Associated starter kit available

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**DVD Elektor 2010**
All articles in Elektor Volume 2010

This DVD-ROM contains all editorial articles published in Volume 2010 of the English, Spanish, Dutch, French and German editions of Elektor. Using the supplied Adobe Reader program, articles are presented in the same layout as originally found in the magazine. An extensive search machine is available to locate keywords in any article. With this DVD you can also produce hard copy of PCB layouts at printer resolution, adapt PCB layout drawings using your favourite graphics program, zoom in / out on selected PCB areas and export circuit diagrams and illustrations to other programs.

MCU-Based GSM Connection

A Fixed Cell Phone with Emergency Auto-Dial

A little embedded intelligence (EI) goes a long way. This microcontroller-based design features a GSM platform, a controller, a keypad, and a handset for easy dialing and wireless calling.

Don't call me crazy for trying to design things that are already on the market. There's a method to my madness. I'm interested in making existing technologies better. Most electronics—from satellites to dishwashers—have some form of low-level artificial intelligence or embedded intelligence (EI). But engineers are never complacent. We're always trying to build in additional intelligence. And so I assure you that we aren't far from a day when ubiquitous consumer gadgets (e.g., cellular phones, MP3 players, and home appliances) will have high-level EI. (Get ready for the “gadgetoids.”) Our products will work in unison to protect the interests and the welfare of their users.

The aforementioned ideas are the guiding principles for my global system for mobile communications (GSM) wireless phone design. The low-cost system has the look of a “retro” phone with a hook switch and cradle (see Photo 1a). But that's where its old-fashioned characteristics end. The phone's MCU-driven EI—along with its GSM platform, touchpad, and concealed antenna—proves it is truly a 21st-century design (see Photo 1b). The system also features emergency autodialing functionality and a fire alarm that can transmit preprogrammed SMS messages to preprogrammed telephone and mobile phone numbers. For instance, consider an elderly person who needs to call a pharmacist, a physician, or a family member. Memorizing all of the numbers or looking for the frequently called numbers before dialing is a common problem. My wireless phone design uses EI to address the problem. A user can simply press the “A” key for 911 alerts or press the “B” key for a medical emergency. Table 1 shows the phone's various functions.

**DESIGN ESSENTIALS**

The phone is built around a Microchip Technology PIC24FJ64GA002 16-bit microcontroller that performs the GSM module initialization, dials, and sends the commands for GSM module dial-up. The phone's Microchip Technology MCP9700 thermistor can send a fire

![Photo 1](image) Don't let the retro casing fool you (a). Inside is a Microchip Technology PIC24FJ64GA002 microcontroller, a GSM board with an antenna, and a connected keypad (b).

<table>
<thead>
<tr>
<th>SI Number</th>
<th>Keypad button</th>
<th>Functional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Numeric keys (0 to 9)</td>
<td>Dial a telephone number</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>&lt;Enter&gt; Make a call</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>Cancel the call</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>911 Emergency alert SMS</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>Medical alert SMS</td>
</tr>
<tr>
<td>6</td>
<td>Temperature sensor</td>
<td>Fire alert SMS</td>
</tr>
<tr>
<td>7</td>
<td>* and #</td>
<td>Unused</td>
</tr>
</tbody>
</table>

**Table 1**—Keypad functions
Table 2—The GPIO port pins/alternate function mapping

<table>
<thead>
<tr>
<th>GPIO Port pins</th>
<th>Alternate function mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO-RB0/KB1</td>
<td>ICD 2 Debugger program pins, PGC, and PGD, respectively</td>
</tr>
<tr>
<td>GPIO-RB2/KB3</td>
<td>UART0 TXD/RXD pins, respectively</td>
</tr>
<tr>
<td>GPIO-RB5</td>
<td>Hook switch state sensor (active low)</td>
</tr>
<tr>
<td>GPIO-RB8</td>
<td>Output – GSM module reset line (active low)</td>
</tr>
<tr>
<td>GPIO-AN0</td>
<td>AN0 – ADC input for the temperature sensor</td>
</tr>
<tr>
<td>GPIO-RB6/7/10/11</td>
<td>Keypad 4 x 4 matrix row inputs (pulled high)</td>
</tr>
<tr>
<td>GPIO-RB12/13/14/15</td>
<td>Keypad 4 x 4 matrix column drive outputs (active low)</td>
</tr>
</tbody>
</table>

You can power the portable phone with either a back-up battery or through an AC mains wall outlet adapter.

The phone’s anatomy is simple. Flashy LCDs, speakerphone features, and voicemail aren’t included. It’s just a 16-bit digital engine driving a GSM module with a preloaded SIM card. No special activation is necessary. You can choose any SIM module from a service provider to run this phone. The design accommodates the use of the typical GSM module working with standard attention (AT) commands and such a module having the GSM forum certification and homologated to the GSM carrier network.

The antenna is a high-gain concealed antenna that does not stick out of the telephone. A distinct advantage of this design is that it looks like a key telephone, so you could have a dummy RJ11 socket for an intruder to think it’s a phone that’s not plugged into the wall socket, and at the same time it wouldn’t give the slightest hint that it’s wireless.

Although it’s not incorporated here, you could include a small security system that detects when doors and windows are opened, and then sends an SMS alert about a possible
intrusion. You could activate this alarm from your GSM mobile through SMS or DTMF signaling over a voice channel. To build a security system, such as an intruder alert system, you'd need door/window sensors that aren't featured in this design. Activation of the alarm system over SMS is possible through control characters that could be passed by the GSM to the MCU UART. Such characters would be parsed to obtain the control code. DTMF would require an additional decoder (e.g., Mitel MT8870) over the voice channel. I already mentioned that this feature is not incorporated in the design, and it's a design that would include an intruder alert system (one that would dial 911 during an intrusion). The idea is to have your phone perform functions ranging from autodialing to building monitoring to appliance control. It can be a communication gateway with added security features. Now, here's how to design this "gadgetoid" with EI.

CONTROL, POWER, & MONITOR

Refer back to Figure 1. The first module is the GSM radio, interfaced to the PIC24FJ64GA002 microcontroller with a keypad and a temperature sensor interfaced to the microcontroller. That's all.

I assembled the board with a Microchip Technology PIC starter board reference design (see Figure 2). The PIC24FJ64GA002 uses a 28-pin base and the GPIOs are available on the I/O header (see Table 2). The 7.3728-MHz crystal is intended to achieve a 5% error on the UART at the data rate of 115.2 kbps required for this application. The programming port is available on the default PGC/PGD pins on pins 4 and 5, and MCLR is available on pin 1. The six-pin RJ12 port for programming the PIC has the PGC, PGD, MCLR, and GND terminated at this port that interfaces with a Microchip Technology MPLAB ICD 2 debugger. The power supply to the PIC board is 3.3 VDC through the DC connector onboard. The 3.3 VDC is generated from the LDOs on the GSM module board.

The GSM module board runs off a 5-V source with the LDO onboard generating 3.3 VDC for the module and the SIM card (see Figure 3). The same supply of 3.3 VDC is routed to the PIC24FJ64GA002 section. The R88 port pin from the PIC24FJ64GA002 microcontroller is used to reset (active low) the GSM module after power-up. The GSM audio I/O port is interfaced to the handset and an internal 3-dBi whip antenna is used. The AT command interface to this module with the PIC24FJ64GA002 is through UART0 pins, as mapped on the microcontroller.

The 4 x 4 keypad has rows as inputs (pulled high) on port pins RB6/7/10/11 and columns as drive outputs on port pins RB12/13/14/15. The keypad subroutine loops on making each column low and scanning the rows for a switch press that drives that particular pin low. The state is read with a delay subroutine to debounce the key press and the dialed digit information is sent as an ASCII character over the UART to the GSM module. The keypad scan routine is a standard routine that's explained in the source code with comments. Refer to the code posted on the Circuit Cellar FTP site.

The MCP9700 voltage output temperature sensor is used to determine fire alert conditions from a preset temperature value of 60°C and higher. It supports a wide temperature range of -40 to 125°C with an operating voltage of 2.3 to 5.5 V with a 10-mV/°C output. The sensor is biased from the VDD of 3.3 V, which serves as the maximum voltage value and is interfaced to AN0 input on the PIC24FJ64GA002. The firmware scans for the ADC value, compares it with a preset hex value corresponding to 60°C, and sends an SMS alert for all values of 60°C and above.

The PIC24FJ64GA002, the GSM module, and the SIM operate from a 3.3-VDC source (see Figure 4). The GSM module board accepts a 5-VDC input and generates 3.3 VDC, which is used for the GSM module, the SIM, and is routed to the PIC board to power the PIC24FJ64GA002 (see Figure 5).

CODE & PROGRAMMING

I used the MPLAB ICD 2 debugger and programmer to flash/debug the PIC board (see Photo 2). The PIC board has PGC/PGD pins available for the same thing. Programming
is straightforward and simple. Plug the debugger into a PC’s USB port, plug the RJ12 into the RJ12 port on the application power, and apply power through the 5-VDC adapter to the PIC board. Next, open the MPLAB IDE v7.62, select ICD 2 under the Debug option, and the application board is instantly detected. Write the code, build flash, and run the same.

The Assembly language code for this application was written with the MPLAB IDE v7.62 [all higher versions are backward-compatible]. Lower versions have a bug for the PIC24FJ64GA002 part and only versions v7.62 or higher are recommended to build the code. (Refer to the PIC24FJ64GA002 instruction set and the code listing in the project software file on the Circuit Cellar FTP site.)

The code is relatively simple [see Figure 6]. The main loop initializes the microcontroller, sets up UART and input/output port pins on port RAx and RBx, and initializes the ADC function for fire alert sensing through AN0 [temperature sensor]. GSM_RESET initializes an iTWO Technology TR-800 GSM/GPRS module. This block is optional and may be deleted for GSM modules that don’t need a start-up reset.

SMS has the subroutines SMS and Receive. It scans RA1 [GSM ring indicator] and RB11 [keypad buttons “A” and “B”] for an incoming call and performs call receive or state alerts by sending a precanned SMS.

To dial any number, the AT commands are used (sent over the UART to the GSM module). The subroutine is called while dialing a number or sending an SMS.

SCAN123A is the keypad scan subroutine preceded by the Initiate subroutine. If an off-hook state is detected, an ATD command is sent to the GSM module followed by a Goto instruction to jump to the subroutines. The subroutine scans the keypad and dialing entries sent to the GSM module over the UART.

Dial checks the hook switch status and initiates a call; Endcall transmits ATH to the GSM to end the call. Check checks the hook switch status after every number is keyed. Transmit sends data to UITXREG.

The precanned SMS messages are sent during an alert condition. Here is an example:

AT+CMGS="<Number to be dialed>" <Enter>
<Message>
CTRL+z

INTEGRATION & TESTING

I built the phone system on an existing TR-800 GSM evaluation board with a SIM cardholder and the power supply circuitry, antenna port,
and other peripherals required to operate the GSM module. However, any standard GSM module (it must have an IMEI number and have a homologation approval from the GSM service providers in the country of use) may be used with minor changes if required. AT commands for dialing/SMS are the same and the modules are compatible with this design to operate in voice call/SMS mode.

Photo 1b shows the system rigged up in the simple push button telephone mold. The results of my dialing and emergency SMS tests were satisfactory. The call/receive function worked well. There was no appreciable difference in GSM signal quality with the onboard stealth antenna used, and it worked error-free like a fixed cell phone terminal. The handset had standard voice quality and I didn’t have to increase audio volume, although it may be achieved by using the standard AT commands.

I built the emergency SMS numbers into the program. In this design, I didn’t keep the provision to input numbers dynamically from a keyboard. Many features can be added by integrating a 1 x 16 or 2 x 16 LCD. The current system is fairly basic because it’s intended to be affordable yet effective.

HANGING UP

I was motivated to design my phone primarily for geriatric use where elderly people are left to fend for themselves. The idea was to create a simple, cost-effective wireless phone that has the added features of emergency dialing, a fire alert, and other such services. And now I have a platform for various EI companion gadgets.

The possibilities for this platform are endless. I’m confident you could easily add building surveillance and monitoring features. Perhaps I’ll read about your design in a future issue of Circuit Cellar.
Indranil Majumdar (majumdar@ieee.org) is an electronic communications engineer who has been working on RF and wireless systems for the last 20 years. He has worked on embedded designs since 1998 and has been extensively involved in the design of wireless embedded systems for vehicle tracking (GPS-GSM/GPRS), GSM POS terminals, smart energy meters using GSM and 2.4-GHz LPR, and 2.4-GHz ZigBee wireless systems for industrial and home automation. Indranil is an amateur astronomer and an avid ham radio operator (VU2KFR, licensed since 1984). He is also a member of the American Radio Relay League and IEEE (both U.S.).

PROJECT FILES

RESOURCES


SOURCES
TR-800 GSM/GPRS Module
iWOW Technology | www.iwow.com

PIC24FJ64GA002 Microcontroller, MCP9700 Thermistor IC, and MPLAB ICD 2 Debugger
Microchip Technology, Inc. | www.microchip.com

MT8870 DTMF Receiver
Mitel Networks Corp. | www.mitel.com

**Need-to-Know Info**

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GPS-GSM Mobile Navigator
by Ma Chao & Lin Ming
*Circuit Cellar* 151, 2003

What’s the more laudable engineering feat, designing a navigation system capable of tracking ships in Shanghai Port or placing at the top of a competitive design contest? With the award-winning GPS-GSM Mobile Navigator, Ma and Lin accomplished both. Topics: GSM, Cellular, Mobile, GPS, Navigation, Communications, Transmission, SMS

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Li-ion Battery System Solution

Implement a BCU and Safety-Certified RTOS

Current lithium-ion (li-ion) systems can be problematic. Here you learn how to implement a battery control unit (BCU) with a safety-certified RTOS. The design enables battery monitoring, data reporting, and circuit protection.

While working for a provider of large-capacity lithium-ion (li-ion) battery cells and battery systems, I became familiar with the major requirements for the maintenance, charging, and circuit protection used in the design of such energy systems. Along the way, I discovered several areas in the designs that needed improvement. In this article I'll describe some of my findings, as well as a useful battery module project that you can build at your own workbench.

My motivation for this project was to find solutions to several design issues found in typical li-ion battery systems. I designed an eight-cell, 32-V nominal voltage li-ion battery pack prototype complete with battery management electronics (see Photo 1).

STORAGE SYSTEMS

Large capacity energy storage systems are finding increased usage in applications such as electric/hybrid vehicles, solar and off-peak energy storage, and lab and development testing for replacing older energy sources and lower energy density batteries. Most, if not all, li-ion battery systems share some common features including circuit protection (typically a circuit contactor), real-time cell voltage monitoring and cell balancing, and operational status data transmission to the user/outside world.

Some systems can be quite expensive. Some are also based on proprietary hardware or less-popular microcontrollers, and upgrades can be extremely difficult, if at all possible. Some systems have moderate software performance, at best, and may suffer from software response latency. They do not typically operate with a safety-guarantee or high-reliability real time operating system (RTOS), and they may not provide a fail-safe condition in the loss of external power. Some of the systems are inflexible and short on general-purpose input/outputs (GPIO). Others rely heavily on external integrated circuits (ICs) on the battery control unit (BCU) board, sometimes for basic functionality rather than implementing those in software.

To clarify a potential safety scenario, let's consider one of the weaknesses just mentioned. Figure 1 shows a comparison of an actual battery management system in use and my proposed alternative design. Figure 1a is a system powered by an external supply, consuming energy 100% of the time due to the contactor design (using a normally closed con-