

# COP800 Based Automated Security/Monitoring System

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## INTRODUCTION

National Semiconductor's COP800 family of full-feature, cost effective, fully static, single chip micro CMOS micro-controllers provide efficient system solutions with a versatile instruction set and high functionality. The heart of the ASM System prototype is a COP800 family member with at least the following features: 4k bytes of on-board program memory, 192 bytes of on-board data memory, memory mapped I/O, fourteen multi-sourced vectored interrupts and a versatile instruction set. The family member used is the COP888CG microcontroller.

This application note describes the implementation of a Security/Monitoring System using the COP888CG microcontroller. The COP888CG contains features such as:

- Low power HALT and IDLE modes
- MICROWIRE/PLUS™ serial communication
- Multiple multi-mode general purpose timers
- Multi-input wakeup/interrupt
- WATCHDOG™ and Clock monitor
- Maskable vectored interrupt scheme
- UART

In addition to these features common to the COP888 sub-family of microcontrollers, COP888CG has a full duplex, double buffered UART and two Differential Comparators.

The COP888CG based Automated Security/Monitoring (ASM) System consists of several features:

- Automatic Telephone Dialing
- Real Time Clock
- Non-Volatile storage of real time information of events
- Continuous display of events on the terminal
- Battery operated remote sensors and transmitters
- Exit and Entry delays
- Expandable to add new features

## SYSTEM OVERVIEW

Figure 1 gives the block diagram of the ASM System prototype hardware. The application consists of following major blocks:

- Central Controlling Unit
- Receiver
- Sensors and Transmitters
- Keypad Unit
- Auto-Dialer Unit
- Data Storage Unit
- Display Terminal Unit
- LED Display Unit

The implementation allows easy expansion of the ASM System features by adding new blocks to the Central Controlling Unit.

COP888CG is the workhorse of the ASM System and provides the processing power to scan the keypad, service the Receiver interrupts, update the real time clock, serially communicate with the LED display unit and Data Storage Unit, activate the Auto-Dialer Unit and use the full-duplex double buffered UART to interface with the Display Terminal Unit. System capabilities may be enhanced or scaled down by simply changing the processor's algorithm. The subsequent sections describe each of the units and their interface with the COP888CG.

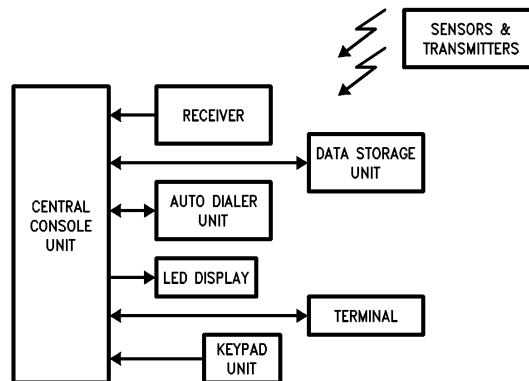


FIGURE 1. Block Diagram of Security/Monitoring System

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## HARDWARE DESCRIPTION

This section describes the various blocks in the ASM System briefly and highlights the hardware considerations in the design of the System.

### Receiver Unit

The Receiver Unit operates with the Sensors and Transmitter Unit. An eight-key dip switch makes it possible to select 256 different digital codes. A detector LED indicates the level of the radio frequency (RF) energy detected by the receiver and enables the user to determine the best locations for the transmitter(s) and receiver, assuring reliable operation.

*Figure 2* shows the interface between the COP888CG and the Receiver Unit on the bi-directional I/O Port L capable of functioning as Multi-Input WakeUp (MIWU). In this implementation the WR-200 series of receivers manufactured by Visonic Ltd was used. These receivers are designed to operate with Visonic standard transmitters. The receiver operates on 12 VDC. When RF signal from the transmitter(s) is detected, the receiver activates a relay which in turn interrupts the microcontroller. The output of the relay is connected to the Port L of the COP888CG whose alternate function includes, the Multi-Input WakeUp feature. The COP888CG, after a time delay of 10 seconds, activates the Auto-Dialer Unit. The microcontroller turns on a LED to indicate an alarm signal was detected and is being processed.

### Sensors and Transmitters

This unit has a built-in reed switch which can be used with a magnet to activate the transmitter. An eight-key dip switch forms the code selector and each key can be set to either ON or OFF position to create a unique code. This code should match with the code selected on the receiver unit.

Model WR-100 Universal Wireless Transmitter, manufactured by Visonic Ltd. was used in the implementation of the Security/Monitoring System.

### Keypad Unit

The Keypad Unit consists of 4 x 4 matrix keyboard. The *Figure 2* shows the keyboard matrix interface to COP888CG. The keyboard is scanned periodically by addressing a column in the keyboard matrix. The program senses the key closure in that column by testing the Port I lines (I0 to I3) which are connected to the rows of the keyboard matrix. Thus, each key is associated with the conjunction of one Port D output line and one Port I input line only.

The keypad unit is used to program the real time clock in order to set the time and date. The telephone number to be dialed in case of a security breach can also be programmed through the keypad as well as the terminal keyboard in the Terminal Unit.

### Auto-Dialer Unit

The Auto-Dialer Unit dials the number programmed by the user upon detection of RF signal by the Receiver from the Sensors and Transmitter Unit. The unit consists of two ICs and some peripheral circuitry. National Semiconductor's TP5700A is the Telephone Speech Circuit and TP5088 is the DTMF generator. These two chips are interfaced to the COP888CG as in *Figure 2*. The COP888CG outputs the digit to be dialed to TP5088 and the output of the DTMF generator is inputted to the Speech Circuit. The Speech Circuit interfaces with the telephone lines.

TP5088 is a low cost CMOS device that provides the toning capability in microprocessor-controlled telephone applications. TP5700A is a linear bipolar device which includes the functions required to build the speech circuit of a telephone. It replaces the hybrid transformer, compensation circuit and sidetone network used traditional designs.

### Data Storage Unit

The Data Storage Unit stores the real time data of events that the Receiver Unit detects and informs the Central Controlling Unit. The storage is non-volatile and can be archived for later references. The Terminal Unit can request the Central Controlling Unit to display the events and the data stored in the Storage Unit. The telephone number to be dialed by the Auto-Dialer Unit is also stored in this unit. This unit interfaces with the COP888CG using the MICROWIRE/PLUS™ serial communication protocol.

In this implementation the COP888CG microcontroller interfaces with NM93C06A Serial EEPROM Memory. The NM93C06A contains 256 bits of read/write EEPROM organized as 16 registers of 16 bits each. Written information has a retention period of at least 10 years. *Figure 2* shows the interface between COP888CG and NMC9306.

Any sequentially accessible memory device that is compatible with the MICROWIRE/PLUS™ serial communication protocol can be used as a Data Storage Unit. The Central Controlling Unit checks for the availability of memory and informs the user of the same if memory is full. Upon receipt of memory full prompt, the user can decide to overwrite or replace the memory device.

### Display Terminal Unit

The Display Terminal Unit interfaces with the COP888CG through the full-duplex, double buffered UART. The COP888CG is interrupted by the terminal and the microcontroller decodes the ASCII character sent and services the corresponding request. The terminal keyboard can be used to program the telephone number to be dialed by the Auto-Dialer Unit. The real time clock is displayed on the terminal screen. The user can request the Central Controlling Unit to display the history of events monitored by the AMS System. The Central Controlling Unit retrieves the information from the Data Storage Unit and displays it on the screen.

The ASM System utilized a Visual 550 terminal. The terminal employs two independent display memories: alphanumeric and graphics. The alphanumeric functions of the V550 is ANSI X3.64 compatible and the graphics functions are fully compatible with Tectronix Plot 10® software.

With slight modification of the Central Controlling Unit's algorithm it is possible to make the ASM System interface with any other terminal unit.

### LED Display Unit

The LED Display Unit is used to display the time and date information. *Figure 2* shows the interface between COP888CG and the Display Terminal Unit. The COP888CG communicates with this unit serially using the MICROWIRE/PLUS protocol.

The NSM4000A LED Display with Driver is used in the ASM System. The NSM4000A is a 4-digit 0.3" height LED display with serial data-in parallel data-out LED driver designed to operate with minimal interface to the data source. The Cen-

tral Controlling Unit does not update the display when it is servicing the Receiver Unit. The APS System has a toggle switch that enables toggling the display between Hours-Minutes to Seconds-1/80th of Seconds. The Keypad Unit is used to toggle the display between time and date.

#### Central Controlling Unit

This is the main unit in the application and is responsible for the efficient operation of the various units in the ASM System. The unit consists of COP888CG and the application software. The next section describes the application software in detail. The COP888CG interfaces with the various units described in the previous sections (*Figure 2*).

The application is a real time system and is totally interrupt driven with some of the tasks being executed in the background. The various units that interface with the COP888CG can be considered as tasks and the Central Controlling Unit executes these tasks based on their priority and the sequence of occurrence. The real time clock counter is given the highest priority. The Receiver Unit uses the Multi-Input Wakeup/Interrupt feature of the COP888CG to wakeup the microcontroller and service the Alarm routine. The Display Unit has a display toggle switch which also uses the Multi-Input Wakeup/Interrupt to toggle the display between Hours-Minutes and Seconds-1/80th of Seconds.

The COP888CG communicates with the Terminal Unit through the on-board, full duplex, double buffered UART. The terminal keyboard can be used to interrupt the COP888CG to program the phone number to dial in case of an emergency. The COP888CG uses the MICROWIRE/PLUSTM serial communication protocol to display the time and date information on the LED display and also to store real time information of events in the non-volatile data storage unit. Thus the MICROWIRE/PLUS protocol is time shared between the Display Unit and Data Storage Unit.

The Keypad Unit is a 4 x 4 array of keys and the COP888CG periodically polls the keypad. The input/output ports of the COP888CG is used to read the key pressed and is decoded by the software. The Auto-Dialer Unit is driven by the input/output lines and the interface between COP888CG. This unit is activated by the COP888CG 10 seconds after the Receiver Unit interrupts the microcontroller. This delay is used to disarm the Alarm routine.

#### SOFTWARE DESCRIPTION

The instruction set of the COP800 family of microcontrollers provide easy optimization of program size and throughput efficiency. Most of the instructions of the COP800 family are single-byte, single-cycle instructions (approximately 60%). The COP800 family of microcontrollers has three memory mapped registers (B, X and SP). The B and X registers can be used as data store memory pointers for register indirect addressing with optional auto post incrementing or decrementing of the associated pointer. This allows greater efficiency in cycle time and program code. The COP800 family allows true bit-manipulation i.e., the ability to set, reset or test any individual bit in data memory including the memory mapped I/O ports.

The architecture of COP800 family is based on a modified Harvard type architecture, where the Control Store Program (in ROM) is separated from the Data Store Memory (in RAM). Both types of memory have their own separate addressing space and separate address busses. This architecture allows the overlap of ROM and RAM memory accesses which is not possible with single-address bus Von Neumann-style architecture. The modified Harvard architecture allows access to ROM data tables which is not possible with the classical Harvard architecture.

The COP888 sub-family of microcontrollers support a total of sixteen vectored interrupts, of which fourteen are maskable interrupts and two high-priority, non-maskable interrupts. A 2-byte interrupt vector is reserved for each of these sixteen interrupts and they are stored in a user-defined 32-byte program memory (ROM) table. Please refer to the COP888 users manual or the Microcontrollers Databook for more detailed information on interrupts.

The MIWU feature, which utilizes the Port L, of the COP888 sub-family can be used to wakeup the microcontroller from the two power saving modes, i.e., HALT or IDLE modes. Alternately, the MIWU/Interrupt allows the user to generate eight additional edge selectable external interrupts. Three 8-bit memory mapped registers (WKEDG, WKEN and WKPND) are used to implement the MIWU/Interrupt. The three control registers each contain an associated pin for each L port pin. The WKEN register is used to select which particular Port L inputs will be used. The user can select whether the trigger condition on a selected L port pin is to be a positive edge (low to high transition) or a negative edge (high to low transition). This selection is made through the WKEDG register. The occurrence of the selected trigger condition for MIWU/Interrupt is latched into the associated bit of the Wakeup Pending Register (WKPND).

The COP800 family has the ability to detect various illegal conditions resulting from coding errors, transient noise, power supply voltage drops, runaway programs, etc. Reading an undefined ROM location gets zeroes, which results in a non-maskable software interrupt thus signalling an illegal condition has occurred. In addition to this, the COP888 sub-family supports both WATCHDOG™ and Clock Monitor. The WATCHDOG™ is used to monitor the number of instruction cycles between WATCHDOG™ services in order to avoid runaway programs or infinite loops. The Clock Monitor is used to detect the absence of a clock or a very slow clock below a specified rate. These features of the COP800 family provide easy implementation of real time applications where the proper execution of the software plays a crucial role.

The major features of the software written for the ASM System implementation are described on the flow chart *Figure 3*. The main program flow is to detect the flags set, service the flags and scan the Keypad. The rest of the software is interrupt driven. The program is real time and the interrupts are serviced as and when they occur. Some of the routines are running in the background all the time, such as, Time Keeping Routine and Keypad Scan Routine. *Figures 4* and *5* gives the flow of the various interrupt service routines. The following sub-sections briefly describe each module of software connected to the units described earlier.

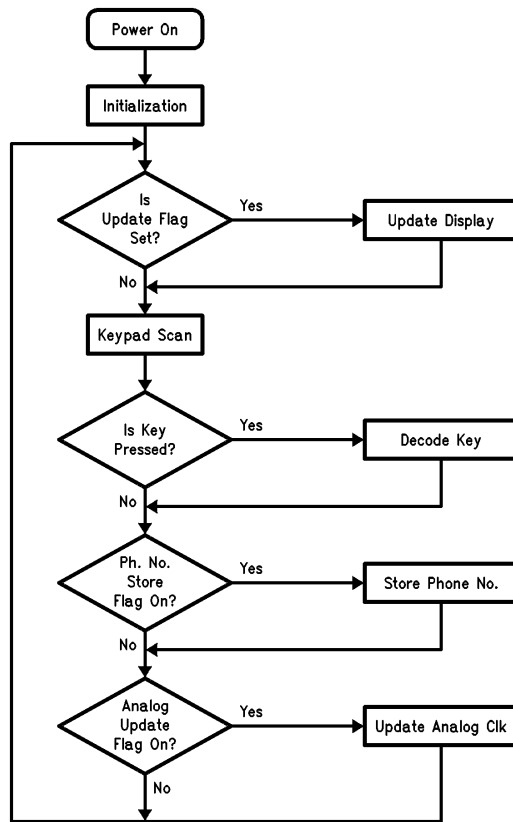


FIGURE 3. ASM System Program Flow

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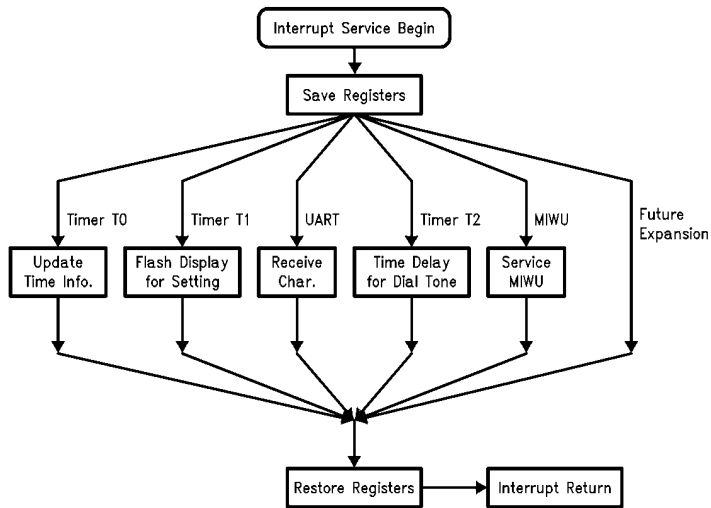
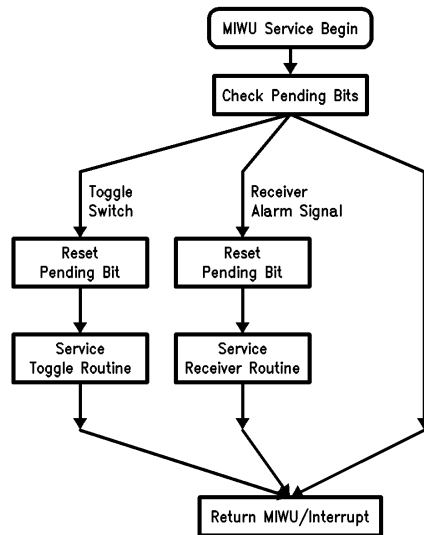


FIGURE 4. Interrupt Service Routines Flow

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TL/DD/10607-5

FIGURE 5. Multi-Input Wakeup/Interrupt Service Routines

#### Initialization Routine

The Initialization Routine loads the Data Memory locations being used in the program with default values and initializes the various control and configuration registers. It also brings up the display on the Terminal Unit and the LED Display Unit.

#### Time Keeping Routine

The Time Keeping Routine is the most important routine and is executed irrespective of the other modules being executed. The program uses the IDLE Timer T0 for this purpose. The IDLE Timer is a 16-bit timer and runs continuously at a fixed rate of the instruction cycle clock. The IDLE Timer counter is not memory mapped and consequently, the user cannot read or write to it. The toggling of the twelfth bit of the IDLE counter can be programmed to generate an interrupt. This interrupt is generated every 4 ms at the maximum instruction cycle clock rate of 1 MHz. The software uses this interrupt to update counters in Data Memory for time keeping. The Time Keeping routine then sets a flag to update the display which is then used by the main program.

#### LED Display Routine

The COP888CG uses the MICROWIRE/PLUS to interface with NSM4000 LED Display with Driver. The time and date information is displayed on the 4-digit LED display. The user is provided with a toggle switch connected to MIWU/Interrupt feature of the COP888CG to toggle the display between Hours-Minutes and Seconds-1/80th of Seconds. The toggle switch is connected to L port pin 5. Upon receipt of the MIWU/Interrupt of L port pin 5 this routine toggles the display. This routine upon receipt of the date display request through the Keypad Unit responds by switching the LED Display to show the date. The toggle switch could be used to change the display back to time. However, the display changes to time after a minute by default.

#### Keypad Scan Routine

This module scans the 4 x 4 matrix keyboard connected to Port D (D1–D4) as rows and to Port I (I0–I3) as columns. Thus each key in the matrix is associated with one Port D line and one Port I line. Each row in the matrix is addressed in sequence and the key closure is sensed by testing the Port I lines. The moment one key closure is detected the program jumps to load the debounce counter. The keypad scan is stopped at that particular row and the program returns to its main flow. The keypad is again scanned and when the debounce counter is decremented. When the debounce counter is zero the key pressed is accepted and decoded. The versatility of the COP888 family of instructions set allows decoding the key pressed with one instruction. The Port D (lines D1–D4) and Port I (lines I0–I3) in conjunction form an eight bit number that is unique to each key. The JID (Jump Indirect) instruction uses the contents of the accumulator to point to the indirect vector table of program address. The accumulator contents are transferred to the program counter (lower 8 bits). The data accessed from the program memory location addressed by program counter is transferred to the program counter (lower 8 bits). The JID instruction is a single-byte, three cycle instruction and provides an efficient way to decode and branch to service the appropriate routine based upon the key pressed.

The Keypad is used to set the time and data information after power up and can also be used to program the phone number to be dialed by the Auto-Dialing Unit.

#### Non-Volatile Data Storage Routine

The COP888CG interfaces with NM93C06A in the ASM System to store the real time data of the events monitored and also the telephone number to be dialed by the Auto-Dialer Unit. This routine is executed whenever the Receiver Unit detects a signal and the ASM System is not disarmed within 10 seconds of detection of the signal or when the

Display Terminal Unit programs the telephone number to be dialed. The Keypad can also be used to program the phone number to be dialed by the Auto-Dialer Unit. The Terminal Unit can request for the history of events, during which the COP888CG reads the NM93C06A. Please refer to the application note on MICROWIRE/PLUS for details regarding the interface between COP888CG and NMC9306.

#### **Display Terminal Interface Routine**

The Display Terminal as previously mentioned interfaces with the COP888CG through the full-duplex, double buffered UART. The terminal is used to display the history of events, real time, and sequence of operations upon detection of signal by the Receiver Unit.

The request for display of events and programming the phone number interrupts the COP888CG. However, the Time Keeping Routine updates the LED display and terminal with real time periodically, except when the COP888CG is servicing the Receiver Unit.

The operation mode of the UART may be selected in conjunction with both a prescaler and baud rate register. Character data lengths of seven, eight or nine bits are program selectable, in conjunction with a start bit, an optional parity bit, and stop bits of  $\frac{7}{8}$ , 1, 1 and  $\frac{7}{8}$ , or 2. The UART also contains a full set of error detection circuitry and a diagnostic test capability, as well as an ATTENTION mode to facilitate networking with other processors.

Please refer to the Users Manual or Microcontroller Data-book for details.

In the ASM System the COP888CG interfaces with the V550 terminal at 2400 baud, 8 data bits, 1 Stop bit, no parity. The receiver buffer full and transmit buffer empty generates an interrupt. The Port L (pins L1, L2, L3) are used for the UART interface as CKX (clock), TDX (transmit) and RDX (receive), respectively.

The display terminal is used to display time both in analog and digital form. The V550 allows interfacing both in alphanumeric and graphic modes with separate memory for each of the modes. The COP888CG is programmed to send out the ASCII ESC sequence required to generate the graphics on the screen.

#### **Auto-Dialing Routine**

This routine is responsible for dialing the number in the event of an emergency. The COP888CG interfaces with TP5088, which in turn interfaces with TP5700A. The COP888CG activates the relay that keeps the telephone line on-hook to the off-hook position. After this it times out to get the dial tone. After a fixed amount of time, the digit to be dialed is sent out on the D port, lines D1–D4, to TP5088 along with the Chip Select. The TP5088 generates the DTMF signal for the digit. The COP888CG takes care of the timing required between two digits and also the on-time of the DTMF signal for each digit. The output of the DTMF signal goes to the TP5700A which interfaces with the Tip and Ring of the telephone lines. The TP5700A receives the signal from the telephone lines and LM567 along with the associated circuitry is used to detect whether the required frequency signal was sent by the unit responding to the telephone. The output of the LM567 is connected to Port I pin 5.

The Receiver Routine polls the Port I pin 5 periodically to check for response from the unit dialed by the Auto-Dialer Unit.

#### **Receiver Routine**

This is the main interrupt service routine of the ASM System. The Receiver Unit interfaces with the COP888CG

through the L port pin 4. Upon receipt of the signal from the Sensors and Transmitter Unit the Receiver Unit activates a relay which causes a MIWU/Interrupt. The interrupt service routine then waits for 10 seconds before reacting to the signal. This time is allowed to disarm the Security/Monitoring System. The Time Keeping Routine is used to calculate the delay and if the user disarms the System by toggling a switch the signal is ignored. Otherwise the Non-Volatile Storage Routine is executed to read the telephone number and this information is passed on to the Auto-Dialer Unit. The Auto-Dialer Unit dials the number and looks for a response over the telephone line. If however, there is no response, the Receiver Routine times out after a minute and tries the same number again. The number of trials can be modified in software and the time out period can also be changed. In the ASM System the number of trials is two. With slight modification the Auto-Dialer Unit can be made to dial a different number during the second attempt. The real time and date of occurrence of the event is stored in the NMC9306 along with the outcome of the telephone call. This routine keeps track of the non-volatile memory capacity and if it overflows, it prompts the user on the terminal of the same. The user is given the choice to overwrite the non-volatile memory or replace the device.

#### **USING THE ASM SYSTEM**

The ASM System upon installation and initial power-up has some preliminary steps to be performed. The time and date should be set, the phone number to be dialed by the Auto-Dialer Unit should be programmed. The toggle switch could be used to toggle the display between Hours-Minutes and Seconds-1/80th of Seconds.

#### **Setting Time and Date**

The steps involved in setting the time and date are:

1. Press key A on the keypad. The LED display flashes.
2. Set the desired time (Hours and Minutes) using the keypad.
3. The LED display and the Terminal Screen displays the time set.
4. Press key C on the keypad. The display toggles and displays the date.
5. Press key A on the keypad. The LED display begins to flash.
6. Set the date (month and day) using the keypad.
7. The LED display now shows the date set.
8. The LED display could be toggled to show the time using the toggle switch. However, the system after one minute will default to display time.

#### **Programming the Phone Number**

The phone number to be dialed could be programmed in two ways, i.e., using the terminal or the keypad. Using the terminal, the steps to be performed are:

1. Press CNTRL B on the terminal keyboard. The COP888CG sends a carriage return to terminal.
2. Press CNTRL D on the terminal keyboard. Then type the number to be dialed. At the end press CNTRL C to end programming.

Using the keypad, perform the following steps:

1. Press "\*" key on the keypad.
2. Press the digits to be dialed.

3. Press “#” key on the keypad to end programming the number.

The ASM System is now ready to start monitoring. Upon receipt of the alarm signal from the Receiving Unit the ASM System will dial the number programmed. In order to display the history of events on the terminal screen press CNTRL S from the terminal keyboard.

**CONCLUSIONS**

The architecture, features and flexibility of the COP800 family of microcontrollers makes it cost-effective as the work-

horse of any system by eliminating external components from the circuit. This approach not only reduces the system cost and development time, but also increases the flexibility and market life of the product.

The Automated Security/Monitoring System implemented using the COP888CG illustrates a single chip system solution. The application also illustrates interfacing the COP888CG to a number of specialized peripherals using an absolute minimum number of I/O lines. The ASM System approximately uses 3k bytes of program memory (ROM) space and demonstrates an efficient method of handling multi-sourced interrupts.

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