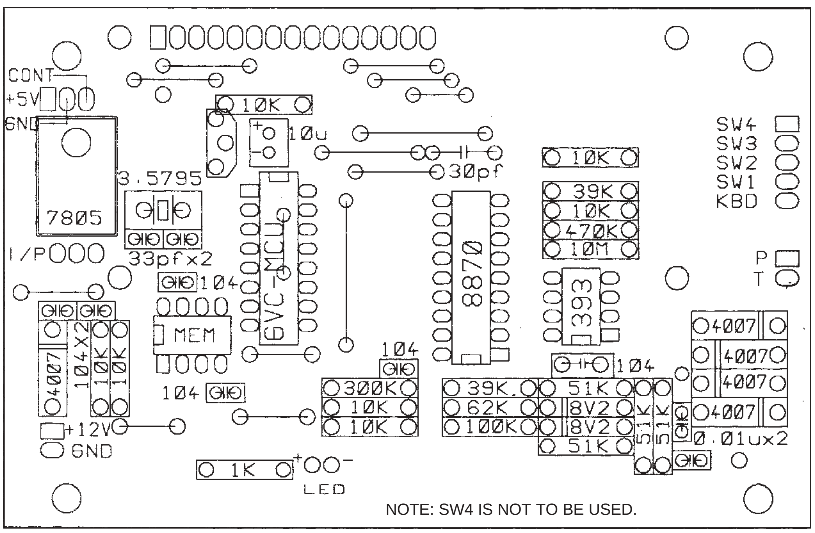

Fig .12: Component layout for PCB in Fig 11

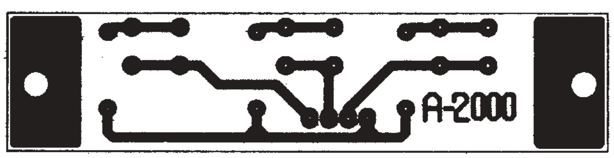

Fig .13: Actual-size, single-sided PCB layout for key-pad

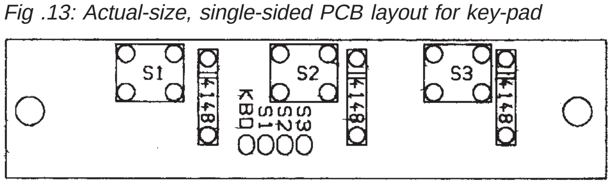

Fig .14: Component layout for key-pad

memory and 11 I/O lines. The author would, in the near future, come out with an enhanced version of the caller-ID unit incorporating additional facilities by making use of Motorola's MC68HC705P6ACP micro-controller which has around 5k program memory and 23 I/O signal pins.

Tech. Editor's note: For more details regarding 68HC705KJ1 micro-controller, readers may refer to an article on the subject at page 45 of Sept. '98 issue of EFY. You may also access relevant technical data books by pointing the browser to http://sps.motorola.com/csic if you have access to Internet. The instruction set and programming aspects of LCD modules had been dealt in some detail in a construction article on the subject which appeared on page 47 of Apr. '97 issue of EFY. However, the interfacing of LCD module was done for 8-bit data. For 4-bit data interfacing, a software

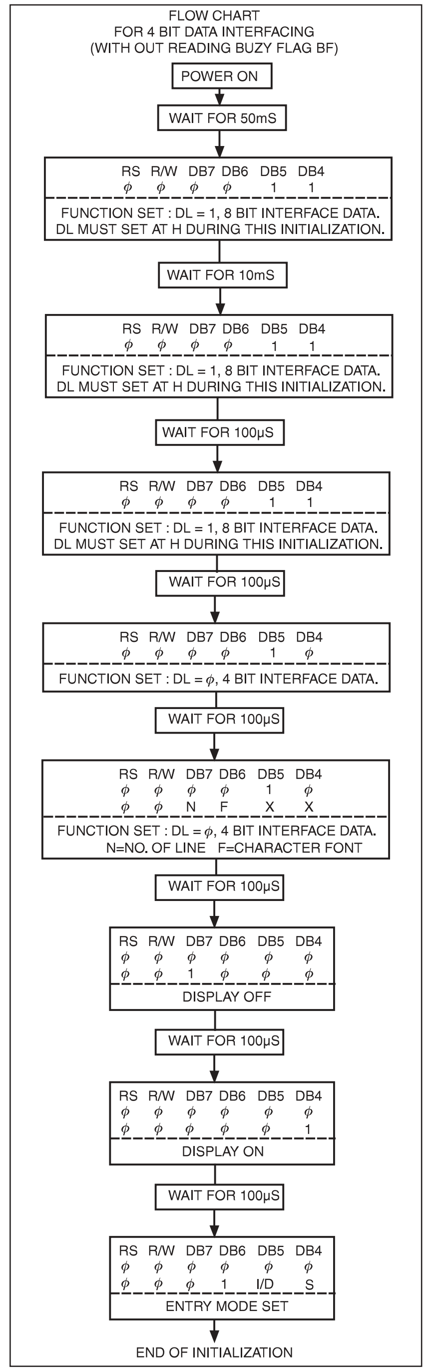

Fig. 17: Flow-chart for 4-bit data interfacing on LCD module (refer Tech. Editor's note)

flow-chart using the same instruction set is given in Fig. 17 for the benefit of EFY readers/subscribers. Flow-chart indicates that in 'function set' instruction the data length parameter 'DL' is first set to (logic 1) for 8-bit data and then changed over to (logic 0) for 4-bit data operation. Only data lines D4 through D7 are used for this initialisation. ❑

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