Explorer-16

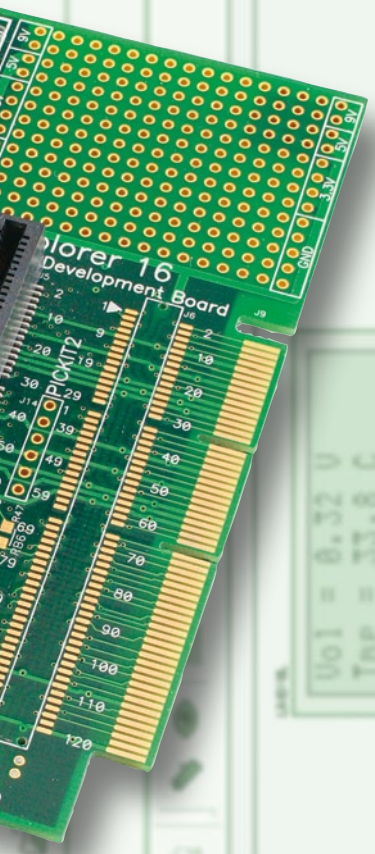
Jan Buiting & Luc Lemmens, *in cooperation with*
Microchip UK & Labcenter Electronics

January is a time for fresh starts and good intentions. If ever there was a golden opportunity to move on to 16-bit microcomputing at a serious level, join Microchip, Labcenter and Elektor with their groundbreaking *Explorer-16* project for which a fantastic hardware offer will be made next month. And there's more in the pipeline if you like to run simulations on your PC. For now, no hardware is required. You have your free CD-ROM supplied with this issue so let's get started with installing Microchip MPLAB and C30 and then Proteus VSM.

If we say that 'Explorer-16' is the next logical step from 8-bit micros, we should hasten to add that the project is also perfect for relative newcomers who will be aware of, but need not necessarily bother about, the rock-solid foundations for popular microcomputing laid by so many 8-bit micros (including PIC® MCUs) these past 15 years or so. There's no objection to starting with 16-bit microcomputing straight away as the tools available for the job are powerful to say the least. That said, we should warn that 'Explorer-16' takes off at a fairly high level although all material to learn about programming your own 16-bit PIC micro is available as part of the project.

Regarding the choice of a PIC 16-bit microcontroller, *Elektor Electronics* being very much an independent magazine, we never went down a single road by using one and the same processor family for years on end. Through our articles we will continue to underline the wide diversity of micros available on the market today and respect every user for his or her preference of PIC, AVR, ARM, 8051 or MC9 over 'the others'. In the case of Explorer-16, the PIC MCU road offered good options and tools for a series of instructive, reader-interactive articles linking to high quality hardware that can be obtained at a discounted price, and (mostly) free software.

Part 1: introduction to MPLAB®, C30 and Proteus VSM



No EXPLORER-16 CD-ROM found here?
Go to the EXPLORER-16 page at
www.elektor.com
or phone Elektor Electronics
on +44 208 2614509.

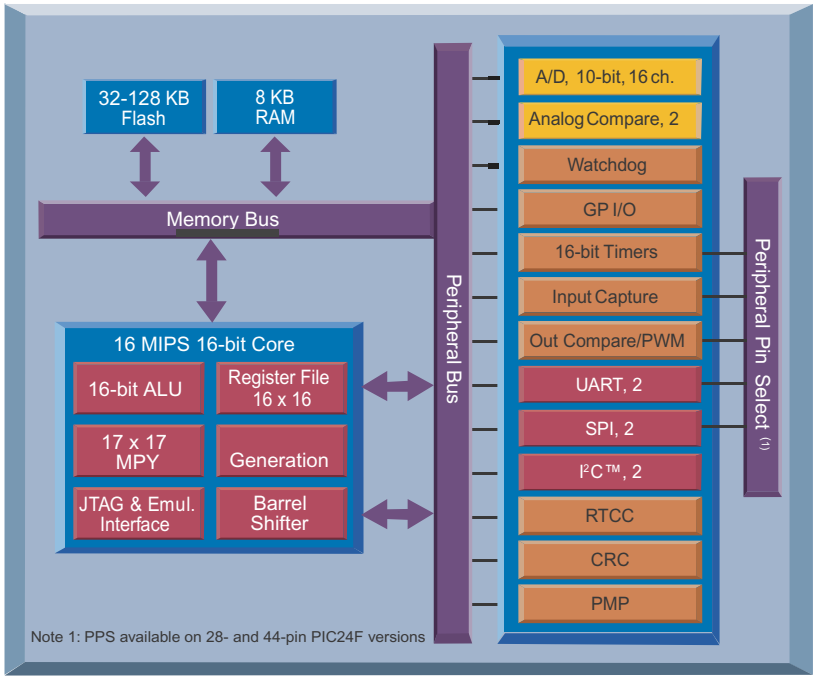


Figure 1. PIC24F functional bock diagram. This is a 16-bit micro.

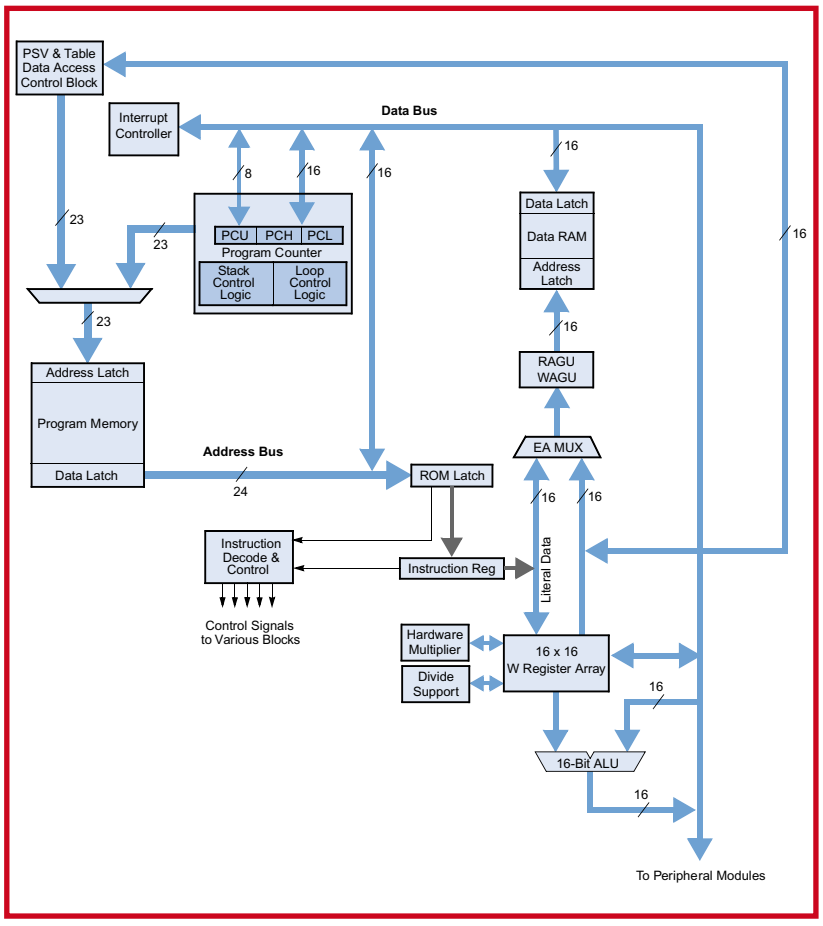


Figure 2. PIC24F CPU core block diagram.

Outlook on the series

This series of articles comprises three main ingredients which we need to mention right at the start.

1. Software

The free CD-ROM you get with this January 2007 issue contains three major pieces of software that lock together into a platform designed to help you become familiar not just with Microchip's 'PIC24F' 16-bit microcontroller, but also with the general concept of microcontroller simulation. All three components are extremely user-friendly (if not downright 'slick') programs that run on a reasonably fast PC with MS Windows installed:

- MPLAB IDE — version 7.50 of this world famous platform for PIC MCU software development.
- MPLAB C30 — version 2.05 (student edition) of the 'C' higher programming language compiler for PIC microcontrollers, complete with an array of utilities.
- Proteus VSM v. 7.00 — a special edition of the Labcenter simulation software that's so fast it can simulate a complete microcontroller board on your PC. Yes, an Explorer-16 board, too, as (for the first time) a PIC24F simulation plug-in is included free of charge to provide the link with the Explorer-16 board!

The software is valuable in itself in that you can cheerfully use it without having any hardware available except of course your PC!

2. Hardware

With the publication of the February 2007 issue, *Elektor Electronics*, the third party in the triumvirate, will offer the **Explorer-16 Development Board** with a special add-on configuration and at an unbeatable price. A preview of the board is shown in the introductory photograph. Mind you, the development board is supplied exclusively by Elektor, i.e., it's not available anywhere else in the configuration to be described in part 2.

3. Website support

File support for the project will be built on a dedicated 'Explorer-16' page of our website at www.elektor.com. Experts at Labcenter, Microchip and Elektor will be contributing and providing help as required. With Part 1 of this series an Explorer-16 topic is available on the Elektor website. The forum is open for everyone to read but only registered users can post new topics and reply to existing ones. But then, registration is free.

Three (possibly four) consecutive instalments are planned. In these we'll be running demos and doing a pretty advanced classroom exercise to explore the workings of Proteus VSM software.

PIC24F Architecture

You knew you had it coming — a functionally oriented block diagram of the PIC24F device (**Figure 1**) and the CPU Core block diagram (**Figure 2**). The good news is that this article series (and the Explorer-16 board) is based on the top-end processor in the family, the **PIC24FJ128GA010** sporting 128 kB Flash… and a 100-pin case! Its 'business card' is shown in the **PIC24F128 Quick Specs inset**. This beast has A/D, UART, SPI, I²C, RTCC, WDT ICE, ISP and POR, not forgetting advanced power-saving technology and a parallel-port master and slave functionality.

EXPLORER-16 is brought to you jointly and exclusively by Microchip Technology, Labcenter Electronics and Elektor Electronics. As part of the project, a free CD-ROM is included with the international print run of Elektor Electronics' January 2007 issue. The Explorer-16 Development Board and a plug-in accessory board will be on offer at a discounted price with the publication of the February 2007 issue so stay tuned.

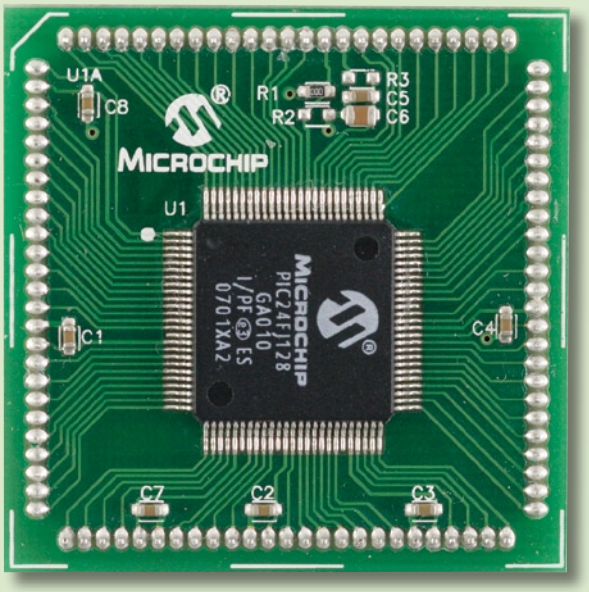
There are two pdf documents, Refs. [1] and [2], you should download straight away and store in a folder named 'Explorer-16': The PIC24F datasheet is an incredible 230 pages, fortunately the pdf has tabs to guide you to the chapters. If you migrate from the popular PIC18F to the 24F, the document in Ref. [3] is valuable.

Software installation

The Explorer-16 CD-ROM you should have received with this issue presents a welcome screen (**Figure 3**) which should pop up after inserting the disc in your CD-ROM drive or DVD drive. If the welcome screen does not appear automatically, click on Start → Run… and then use Browse to point to the file *index.htm* on the CD-ROM or DVD drive.

The software installation screen you should see after leaving the welcome screen is shown in **Figure 4**. No-frills installers are used for the software components of this project. We recommend installing all three components. It should be noted that the installer employs the program installed as the *default web browser* on your PC. It was successfully used with Internet Explorer build 6.0.2900.

PIC24FJ128 Quick Specs



CPU

- Modified Harvard architecture
- Up to 16 MIPS operation @ 32 MHz
- 8 MHz internal oscillator:
  - 4x PLL option
  - Multiple divide options
- 17-bit x 17-bit single-cycle hardware Fractional/Integer Multiplier
- 32-bit by 16-bit hardware divider
- 16 x 16-bit working register array
- C compiler optimized instruction set architecture:
- 76 base instructions
  - Flexible addressing modes
- Linear program memory addressing up to 12 MBytes
- Linear data memory addressing up to 64 kBytes
- Two address generation units for separate read and write addressing of data memory

Special microcontroller features

- Operating voltage range of 2.0V to 3.6V
- Flash program memory:
  - 1000 erase/write cycles, typical
  - Flash retention 20 years, typical
- Self-reprogrammable under software control
- Selectable power management modes:
  - Sleep, idle and alternate clock modes
- Fail-safe clock monitor operation:
  - Detects clock failure and switches to on-chip, low-power RC oscillator
- On-chip LDO regulator
- JTAG boundary scan and programming support
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Flexible Watchdog Timer (WDT) with on-chip, low-power RC oscillator for reliable operation
- In-Circuit Serial Programming™ (ICSP™) and In-Circuit Emulation (ICE) via 2 pins

Analogue features

- 10-bit, up to 16-channel analogue-to-digital Converter (A/D)
  - 500 ksps conversion rate
  - Conversion available during sleep and idle
- Dual analogue comparators with programmable input/output configuration

Peripheral features

- Two 3-wire/4-wire SPI modules, supporting 4 Frame modes with 4-level FIFO buffer
- Two I²C™ modules support multi-master/slave mode and 7-bit/10-bit addressing
- Two UART modules:
  - Supports RS-232, RS-485 and LIN 1.2
  - Supports IrDA® with on-chip hardware encoder/decoder
  - Auto-wake-up on start bit
  - Auto-baud detect
  - 4-level FIFO buffer
- Parallel Master Slave Port (PMP/PSP):
  - Supports 8-bit or 16-bit data
  - Supports 16 address lines
- Hardware real-time clock/calendar (RTCC):
  - Provides clock, calendar and alarm functions
- Five 16-bit timers/counters with programmable prescaler
- Five 16-bit capture inputs
- Five 16-bit compare/PWM outputs
- High-current sink/source on select I/O pins: 18 mA/18 mA
- Configurable open-drain output on digital I/O pins
- Up to 5 external interrupt sources

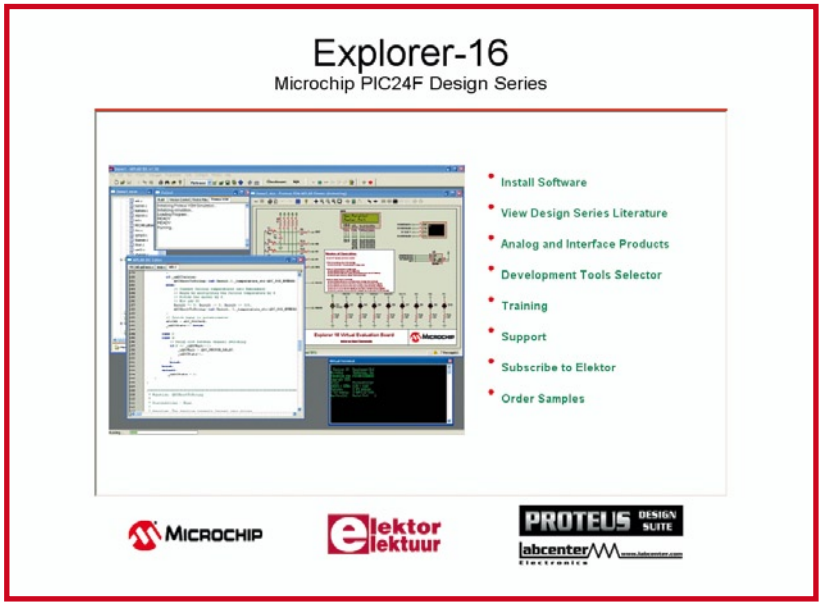


Figure.3. Apart from being a gateway to the three installers, the welcome screen contains links to know-how and documentation collected specially for the Explorer-16 project.

MPLAB IDE v. 7.50 follows a traditional Windows program install procedure. At some point you will see this message: *The publisher could not be verified. Are you sure you want to run this software?* Click Run to continue.

MPLAB C30 Compiler v 2.05 – Student Edition is a similar installation. The *Release Notes* document that's available at the end of the installation is particularly worthwhile to read (and print).

Proteus VSM 7.00 Demo is also easy to install simply by accepting the defaults suggested by the installer program. The Guided Tour of the MPLAB viewer you'll see near the end of the installation has some interesting information and shows the effort that Labcenter and Microchip have put into their cooperation for the Explorer-16 project.

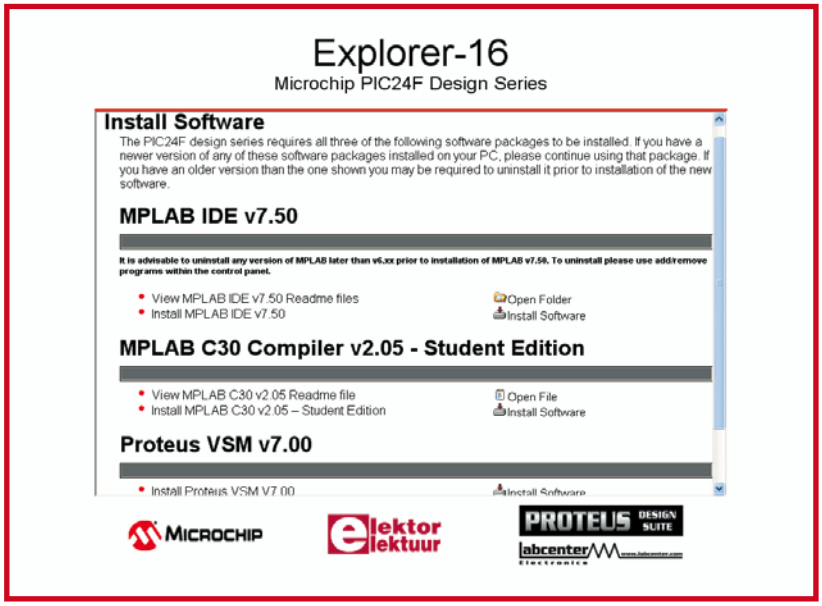


Figure 4. The component install screen for the free CD-ROM supplied with this issue.

MPLAB IDE

Paradoxically — considering its size and power — little needs to be said about this renowned PIC microcontroller development platform from Microchip. The reason is simple: MPLAB has been around for many years now and has matured into the *de facto* development platform for PIC MCUs. The program, (or suite of utilities, really), is comprehensive, user-friendly and marked by excellent support not just by virtue of the Help file functions but also through Microchip's online Forum and technical support.
MPLAB Integrated Development Environment (IDE) is a development platform for the Microchip Technology PIC MCU and dsPIC® microcontroller families.
MPLAB IDE includes the following components: MPASM™ Assembler; MPSIM™ software simulator; MPLINK™ linker; Source Level Debugger; On-line Help; Project and set-up wizards; Project Manager; Visual Device Initializer; Programmer's Editor; drivers for various hardware tools. Special versions of a number of utilities like the assembler and linker, are supplied for the dsPIC30 devices.
With MPLAB IDE you can:

- write, build and debug source code;
- automatically locate errors in source files for editing;
- debug with breakpoints;
- single-step the program with software simulator, in-circuit debugger or in-circuit emulator;
- view variables in watch windows;
- program code with certain programmers;
- find quick answers to questions using the MPLAB IDE on-line help.

MPLAB looks rather dead when launched. To see some action on the screen follow File → Open Workspace and then navigate to the 'examples' folder. Various projects can be opened there. Although not very meaningful just yet, they allow the newcomer to explore a large number of functions without 'serious consequences'.
Importantly, release notes for all utilities in MPLAB can be found at Start → All Programs → Microchip → MPLAB IDE v. 7.50 → Documentation. This screen also lists 'install and repair' utilities.
Even an introductory discussion of the features packed into MPLAB and the best way to use them for your PIC projects would easily fill an entire magazine hence is beyond the scope of this article. Not to worry, the complete *MPLAB Users Guide* and various other pdf documents are accessible via the CD-ROM install screen under 'View Design Series Literature'. Plus, there's *MPLAB Getting Started*.

MPLAB C30

The free Explorer-16 CD-ROM contains the student edition of the Microchip C30 compiler, version 2.05. This is a fully functioning C compiler for the first 60 days after which a number of the cleverest optimisations are disabled. If you start using the C30 compiler now, you will have a full version of the product all the way till the third article instalment.
The functions disabled after 60 days are described by Microchip as: '*procedural abstraction*' and '*optimisation options -02, -03 and –Os*'. Not too worrying, we'd say. Everything else works the same as the full version and

with the huge memory capacity on the PIC24F128 used, code size optimisation is unlikely to become a problem. Of course, you are free to use C30 for any smaller 16-bit PIC MCU or dsPIC® DSC you may have available, just give it a try.
The student edition of C30 may be upgraded to a full edition by purchasing a licence key from Microchip. Good news: with the publication of the February 2007 issue, buyers of the Explorer-16 Development Board will be able to purchase the full version of C30 at a discounted price by returning a voucher enclosed in the box.
MPLAB C30 seems to be a lesser known 'plug-in' of the MPLAB environment so a short introduction is given here (realising that the real work starts with coding your own C programs, compiling, debugging and finally transferring them to a PIC — but stop, do your simulation first!).
MPLAB C30 is a fully ANSI compliant compiler with standard libraries for all popular PICs including the latest dsPIC® DSC devices. It is fully integrated with the MPLAB IDE for high level debugging at the source code level.
This compiler comes complete with its own assembler, linker and librarian to write mixed-mode C and assembly programs and link the resulting object files into a single executable file.
The MPLAB C30 library includes functions for string manipulation, dynamic memory allocation, data conversion, timekeeping, and math functions (trigonometric, exponential and hyperbolic).
The 'small code model' offered by C30 takes advantage of a more efficient form of call instructions, while the 'small data model' supports the use of compact instructions for accessing data in SFR space.
Although C30 is embedded into the MPLAB environment, you still be able to run it as a separate command line program. Use the 'Open Workspace' menu item in MPLAB and navigate to MPLAB C30 → Examples → MPLAB Link30. The example 'Locate_access_EEPROM' is shown in **Figure 5** with the *Program Memory* and *File Registers* viewers open.
The complete C30 Users Guide is accessible via the menu on the CD-ROM, as discussed with MPLAB. Alternatively, navigate to the folder 'Documentation' on the CD-ROM.

Proteus VSM

The circuit simulation component of the Explorer-16 project is presented to you courtesy of our long-standing advertiser Labcenter Electronics. VSM (virtual systems modelling) is part of the Proteus Design Suite which also comprises:

- ISIS schematic capture;
- ProSPICE mixed mode simulation;
- ARES PCB design.

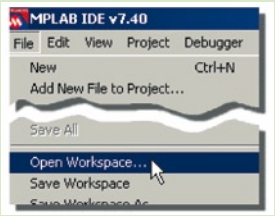
Specially for the Explorer-16 project, Labcenter are supplying a large number of sample designs featuring the PIC10, PIC12, PIC16, PIC18 and, of course, the PIC24F. You can run any software code you like on the samples but to experiment on your own hardware designs you will need to purchase the full Proteus VSM package. Alternatively, you can take advantage of a special offer exclusive to Elektor readers by visiting www.labcenter.co.uk/products/elektoroffer.htm.
To get a taster, if you start a copy of ISIS via Start → Labcenter → Proteus 7 Demonstration → ISIS 7 Demo, you are invited to view a number of examples. Some nice ones are found in the Tutorials folder.

Kick start to Proteus VSM within MPLAB

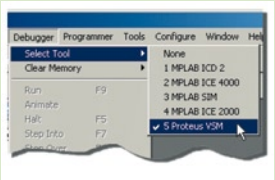
This short demonstration will show you how the basics of how to configure and run a Proteus VSM simulation under the control of the MPLAB IDE.

1. Download the file Demo1.zip from the Explorer-16 page you can reach via *www.elektor.com*. Save the unzipped Demo1 folder the directory: c:\program files\microchip\mplab c30\examples.

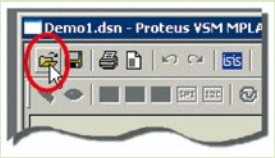
2. Launch the MPLAB IDE application, go to the File menu, select the Open Workspace command, navigate into the Demo1 directory and open the Demo1.mcw workspace.



3. Go to the Debugger Menu in the MPLAB IDE, select the Select Tool command and then Proteus VSM. This configures MPLAB to use Proteus as the tool of choice for debugging.

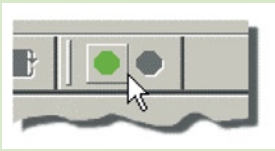


4. You should now see that the Proteus VSM Viewer has opened inside MPLAB. Use the Open Icon on the viewer and select the Demo1 schematic from the resulting file selector.

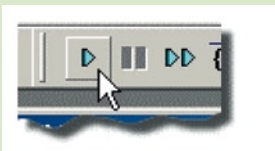


5. Now select 'Build All' from the Debugger menu.

6. Now that we have the schematic and project we can start the simulation. Use the green button at the top of the MPLAB IDE to connect the Proteus simulation to MPLAB.



7. At this point the simulation is paused at time zero. Start the Simulation by clicking on the Play button near the top right of the MPLAB IDE. This will execute the program code and the VSM Viewer will show you the effects of your program on the design.



8. Use the red button at the top of the MPLAB IDE to disconnect the VSM Viewer from MPLAB and stop the simulation. A more detailed demonstration of debugging follows later in the series.

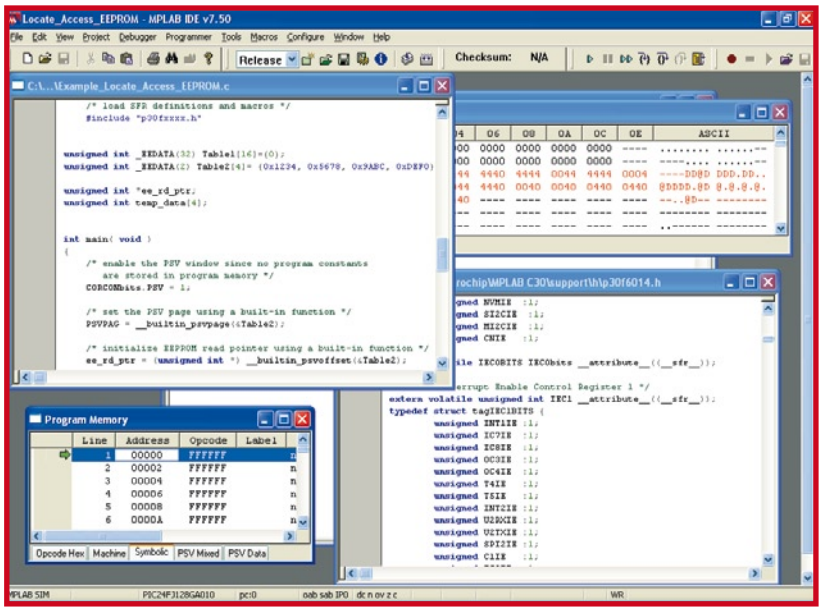


Figure 5. MPLAB C30 in action. Various windows can be opened to see what the program is doing in memory and register-wise.

Like C30, VSM is embedded in MPLAB; you'll find it under Debugger → Tool. If you are dying to see it in action at this point, follow the 8-step kick start to VSM/MPLAB shown in the **Kick start to Proteus VSM within**

MPLAB inset. This impressive demo requires an archive file called **Demo1.zip** to be downloaded from the Explorer-16 page of our website. You can also apply the same procedure to any of the pre-installed Virtual Evaluation Boards. More about VSM on [4].

Next month

We reckon the amount of software presented in this article will keep you busy for about a month. In the February 2007 issue we'll discuss the Explorer-16 hardware (on special offer then) and show its first application which is related to speech reproduction. This will take us along C30 and MPLAB to see how the software is built. We'll also delve into Proteus VSM to demonstrate that simulation is now a firmly established — if not essential — step in prototyping microcontroller circuits.

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Web links

[1] Microchip PIC24FJ128GA Family Data Sheet:
ww1.microchip.com/downloads/en/DeviceDoc/39747C.pdf
[2] Microchip High-Performance PIC24 Microcontroller Family overview:
ww1.microchip.com/downloads/en/DeviceDoc/39754b.pdf
[3] PIC18F to PIC24F Migration, an Overview:
ww1.microchip.com/downloads/en/DeviceDoc/39764a.pdf
[4] Proteus VSM
www.labcenter.co.uk/products/vsm_overview.htm