

An Encyclopedia Coverage of Compiler's, Programmer's & Simulator's for 8051, PIC, AVR, ARM, Arduino Embedded Technologies

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ABSTRACT

In today's world, everything from small needle to airplane engineering is surrounded by embedded systems. Embedded System technology not only lays foundation for development but is also acting as Backbone for mankind in almost in every area of science, engineering, research and daily living. The world of embedded systems is mainly surrounded by: Microcontrollers and Microprocessor's. To work in the area of Embedded Systems design and development is interesting and challenging- Interesting in the sense, as everything is getting intelligent, advanced and feature rich day by day and the embedded system's field is progressing by leaps and bounds. But challenging in the way, that resources are very limited in terms of design and implementation. The most important crucial challenges nowadays in front of embedded system engineers are- **Which programmer to Use? Which compiler to use for source code development? Which simulator to use to simulate the overall behavior of system?** As every compiler, programmer and simulator has distinct features, so selecting the best one as per one's requirement has always remained a challenge. The main aim of this research paper is to overcome that difficulty by providing the researchers and embedded system engineers an encyclopedic platform of compilers, programmers and simulators for all sorts of embedded system technologies like 8051, PIC, ARM, AVR and Arduino so that choosing of the best platform in terms of compiler, programmer and simulator can become easy and time saving for everyone working in this area.

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1. INTRODUCTION

1.1. Introduction to Embedded Systems

According to Techopedia, "Embedded Systems are managed by single or Multi-Processing cores in form of microcontrollers or Digital Signal Processors (DSPs), Field-Programmable Gate Arrays (FPGA) and Application-Specific Integrated Circuits (ASIC) and Gate Arrays. Taking the case of Computer Systems, all sorts of hardware's like Routers, Switches, Wi-Fi Systems etc. are embedded systems and in normal life embedded systems are available everywhere from wrist watches to powerful electronic home appliances and from daily use items to powerful electronic gadgets.

The first modern embedded system was Apollo Guidance Computer invented by Charles Stark Draper at MIT labs. Since then, embedded system technology has grown up by leaps and bounds and

embedded systems are becoming cheap in terms of price and getting powerful in terms of processing and multi-functioning capabilities.

Basically, Embedded Systems were developed to perform a specific task as compared to general purpose computers. Embedded Systems comprise of tons of small and handy computerized parts and act as general purpose machine. In order to enable any embedded machine to perform some task, the most important part required for that functioning is “Firmware” which is basically regarded as program stored on ROM or Flash Memory Chip of the system and can contain small to millions different sorts of instructions for performing varied tasks.

Embedded systems can have GUI or no interface and nowadays most of the standalone machines like ATM etc. have touch screen interface for performing input and output operations.

Embedded System= Embedded Hardware + Embedded Software

Example: Considering an example of ATM machine which comprise of both hardware and software. Hardware consists of Touch Screen, Keyboard, Printer, and Money operating Black Box and in addition to hardware it consists of sophisticated cum secured embedded software which acts as Middleware between the User and Hardware. Embedded software is being interacted by the user to control all sorts of operations like money transfer, money withdrawal, password changing and making FD’s or any other banking operation etc. Without proper embedded software, embedded system is of no use.

Embedded System (Hardware + Software) is further divided into two categories:

Microprocessor & Microcontroller

The main difference between Microprocessor and Microcontroller is that Microprocessor has same functionalities like normal computer CPU on a single IC. Microprocessor is regarded as multipurpose programmable device which takes input from the user, process the data as per the instructions and gives output. Whereas Microcontroller has all parts like CPU, RAM, ROM in-built into it. Microprocessors outperforms microcontrollers in terms of performance and processing capabilities but have limitations in terms of cost and size.

The following figure 1 highlights Block Diagram of Microcontroller and Microprocessor:

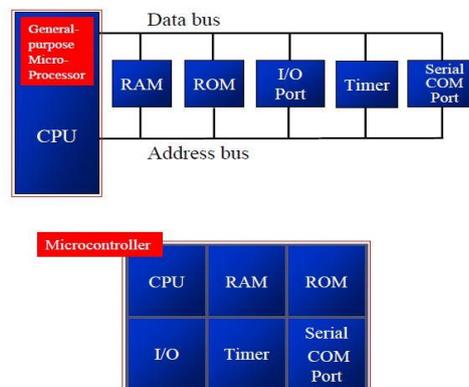


Figure 1. Block Diagram of Microcontroller and Microprocessor

Considering the wide applications being developed nowadays which is making everything intelligent cum smart, microcontrollers are playing an efficient role. But no microcontroller is efficient and performance oriented unless combined with intelligent piece of program code.

Time to time, there has come a remarkable change in Microcontroller technology and various types of Microcontroller generations have evolved. Starting from 8051 to ARM these days, everything has been changed by microcontrollers. Various microcontrollers like 8051, PIC, AVR, ARM and ARDUINO along with their various customized boards have come up in the market and has given researchers and industry to take up and develop wide range of products from daily use to highly sophisticated and reliable operations.

The main issue behind microcontroller usage in front of researchers, hobbyists cum enthusiasts and even industry is to select the right compiler, programmer and simulator as these are available in in huge

abundance and various issues like: *Which Compiler is available for which microcontroller? Which is the Right Programmer for which microcontrollers? Which Simulator is suitable for microcontroller?* All these has always remained big questions cum challenges in front of researchers to start their work and produce effective result outcomes.

In this paper, an encyclopedia coverage of various compiler's, programmer's and simulation tools for all sorts of microcontrollers available in market like 8051, PIC, AVR, ARM and Arduino would be covered so that finding the right compiler, programmer and simulator would no longer be a serious issue for working in Embedded Systems area.

1.2. Organization of Paper

Section II will give general overview of technical terms like Embedded Compiler, Programmer and Simulator; Section III discusses all embedded compilers available for microcontrollers; Section IV elaborates various simulators available for microcontrollers; Section V gives overview of various programmers available for microcontrollers and Section VI discusses Conclusion of the paper.

2. TECHNICAL TERMS- DEFINITIONS

2.1. Compiler

In general terms, "*Compiler*"- a system software which performs the task of converting High Level Language instructions to Machine Level Language instructions. The basic reason behind use of compiler to convert the source code in executable form. If the compiled code can run on different machine with other type of CPU, operating systems, then the compiler is termed as "*Cross-Compiler*". A program which gets translates from low level language to high level one is called "*Decompiler*". A program which translates between various high level languages is called source-to-source compiler.

A compiler performs various types of operations like: *Lexical Analysis, Preprocessing, Parsing, Semantic Analysis, Code Generation and Code Optimization.*

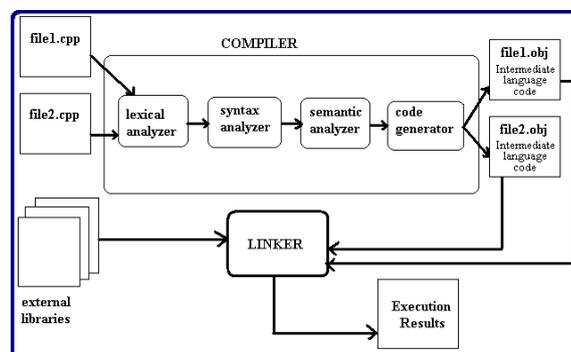


Figure 2. Basic Operation of Compiler

Compiler Structure:

Compiler acts as Middleware between User High Level Language and Computer understandable machine level language. A compiler performs the task of code verification, object code generation and producing output in executable manner. The structure of compiler is comprised of following:

- Front GUI End: The front end of the compiler provides user interface for writing the source code, performs auto-correction of source code, shows various logical and syntax errors etc. Front end of the compiler performs Lexical analysis, syntax analysis and semantic analysis.
- Middle End: The middle end of compiler is responsible for optimizations, removal of useless code, discovery and propagation of constant values and specialization of computation based on the context.
- Back End: The back end of compiler generates assembly code, register allocation and optimization of target code.

2.2. Programmer

In the field of embedded systems, the most important role is performed by “Programmer”. User types the source code in compiler and after compiling the code, the compiler generates “HEX Values”. The Hex file with .HEX extension needs to be transferred to ROM Memory of Microcontroller, no matter what microcontroller is being used by end user. To transfer the .HEX file generated by compiler to microcontroller, Embedded Programmers are being utilized.

Embedded Programmers are basically hardware devices connected to computer and makes use of System Software to transfer the code from machine to Microcontroller.

Embedded Programmers perform the operations of reading, writing, erasing and locking the code on Microcontroller’s ROM memory.

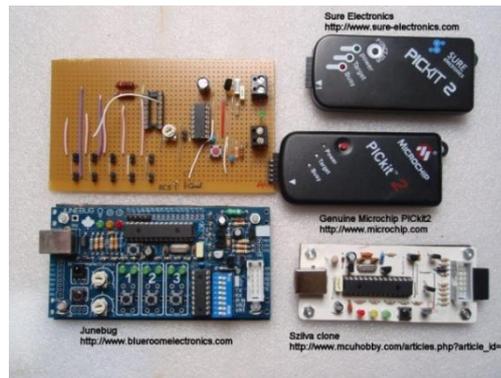


Figure 3. Various Embedded Programmers for All Microcontrollers

2.3. Simulator

In general terms, Simulator provides enhanced virtual environment depicting the real world. The act of simulating requires the model development, then the key characteristics or behaviors of the physical system and then the model finally becomes the system itself.

Simulator makes use of knowledge of processor or microcontroller and target system architecture on host. Performs the task of cross compilation and place the instructions in RAM. Simulator makes use of Linker and Locator to transfer the compiled code in RAM and actually functions like code that run on the target system.

Various simulators are available for different processors and processing devices making use of embedded systems.

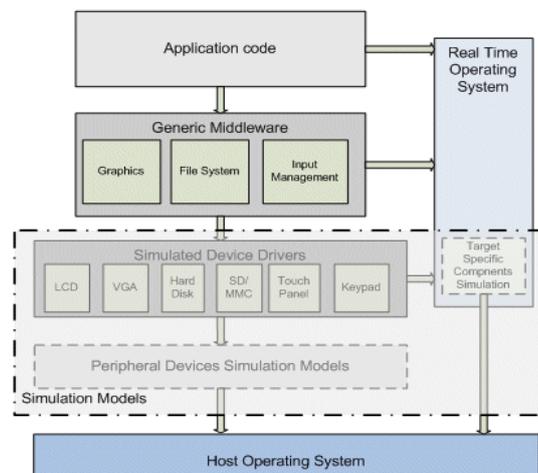


Figure 4. Simulation Model Structure

3. EMBEDDED SYSTEMS-COMPILER'S-8051, PIC, AVR, ARM, & ARDUINO

In this section various compilers of 8051, PIC, AVR, ARM and Arduino microcontrollers would be discussed.

3.1. 8051

The following are the Compilers for 8051 Microcontroller:

a) CEIBO++ Compiler [1]:

Ceibo Compiler is integrated with Keil Software and was regarded as first compiler for 8051 microcontroller. CEIBO++ is regarded as powerful embedded C++ compiler which contains all C and ASM capabilities and strong support for OOP's.

Latest Version: V 3.02

Download: <http://www.ceibo.com/eng/general/swupdate.shtml>

Software: Free Software

Features:

- C Programs are easily integrated with new C++ features.
- The Object files generated by CEIBO contains all debug information and is compatible with various emulators and can run without modification.
- CEIBO includes all Embedded C++ libraries which makes the class libraries easy to understand as compared to procedural predecessors.

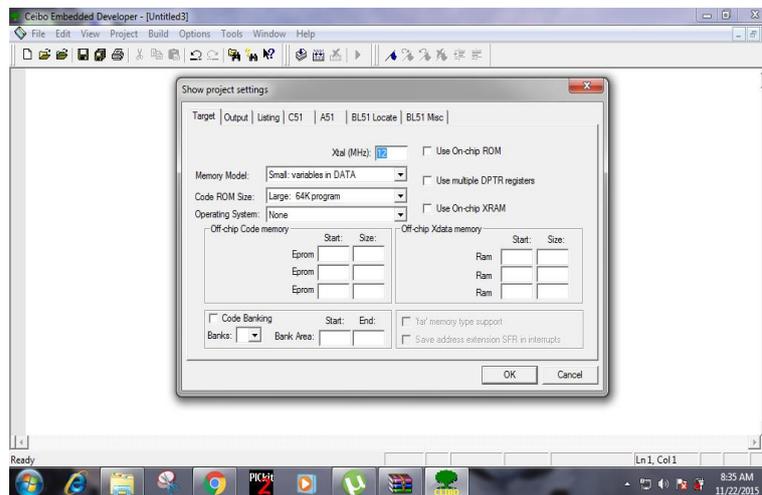


Figure 5. CEIBO++ Working

b) Crossware 8051 Development Suite [2]

Crossware 8051 Development Suite provides advanced environment for rapid development of 8051 microcontrollers. It provides vast extensions that allow access to 8051 specific features for writing complete C language without any need to resort to assembler code. Crossware 8051 Development suite supports both small and large memory models so that user can write code for all 8051 variants without any issue of external RAM.

Version: Crossware 8051 Development Suite 2015

Download: <http://www.crossware.com/i8051/TryItNow>

Software Type: Commercial; Trial Period: 15 Days

Features:

- Advanced ANSI C Compiler and Libraries
- Generates fast in-line code with less library calls for high speed performance on target board and optionally uses library routines for minimizing code size where speed is not an issue.

- Integrated relocatable assembler.
- Full type checking across modules which tracks all sorts of programming errors and ensuring C variables, function arguments, structure members etc. are consistent across source files and with libraries.
- Memory Banking and Relocating Linker
- Relocatable Macro Cross Assembler
- Easy to use Code creation wizard for source code and interrupt handling
- Source Level Debugger
- Multi-threaded and Multi-target IDE to write, edit and debug code.

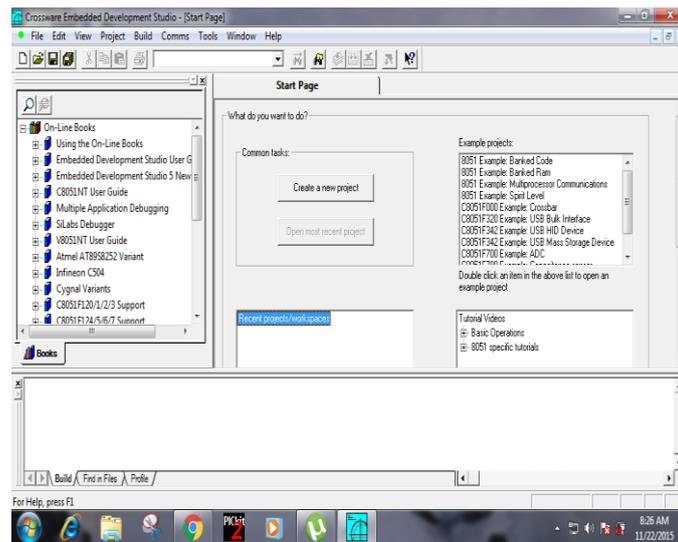


Figure 6. GUI Interface for Crossware 8051 Development Suite

c) IAR Embedded Workbench for 8051 [3]

IAR Embedded Workbench provides enhanced support for wide range of 8051 microcontroller devices. It provides uninterrupted workflow and single toolbox workbench in which all components are integrated at single place for interrupt free working. IAR workbench for 8051 provides platform for users with powerful build tools and debugger on user-friendly IDE environment. It provides enhanced and efficient features with tight integration with Hardware, RTOS products and middleware.

Version: IAR Embedded Workbench for 8051 (2015 Latest Release)

Download: <http://supp.iar.com/Download/SW/?item=EW8051-EVAL>

Software Type: Commercial; Evaluation: 30 Days

Features:

- Easy to interface graphical GUI providing IDE environment with project management tools, C, C++ compiler for 8051 and C-SPY Debugger with 8051 simulator.
- Run-time Libraries with complete source code, Linker, Library tools and support for multiple DPTR in compiler and libraries.
- Support for DATA, IDATA, XDATA, PDATA, BDATA, JTAG Drivers and ROM Monitor.
- Inbuilt project examples and code templates and support for RTOS-aware debugging.

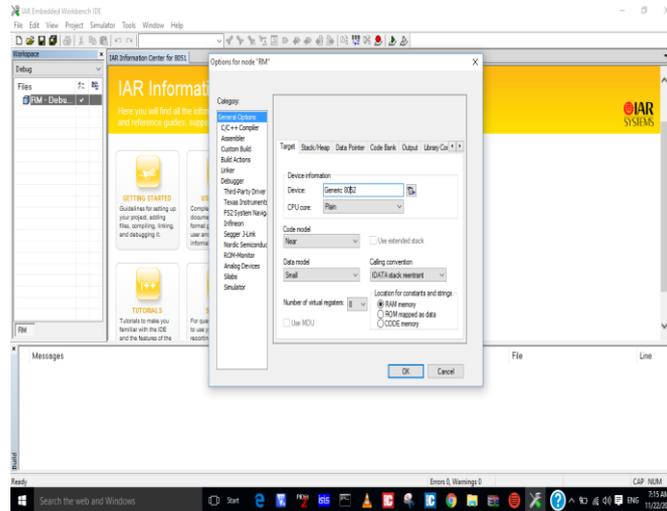


Figure 7. Programming Window of IAR Workbench 8051

d) Keil uVision IDE for 8051 Microcontroller [4]

Keil uVision IDE software application provides extensive facilities for 8051 embedded system development. It comprise of Source Code Editor, Debugger, Assembler, Cross Compiler and Simulator. It supports Embedded C and assembly programming for all 8051 compliant microcontrollers. KEIL also generated HEX file which can be as such used to flash 8051 microcontrollers.

Version: KEIL uVision IDE 5

Download: <https://www.keil.com/demo/eval/c51.htm>

Software Type: Commercial; Demo Version (Free with Limited Options)

Features:

- uVision provides comprehensive platform for 8051 microcontroller with compiler, assembler, linker and memory options.
- Wide range of examples of 8051 devices.
- uVision Debugger is regarded as accurate in simulating on-chip peripherals like I²C, CAN, UART, SPI, ADC, DAC and PWM. With high accuracy, users can easily implement on live hardware.
- Support various 8051 microcontrollers like ACER Labs M6032, Analog Devices ADuC841, Atmel AT89C51, Dallas Semiconductor DS80C320, Intel 8051AH, Nordic Semiconductor Nrf24le1, NXP, and Silicon Laboratories C8051F020.

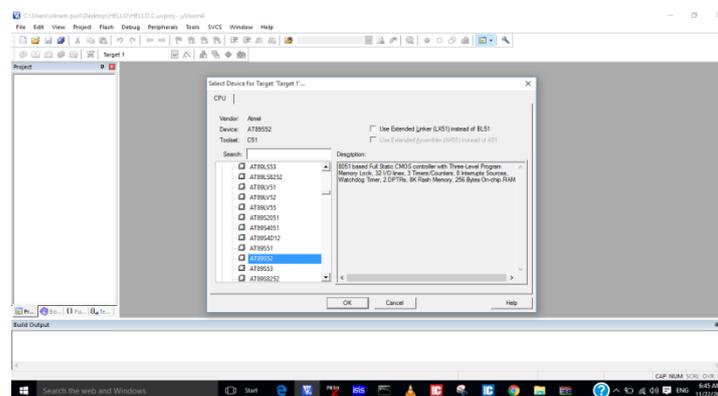


Figure 8. GUI Interface of Keil uVision

e) MCU 8051 IDE [5]

MCU 8051 IDE is open source and free to use integrated development environment for 8051 based microcontrollers. MCU 8051 IDE features source code editor, simulator, Hardware programmer, in-built assembler along with support for 2 external assemblers and many other tools. MCU 8051 IDE makes use of C and Assembly language. It can be installed on Windows and Linux operating system and MCU 8051 IDE simulator supports more than 79 MCU from Atmel.

Version: 1.4

Download: <http://www.moravia-microsystems.com/download/mcu8051ide/>

Software Type: Open Source/GNU

Features:

- MCU IDE support C Language, ASEM-51 and other assemblers, VIM and Nano source code editors, Hexadecimal editor, advanced text editor for source code validation.
- Simulator support simulation of various embedded components like LEDs, LCD's, Matrices etc, and support various advanced debugging features.

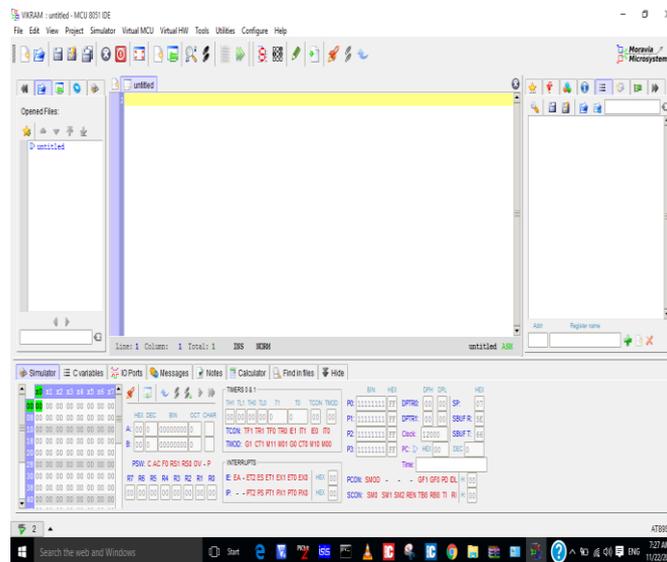


Figure 9. Programming Window of MCU IDE 1.4

f) mikroC PRO for 8051 [6]

mikroC PRO for 8051 is basically C compiler for 8051 compatible microcontrollers from Atmel and Silicon Labs. mikroC PRO provides enhanced and simple GUI interface IDE with high end optimizations and feature rich toolbox options with wide and broad support for hardware and software libraries.

Version: 3.6.0

Download: <http://www.mikroe.com/mikrobasic/8051/>

Software Type: Commercial, Demo Version (Limited Capability)

Features:

- Supports Code Editor with enhanced features like highlighting syntax, code folding, code assistant, Parameters Assistant, Code Auto correct and Code Templates.
- Supports Code Explorer for easy GUI interface for code development.

- Supports enhanced library manager for handling libraries in a project.

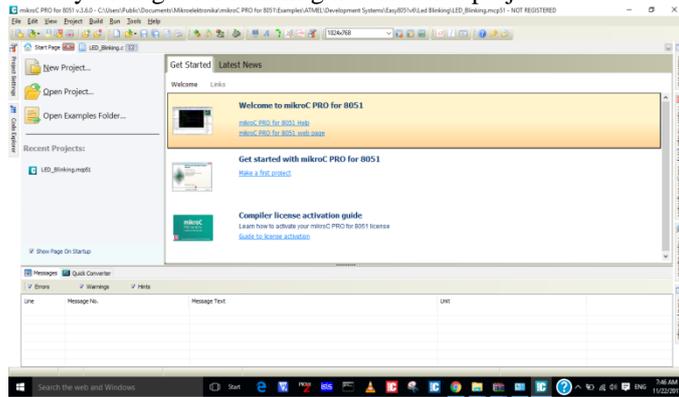


Figure 10. GUI Interface for mikroC for 8051

g) TASKING 8051 Toolset [7]

TASKING 8051 has C Cross compiler also known as cc51 (Library Name). The Toolset from TASKING comprise of C Compiler, Macro Pre-processor, Assembler, Linker/Locator, Library Manager and Debugger. TASKING C-8051 compiler is not a generic C Compiler but only utilized for 8051 source code.

Version: 7.2

Download: <http://tasking.com/support/8051#7.2>

Software Type: Commercial, Demo Version (Limited Functionality)

Features:

- Multiple Address Spaces
- Bit Memory
- Special Function Registers
- Interrupt functions using bank switching and number of built-in function to access 8051 special instructions.
- Single pass cum optimized compiler capable for generating fast and efficient 8051 code.

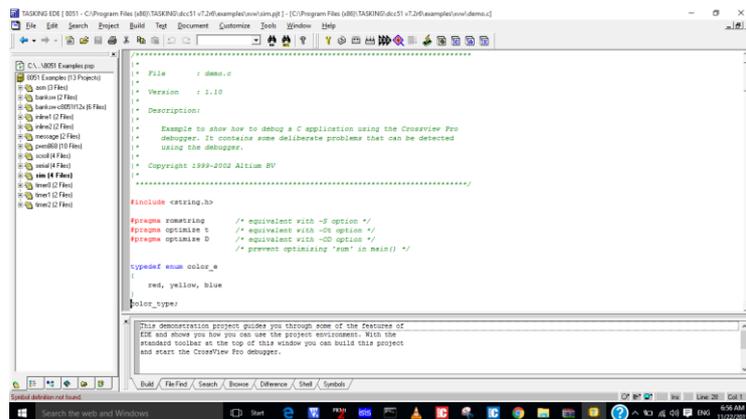


Figure 11. GUI Interface of TASKING 7.2 8051 TOOLSET

3.2. PIC

PIC has following two compilers available for users to develop source code for all sorts of PIC Microcontrollers and PIC Standard and Clone Boards:

a) mikroC Pro for PIC [8] [9]

mikroElektronika Inc. has developed an Integrated Development Environment (IDE) for PIC microcontroller known as MikroC. The IDE comprises of C Compiler, Simulator and mikro LCD Debugger. In addition to compiler, various tools are also been provided by the company like Graphical LCD bitmap editor, LCD custom character editor, USART terminal etc. mikroC Pro for PIC is an advanced compiler cum powerful compiler with high end optimizations, hardware cum software libraries and lots of ready to use examples.

Version: 6.6.2

Download: <http://www.mikroe.com/mikroc/pic/>

Software: Commercial, Demo/Trial for Limited Period also available.

Features:

- In-built code editor provides various features in terms of Code and Parameter Assistants, Code Folding, Syntax Highlighting, Auto correct, Code Templates etc.
- mikroC Pro for PIC libraries provides enhanced development features: Data Acquisition, Memory, Displays, Conversions, Communication etc.)
- Monitors program structure, variables and functions.
- Generates HEX file after successful compilation for easy flashing towards PIC microcontroller
- Assists in program flow and debug executable logic with integrated software simulator.

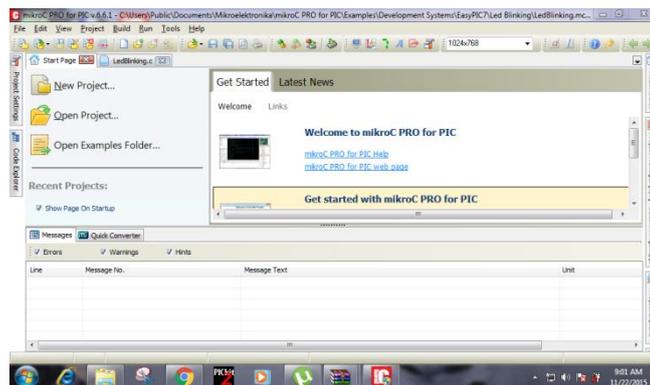


Figure 12. GUI Interface for mikroC Compiler

b) MPLAB X [10]

MPLAB (Microprocessor Lab) is a free IDE environment for programming PIC and dsPIC microcontrollers and was developed by Microchip Technology. The latest version of MPLAB is MPLAB x which is a powerful cross platform software and can be deployed on Windows, Linux and MAC pc's. MPLAB X platform is based on NetBeans open source platform and supports programming, editing and debugging of all sorts of 8-Bit, 16-Bit and 32-Bit PIC Microcontrollers.

Version: MPLAB X

Download: <http://www.microchip.com/pagehandler/en-us/family/mplabx/>

Software: Free

Features:

- Supports enhanced features like Multi-configurations for projects, multiple debug tools, live parsing, Live Code templates and a new Call Graph for easy navigation of complex code.

- Easy to use GUI with high end support for hyperlinks, easy import of projects and changes tracking.

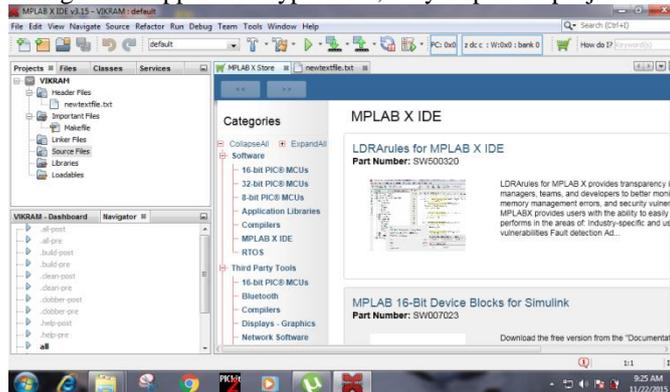


Figure 13. Programming Window of MPLAB X

3.3. AVR

The following are the Compilers used for compiling and developing source code for AVR based Boards:

a) Atmel Studio 7 [11]

Atmel Studio is regarded as Integrated Development Platform (IDP) for developing cum debugging all variants of AVR Based microcontrollers based applications. Atmel Studio provides easy to use Interface for writing, building and debugging C/C++/Assembly code for AVR technology. In addition to AVR, Atmel studio can also be utilized for developing source code for ARM based microcontrollers. Atmel studio, being a free product provides an enhanced library support for more than 1600 project code repositories.

Version: Atmel Studio 7

Download: <http://www.atmel.com/tools/atmelstudio.aspx#download>

Software: Freeware

Features:

- Atmel studio extends support for development to over 300+ Atmel AVR, ARM Based and other third party vendor microcontrollers.
- Enhanced Software Framework which includes source code library, drivers, and communication stacks, easy GUI and enhanced cum advanced ASF explorer for integrating ASF components to product design.
- Atmel QTouch Composer: Acts as good platform for easy testing of performance of system, power monitor and displays real-time and trace graph for data for further usage towards debugging.
- Inbuilt C/C++ compiler for writing, testing and building code as well as support for assembly code operations.
- Other features include: New Project Wizard, Full Chip Simulation, Atmel Spaces, Editor Integration with Visual Assist, Full debug views and advanced Gallery facilitating online apps (Development Tools cum Embedded Software) for Atmel based chip.

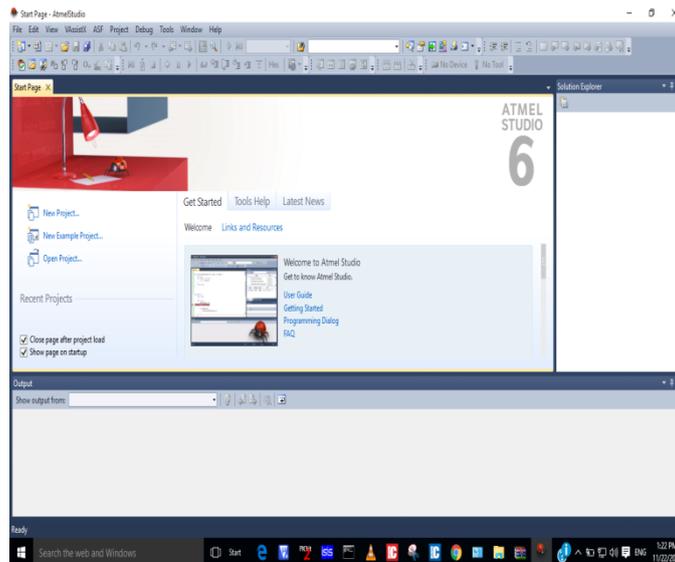


Figure 14. AVR Studio Interface

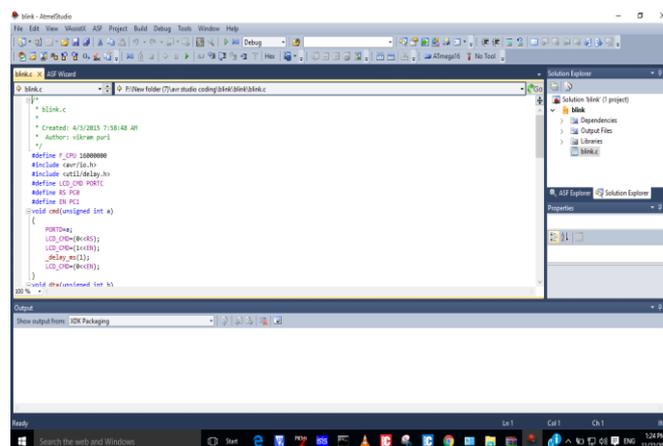


Figure 15. Programming Window of Atmel Studio

b) CodeVisionAVR C Compiler

CodeVisionAVR C Compiler is regarded as cross-compiler IDE cum Automatic Program Generator for AVR microcontrollers based on C Language. The compiler facilitates almost all elements of ANSI C, as allowed by AVR architecture with some additional features to support all sorts of AVR Architecture and embedded systems development.

CodeVisionAVR C Compiler provides an additional utility i.e. In-System AVR Chip Programmer to automatically transfer the programme to Microcontroller on successful compilation.

The latest version has extended support to new Atmel Studio 7 by providing libraries for DOGX160-7, DIP2013 and other AVR microcontrollers.

Version: 3.24

Download: http://www.hpinfotech.ro/cvavr_download.html

Software: Commercial; Evaluation (Free till 4KB of Code)

Features:

- Supports all Windows Operating Systems from Windows XP to Windows 8.1

- Easy GUI IDE environment with proper C compiler support.
- Editor facilitates code-auto-indentation, syntax highlights, function parameters, structure/union members and autocomplete- in turn nice support for code writing from Novice level users to advanced programmers.
- Extension of support to Atmel studio 7
- Tons of Data Types support like Bit, bool, char, short, long, 64-bit long, float etc.
- Compatibility with various Atmel's In-Circuit Emulators: AVR JTAG-ICE, AVR Dragon etc.

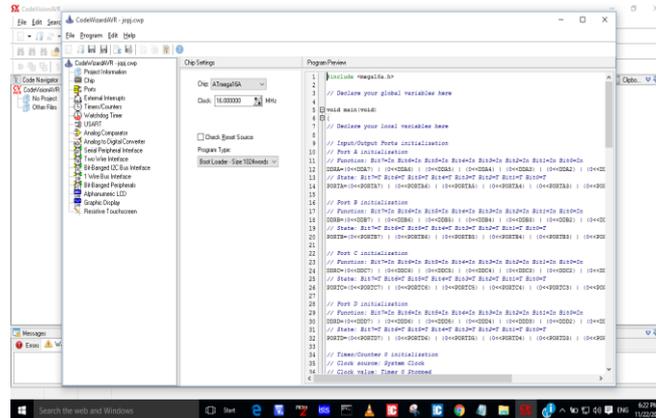


Figure 16. Programming Window of CodeVisionAVR C Compiler

c) WinAVR [14]

WinAVR is regarded as comprehensive, open source and free to use executable suite for Atmel AVR series of RISC microprocessors based on C/C++ code and also integrates GCC compiler. WinAVR package comprise of various tools of AVR like avr-gcc (compiler), avrdude (programmer), avr-gdb (debugger).

Version: WinAVR 2010

Download: <http://sourceforge.net/projects/winavr/files/>

Software: Free and Open Source

Features:

- Comprehensive Toolset for Debugging, simulating and emulating AVR C/C++ source code.
- Open source and Free to use product and also facilitates open source developers to contribute and extend the features of software.
- Easy GUI comprised of Editor, Graphical Front-end GCC compiler, Assembler, Linker, C Library and Demo Programs.
- Easy portability with hardware via avrdude and uisp making WinAVR- The most flexible user friendly package for AVR microcontroller programming.

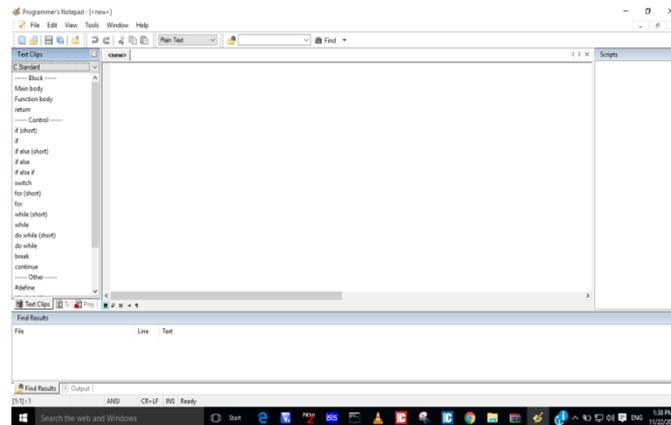


Figure 17. Programming Window of WinAVR

d) mikroC Pro for AVR [15]

mikroC Pro for AVR is ANSI C compiler for AVR devices from Atmel corporation. The compiler comprise of intuitive IDE, powerful compiler with SSA optimizations along with various hardware and software libraries. mikroC compiler contains lots of ready to use examples for as such interface with AVR controllers.

Version: 6.10

Download: <http://www.mikroe.com/mikroc/avr/>

Software: Commercial

Features:

- Inbuilt Code Editor with enhanced features like Code and Parameter Assistants, Code Folding, Syntax Highlighting, Auto Correct, Code Templates etc.
- Code Explorer for code monitoring i.e. Structure of Code, variables and functions.
- In depth report and Graphs Generation for RAM and ROM map, code statistics, assembly listing, calling tree etc.
- Easy program flow inspection and debug executable logic with tight software simulator integration.

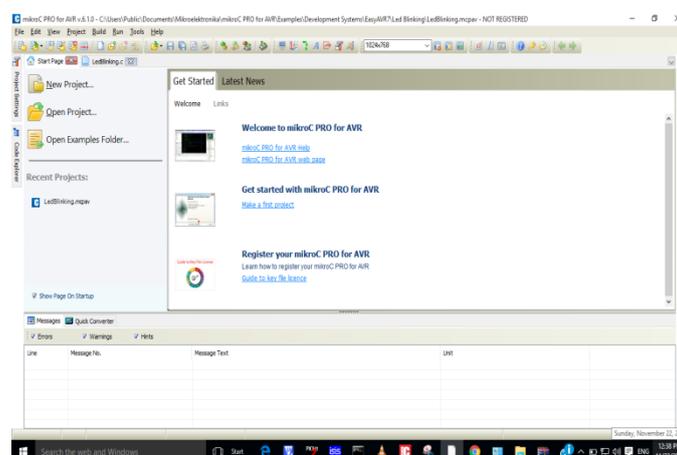


Figure 18. mikroC Compiler for AVR- GUI

e) IAR Embedded Workbench for AVR [17] [18]

IAR Embedded Workbench for AVR provides single toolbox for compiling all sorts of code for all AVR based microcontrollers. Atmel and IAR systems have jointly designed AVR 8-bit RISC microcontroller code and customized C Compiler.

IAR Embedded Workbench for Atmel AVR comprise of following:

- IDE Tools: Editor, Project Manager, Library Builder and Librarian
 - Build Tools: IAR C/C++ Compiler, Assembler, Linker
 - IAR C-SPY Debugger: Simulator Driver, Hardware System, Drivers, RTOS Plugins
- Version: 6.10.2

Download: <http://supp.iar.com/Download/SW/?item=EWAVR-EVAL>

Software: Commercial; 30 Days Trial Evaluation License

Features:

- Powerful C/C++ development tool package with support for almost all sorts of AVR microcontrollers.
- Support for all types of AVR microcontrollers i.e. from 8-Bit to 32-Bit.
- Provides world-leading code optimizations which assist in developing compact, fast and high performance code for AVR microcontrollers.
- Provides state of art improvements to developers via better performing applications and faster application running.

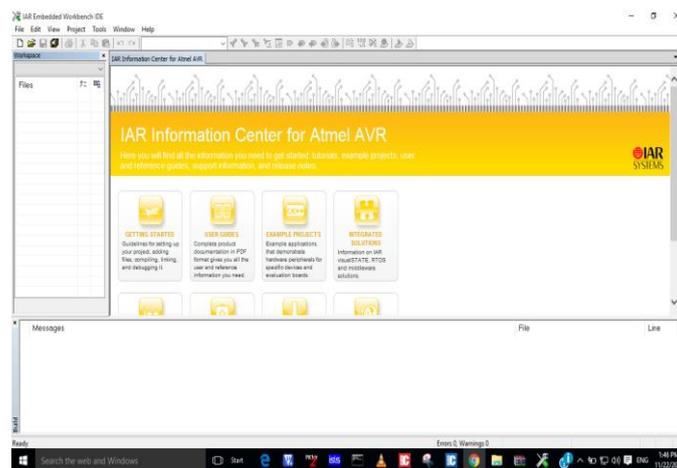


Figure 19. IAR Embedded Workbench for AVR- GUI

3.4. Arduino

The following are the Compilers used for compiling and developing source code for Arduino based Boards cum Lilypad's:

a) Arduino Software IDE

Arduino software IDE gives a unique platform for researchers to write code for Arduino Boards and Lilypad's. The software is open source and is available for cross-platform operating system like Windows, Linux and Mac OS X. The software is based on Java Language.

Version: Arduino 1.6.6

Download: <https://www.arduino.cc/en/Main/Donate>

Software: Free & Open Source

Features:

- Improved speed in Code Compiling and Build up.
- AutoSaving utility while compiling and uploading sketch.

- Feature-rich improvements in Serial monitor- Faster performance supported by modern JSSC serial library as compared to old RXTX.
- Enhanced Arduino API libraries like String, Serial, and Print.
- Enhanced upgrades in Tools and Toolchains like avr-gcc, arm-gcc, avrdude, bossac.
- Stable and Bug-free USB performance.
- Support for 3rd party hardware vendors along with configuration files (platform.txt and boards.txt)
- Patch fixes with regard to upload problems on Leonardo, Micro and Yun.
- Enhanced libraries support in terms of Ethernet, Robotics, GSM etc.
- State of Art GUI Interface with Multiple tabs, Line Number show, command line interface and interface bugs fixation for transfer of code to Arduino boards.

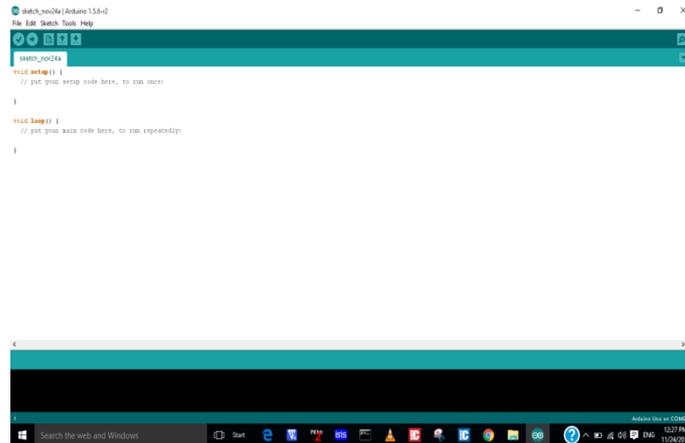


Figure 20. Arduino IDE Interface

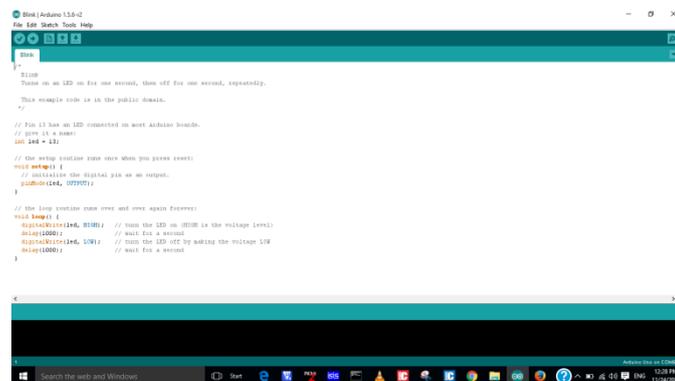


Figure 21. Programming Window of Arduino IDE

3.5. ARM

The following are the Compilers used for compiling and developing source code for ARM based Boards:

a) mikroC PRO for ARM [21]

mikroC PRO for ARM is ANSI C Compiler for ARM Cortex-M0, Cortex-M3 and Cortex M4 devices. This compiler provides enhanced developing code features for ARM devices via interactive IDE, powerful compiler and advanced SSA optimization. The compiler is equipped with hardware and software libraries along with various tools facilitating users to easily program ARM devices.

Version: 4.5.0

Download: <http://www.mikroe.com/mikroc/arm/>

Software: Commercial; Evaluation version also available.

Features:

- Powerful code editor with high end features like Code and Parameter Assistants, Code Folding, Syntax Highlighting, Auto Correct, Code Templates etc.
- Easy monitoring of program structure, variables and functions via code explorer.
- Speedy ARM development via ARM libraries integration in terms of data acquisition, memory, displays, conversion, communication etc.
- Real Time debugging tool for efficient monitoring of program execution.
- Integrated software simulator for efficient inspection of program flow and debug executable logic.
- Enhanced flexibility of HEX code- compatible with all programmers.
- Built in ready to use ARM programming code examples.

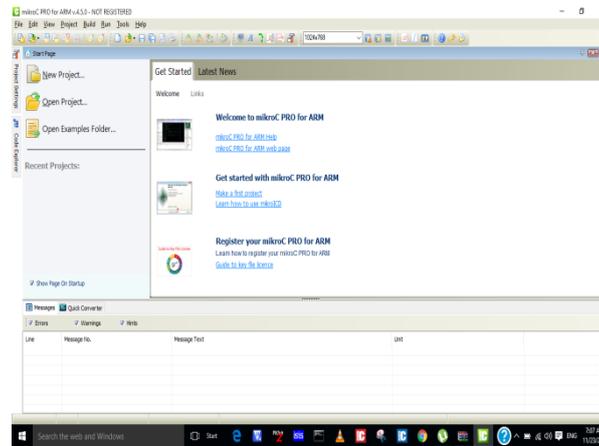


Figure 22. GUI of mikroC PRO for ARM

b) KEIL MDK [22] [23]

KEIL MDK (Microcontroller Development Kit), is currently regarded as most advanced, comprehensive and almost complete in itself package for programming all sorts of ARM Cortex-M microcontrollers. MDK kit is comprised of IDE, C/C++ Compiler, Debugger, Software Pack Management and CMSIS (Cortex Microcontroller Software Interface Standard complaint). MDK software supports Real-Time Environment (RTE) for managing devices.

Components of MDK:

- a. MDK Core: MDK Core comprise of:
 - i. μ Vision IDE and Debugger
 - ii. ARM C/C++ Compiler toolchain
 - iii. Pack Installer for installing and managing add on software packs.
- b. Software Packs:
 - i. Device
 - ii. CMSIS
 - iii. MDK-Professional Middleware

Version: KEIL MDK 5

Download: <http://www2.keil.com/mdk5/install/>

Software: Commercial; Demo Edition (Limited Features)

Features:

- Comprise of TCP/IP networking suite, USB Device and USB Host stacks.
- Comprehensive support for Cortex-M, R4, ARM 7 and 9 devices.

- Built in example codes suitable for beginner to advanced users for getting abreast with ARM programming environment.
- Simple and complete GUI library for facilitating users with easy to go GUI interface.

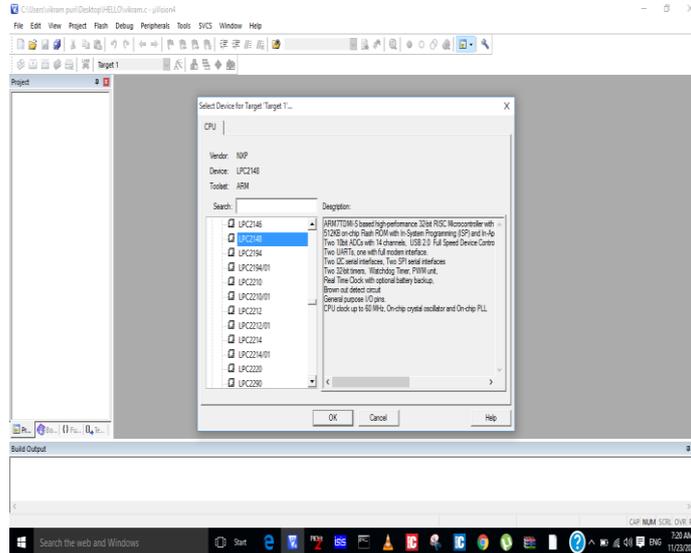


Figure 23. GUI Interface of KEIL MDK

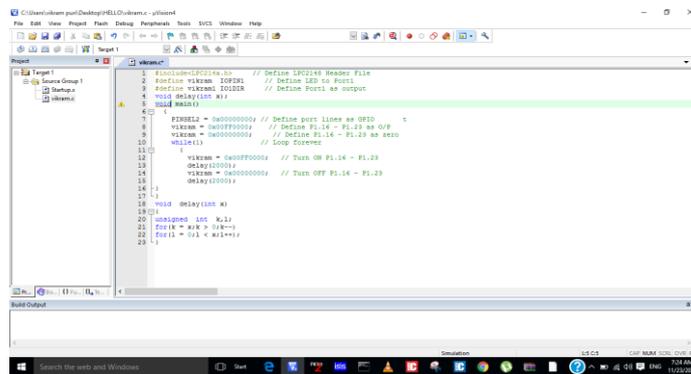


Figure 24. Programming Window of KEIL MDK

c) IAR Embedded Workbench for ARM [24]

IAR Embedded Workbench for ARM provides enhanced user-friendly all in one feature-rich toolbox for users to program ARM based microcontrollers.

Version: IAR Embedded Workbench for ARM 2015

Download: <https://www.iar.com/iar-embedded-workbench/arm/>

Software: Commercial; Trial Version (30-Days)

Features:

- User friendly IDE with easy to use project management tools and editor.
- Built in more than 4300 examples of ARM code
- Supports C, C++ and Embedded C
- Comprehensive debugger with ARM simulator and JTAG/SWD support.

- Hardware Debugging support for all sorts of ARM7/9/11 and Cortex-M/R/A cores.
- Supports powerful build tools like EABI (Embedded Application Binary Interface) and CMSIS.
- Consists of RTOS Plugins, RDI debug probes and GDB server.

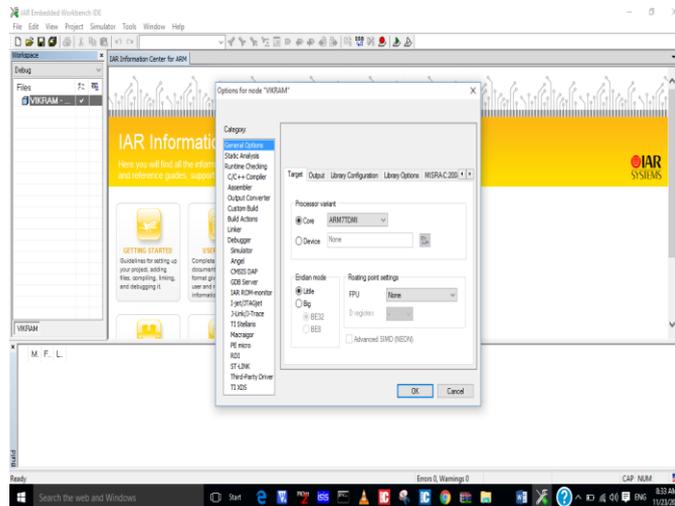


Figure 25. Programming Flow of IAR Embedded Workbench for ARM

4. EMBEDDED SIMULATOR'S

In this section Simulator being used for embedded system would be discussed

4.1. Proteus [25]

Proteus is the Sole Embedded Systems Simulator software supporting simulation of all forms of microcontrollers. The reason behind the popularity of Proteus is support for almost all microcontrollers and is regarded as the handiest tool to test programs and embedded designs for researchers and hobbyists.

Proteus combines advanced schematic capture, mixed mode SPICE simulation, PCB layout and auto routing to make a complete electronic design system.

Proteus product range also includes revolutionary VSM technology which allows the programmers to simulate microcontroller based design, complete with all surrounding electronic.

With Virtual system modeling facility, the researcher can transform the product design cycle which in turn leads to faster product launches and lowers cost.

In nutshell, Proteus VSM technology is improvising efficiency, quality and flexibility of design process.

Proteus VSM

Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models which facilitates co-simulation of complete microcontroller designs.

The end user with this facility can interact with the design using on-screen indicators such as LED's and LCD's and other stuff like buttons, switches etc. The simulation is purely real-time. Proteus VSM facilitates various debugging facilities which includes breakpoints, single stepping and variable display for both assembly and high level language source.

Version: Proteus Version 8.3

Download: <http://www.labcenter.com/index.cfm>

Software: Commercial; Demo Version (Limited Features)

Features:

- Supports MCAD data exchange via STEP and IGES file formats.
- Import component STEP/IGES files for the parts in user's projects and explanation is done via simple scripting language.
- Supports multiple track editing operations and enhancements to track necking.
- Supports re-usability via sub-circuit binding on the Replicate command.
- Addition of MSP430G2X and PIC 1845K50 together with ILI9341 TFT display.

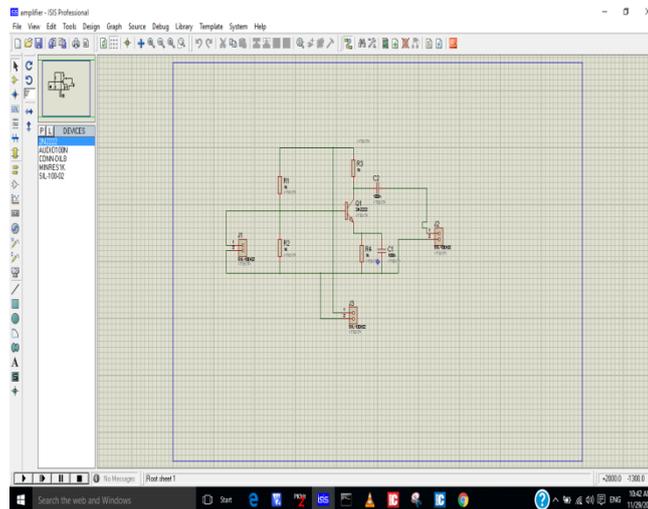


Figure 26. Simulation Window of Proteus

4. Embedded Programmer's- 8051, PIC, AVR, ARM

In this section, various Embedded System's Programmers are discussed. The following are the various programmers for 8051, PIC, AVR and ARM.

4.2. 8051

The following are the 8051 Programmers:

a) ProgISP [26]

ProgISP is regarded as very powerful and stable burning tool with proper for burning 8051 code onto microcontrollers.

Version: 1.72

Download:

https://drive.google.com/file/d/0B_ctPy0pJuW6LWR3M1dDUFhIS1k/view?usp=sharing

Software: Free

Features:

- Supports all programming of AVR Chips and also support AT89S51, AT89S52
- Support Custom serial download programming, USBASP Programmer, Custom programmed chips, High-Voltage Programmer and custom programming fuse information message.
- Basically Green software with No Installation and no Resource Hogging.
- Prompt support custom localization information
- Support for project management- all configuration data and programming data can be packed as a single file.

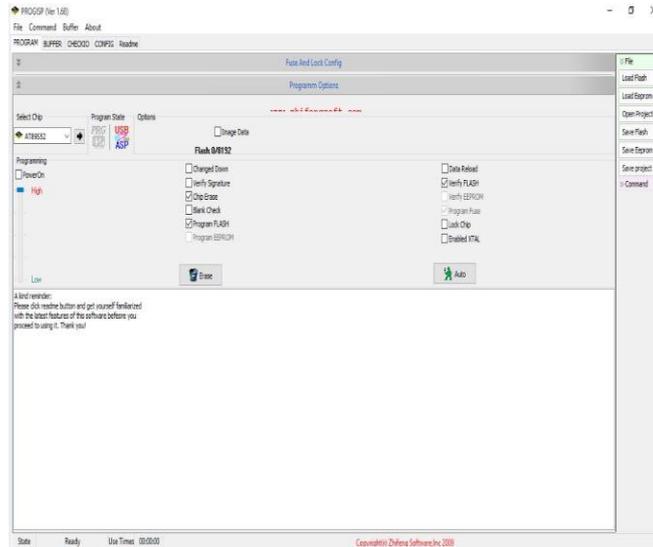


Figure 27. GUI of ProgISP 8051 Programmer

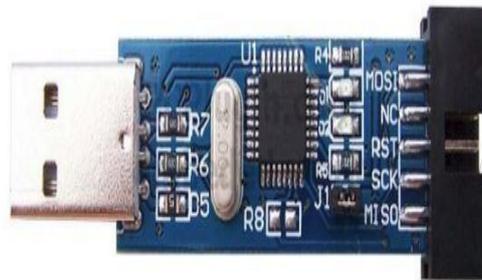


Figure 28. ProgISP Programmer

b) Wlpro [27]:

Wlpro Programmer supports all the family of 8051, 8052, MegaAVR and TinyAVR microcontrollers. Very Simple to use and can be used only in Windows Operating System.

Version: 2.1

Download: <http://wlpro.software.informer.com/2.1/>

Software: Freeware

Features:

- Easy to use and simple USB interface and intuitive GUI
- Supports 8051/52/MegaAVR/TinyAVR/EEPROM
- ZIF Socket
- Small Size and Low cost device

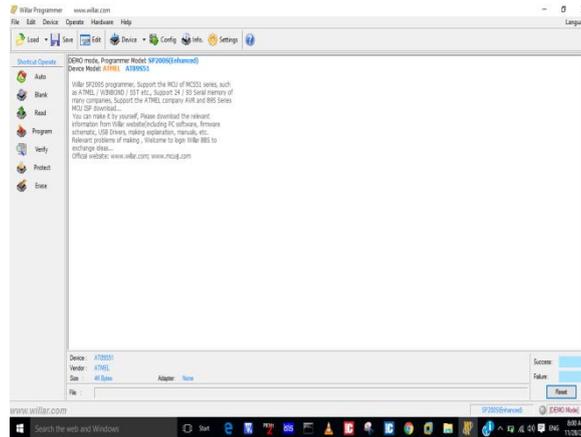


Figure 29. GUI of Wlpro 2.1 Programmer



Figure 30. Wlpro Programmer Hardware

4.3. PIC

The following are the programmers of PIC Microcontroller:

a) PICKITv2 Programmer/Debugger [28]

The PICKIT v2 Development Programmer/Debugger (PG164120) is regarded as low cost development tools with easy user interface for programming and debugging Microchip's Flash family of microcontrollers. Supports all interfaces including baselines like PIC10F, PIC12F5xx, PIC16F5xx, Mid-range microcontrollers like PIC12F6xx, PIC16F, PIC18F, PIC24, dsPIC30, dsPIC33 and PIC 32 families of 8-bit, 16-bit and 32-bit microcontrollers. With powerful integration of MPLAB IDE [10], PICKIT 2 enables in-circuit debugging on most PIC microcontrollers.

Version: PICKIT v2.61, PICKIT v3

Download: <http://www.microchip.com/DevelopmentTools/ProductDetails.aspx?PartNO=pg164120>

Software: Free

Features:

- USB Support
- Real Time Execution
- MPLAB IDE compatible
- Supports low voltage to 2.0 volts
- Diagnostic LEDs
- Read/Write program and data memory of microcontroller
- Erase of program memory space with verification

- Freeze-peripherals at breakpoint
- Program up to 512K byte flash with Programmer-to-Go
- Totally enclosed

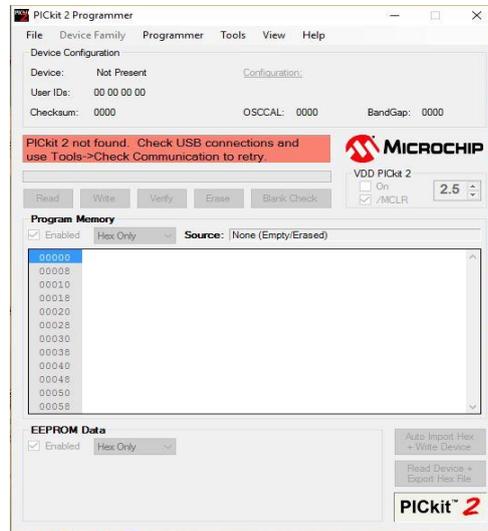


Figure 31. PICkit v 2.61



Figure 32. PICKIT v2 Hardware

4.4. AVR

AVR microcontrollers use the same programmer i.e. ProgISP [26] as mentioned above.

4.5. ARM

a) ARM

The following are the programmers of ARM:

1. Flash Magic [29] [30]

Flash Magic is power PC tool for programming flash based microcontrollers from NXP using either Serial or Ethernet Protocol in the target hardware. Flash Magic is regarded as effective and powerful tool for burning HEX based code on ARM microcontrollers as almost all ARM microcontrollers are being supported by Flash Magic.

Version: 9.51

Download: <http://www.flashmagictool.com/>

Software: Free; Production System Version, Production System NET

Features:

- Easy and simple GUI interface for end users for easy flashing of ARM based microcontrollers.
- Easy programming of Intel HEX files along with automatic verification of code after programming.
- Facilitates automatic program checksums. Using the bundled checksum calculation routine, the firmware can easily verify the integrity of a flash block, ensuring no unauthorized or corrupt code execution.
- Displays the content of flash in ASCII and Hexadecimal formats.
- Makes use of high speed serial communications on devices which supports it.
- Command line interface allowing use in IDEs and Batch files.
- Efficient in controlling the DTR and RTS232 signals to place the device into BootROM and execute modes automatically.
- Features powerful and flexible Just in Time Code feature.
- Ethernet Bootloader for LPC1xxx/LPC2xxx devices.
- Facilitates easy build of own flash magic based applications using .NET language support.

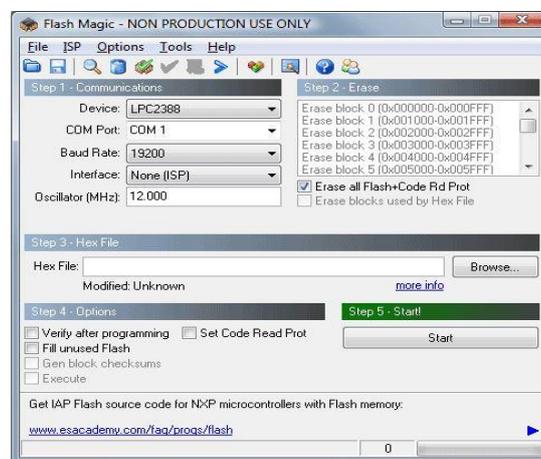


Figure 33. GUI Interface of Magic Tool

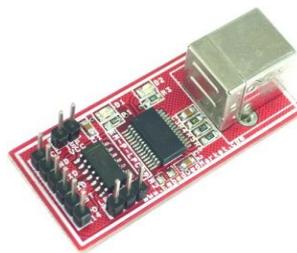


Figure 34. ARM 7 Hardware Programmer

5. CONCLUSIONS

In this research paper, an encyclopaedic coverage is done comprising various compilers, simulator and programmers of various embedded system technologies like 8051, PIC, ARM, AVR and Arduino. The encyclopaedia coverage will act as base for many researchers and hobbyists cum basic users to choose the best compiler, simulator and programmer for working depending on the microcontroller technology. In addition a through coverage is being done for each and every tool with regard to features and availability which will complete platform to choose the best among available.

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BIOGRAPHIES OF AUTHORS



Anand Nayyar, Er. Anand Nayyar (*Academician, Educationist, Researcher, Scholar, Inventor, Innovator, Scientist, Consultant and Orator*). Has done MCA, M.Phil, M.Tech, MBA and Pursuing Ph.D (Computer Science) in area of Wireless Sensor Networks. He is a certified professional in many International Certifications like CompTIA A+, CCNA, MCP, MCSA, MCSE, MCTS, MCITP, MCSD.net, CEH, RHCT, RHCE, OCP, Tally Certified Professional, Project Management, AutoCAD, DTP, Web Development, Manipal Global and Google Certified Digital Marketing Professional, Google Certified Power Searcher. He has published more than 200 Research Papers and published more than 15 Books on Computer Science. He has been awarded Shiksha Ratan Puraskar, Best Citizen of India, ISTE Best Teacher Award, Young Scientist Award, Bharat Excellence Award, Outstanding Reviewer Award, Rashtriya Gaurav Award, Rashtriya Jewel Award, Global Excellence Award, Exemplary Educationist Award, Distinguished Faculty Award, and Indira Gandhi Award of Excellence. He has been cited in Marquis Who's Who in the World in 2014/2015 and Rifacimento International: Asia Reference: Who's Who in Asia. He has acted as Session Chair and Session Co-Chair in more than 20 National Conferences and 35 International Conferences and also 8 National/International Conferences as Keynote Speaker. He is member of more than 45 International & National Research Societies.



Er. Vikram Puri has done B.Tech in Electronics and Communications Engineering in 2014. He is Member of ACM, theIRED, IAENG. He is working on the area of Embedded Systems, Robotics, Microcontrollers, Wireless Sensor Networks and Drone based Flying Adhoc Network. He has published 10 Research Papers in the area of Embedded Systems and has developed more than 100 Robots in the area of Surveillance, Flying Drones, Gesture control and Image Processing.